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OF

PHOTOGRAPHY.

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OF

PHOTOGRAPHY.

FOURTH EDITION.

REWRITTEN AND ENLARGED.

BY

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PREFACE.

THE large amount of work that has been done during the last few years rendered it desirable, in preparing a new edition of this volume, to do more than merely bring it up to date. The author has therefore rewritten the book, thoroughly revising those parts of the previous edition that have been used, and the whole has been reset in a form that it is hoped will facilitate reference. Those who have become accustomed to the previous editions will find that the same general plan has been adopted. The volume has been considerable enlarged, the number of chapters being increased from fifty-five to sixty-eight.

The author's aim has been to provide the student of photography with a serviceable guide, helping him to acquire his knowledge systematically and reasonably as well as practically. As an acquaintance with chemistry and optics is necessary for the study of photography, and all students have not taken up these branches of science, a few pages are devoted to the exposition of those fundamental principles that are necessary for understanding the subject. These few pages are not intended to teach either chemistry or optics, but only to make clear to the student the matters that immediately concern him, and to enable him to use intelligently the methods given in his practical work. Experience shows that the

treatment of these subjects is sufficient for this purpose, though, of course, an extended study of them is to be preferred.

One of the added chapters treats of the developable image. The theory that light, when it produces a developable image in an ordinary gelatino-bromide plate, causes any decomposition of the silver bromide, in the opinion of the author, has long been untenable. A mechanical working hypothesis has been suggested.

The chapter on measurements obviously touches only the fringe of the subject. If it were possible to write a useful treatise on this matter, the aim and scope of the present volume would render its inclusion here impossible.

Those who are interested in the early development of photography will find many historical facts in connection with the various subjects, in addition to the chapter on the "Development of Photography" (Part I., Chapter II.) Specific references to original authorities are not often given, but the year is stated, and those who desire more information will naturally turn to such current literature of the year mentioned as may be available. It is generally not possible, if desirable, to give exact references, because new subjects, as a rule, are treated of in many serial publications, and sometimes in many numbers of each, and very often there is no original authoritative published statement to refer to. When it appeared advantageous and not misleading, references have been given to publications where some subjects may be further studied.

As both the English and metric systems of weights and measures remain in common use, both are given, except that quoted formulæ are not translated.

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PART I.—PRELIMINARIES.

CHAPTER I.

INTRODUCTORY AND TO BEGINNERS.

THE term " photograph " is sometimes applied collectively to indicate the copy of any design or the pictorial representation of any object, in the production of which the action of light has formed an essential feature; but it is more generally restricted to prints which are themselves prepared by the direct agency of light, and impressions pulled in printing presses from blocks or plates that have been made by photographic means are referred to as " photo-mechanical prints." In this volume it is not intended to treat of photo-mechanical methods. A short survey of the chief principles upon which they depend is given, and there the subject is left. Those who wish to pursue it must refer to special treatises on these matters.

Light is the characteristic force employed by the photographer. Alone, however, it is not always practically effective. It cannot etch a plate, but it produces changes that guide the etching liquid, and, although it cannot make a negative, it gives the possibility of developing one. In every case, perhaps, where a photograph is made, the action of light is supplemented by that of chemical reagents.

Before entering, therefore, upon the consideration of what may be called the science of photography proper, it is advisable to become somewhat acquainted with the principles of chemistry and optics. The student may gain his knowledge of these matters from the ordinary sources, and this is the better method; but those who have not the time or the inclination to study collateral subjects will find in the course of the early chapters an elementary sketch of the simpler principles involved.

It is advisable for anyone who wishes to study photography from a practical point of view to begin to work at once, even though he may at first be obliged to follow instructions that he cannot appreciate.

Unless for some special reason it is desired to get only a hand camera, the beginner is advised to practise at first with an ordinary bellows-body camera mounted on a tripod. In order to work advantageously, it is essential that the apparatus be firm and truly made. The camera must support the lens and sensitive plate so rigidly that no movement of either is possible except by the manipulation of the photographer. The simpler the construction of the camera the better, so long as it has a rising front and a swing back, and even this last is very rarely necessary. It should be regarded as a scientific instrument, so far as its adjustments are concerned. The most costly camera may prove to be the cheapest, on account of the wear that it will stand, if complicated and unnecessary contrivances are avoided. The camera is more fully treated of in a subsequent chapter in the section on Apparatus. With regard to the tripod and dark room lantern, reference may be made to the

subsequent pages wherein they are referred to, and the selection of a focussing cloth, dishes, and bottles calls for no special remark.

Having obtained some gelatino-bromide plates of the ordinary kind and of a moderate sensitiveness, the chapters on "Exposure," "Development with Pyrogallol," and "Fixing" may be consulted for the preliminary work. Some of the most suitable objects to practise on at first are a life-size plaster bust, so placed that one side is more brilliantly lighted than the other; or some very bold printing, such as a newspaper placard; or, for out-of-door subjects, a church porch upon which the sun shines obliquely, so as to give a good range of light and shadow.

As the preliminary printing practice, either bromide paper or platinotype paper may be selected. The first has the advantage that it is developed and fixed very much in the same way as the negative, but printing on platinum paper affords a rather better test of the quality of the negative.

These suggestions have been made especially for those who are obliged to begin their work without personal assistance. Even a little help from a competent teacher will be found of great advantage.

CHAPTER II.

THE DEVELOPMENT OF PHOTOGRAPHY.

PHOTOGRAPHY as a practical art is not yet seventy years old, though photographic processes must have been in progress on the earth before the existence of man. Every blade of grass bears upon itself a photographic record as to how much of it was above the ground and how much below, for the green colour that is so familiar is only produced where light gains access to the plant. Some of the effects of light must have been known thousands of years ago; but it is proposed here to refer only to the principal events that have an immediate bearing on the art as now practised, or on the materials used in connection with it.

The production of an image by means of a small hole must have been known a very long time ago in Eastern countries, where the illumination of outdoor objects is exceedingly brilliant and the interior of dwellings generally dark. Aristotle, three hundred years or more before the Christian era, refers to this phenomenon. The earliest known record of the effects of mirrors and lenses in the production of images appears to be by Roger Bacon about A.D. 1267.

In 1558, and subsequently, Giovanni Baptista della Porta, to whom is generally ascribed the invention of the camera, appears rather to have popularised it, bringing into prominence the application of facts that were already known to a few of his contemporaries, and probably had

been known long before. He described the production of images in a dark room by means of a simple hole, and also by the use of lenses and mirrors. But Daniello Barbaro, in 1568, appears to have been the first to describe the use of a convex lens for producing an image in a dark chamber. Those who care to search further into the history of the camera will find much assistance in a communication by Major-General J. Waterhouse to the Royal Photographic Society, which was published in their journal for 1901 (xxv., 270).

But it must be remembered that a camera is a mere convenience, and involves no other principle than the production of an image on a screen. It is, therefore, simply an arrangement for holding the image-producing lens or mirror and the screen. Generally stray light is excluded, but not always, as in astronomical work and sometimes actually in portraiture in the early days of Daguerreotype. Therefore, the two hands form a camera, so far as its fundamental principle is concerned, when one holds a lens and the other a piece of paper to receive the image of the sun or other object.

In the sixteenth century it was known to the alchemists that silver chloride is darkened by the action of light upon it.

In 1727, a German physician, John Henry Schulze, accidentally discovered that a pasty mixture of chalk and a solution of silver nitrate darkened when exposed to sunlight. He was very much astonished and amused that light should produce darkness (though this fact was known some two hundred years before), especially as he was seeking to prepare a phosphorescent substance. He entertained his friends by showing them the strange result,

and to make it more striking he cut out patterns and words, after the manner of stencil plates, and by attaching these to the side of the bottle that contained his muddy mixture and then exposing it to sunshine, he obtained the design or inscription on the contents of the bottle. He shook the bottle, and the design or motto disappeared! He particularly describes the precautions necessary to ensure the disappearance of the darkened design, so that the entertainment might be complete and the bottle ready for the next performance. Schulze has been called the discoverer of photography, but there is no evidence that he discovered photography any more than the alchemists did two hundred years before him, and he certainly had no notion of making photographs for their own sake, but quite otherwise.

In 1737, Hellot showed that silver nitrate solution on paper would darken in the light. He did nothing in a photographic way with the solution, using it only as a secret ink, the writing with it being invisible at first, and darkening on exposure.

In 1774, Charles William Scheele isolated chlorine (from hydrochloric acid by the action of the black oxide of manganese), and investigated its properties to a certain extent.

In 1777, Scheele prepared some silver chloride, and exposed it to sunshine for two weeks. He dissolved away the unaltered silver chloride by means of ammonia, and found metallic silver in the dark residue by treating it with nitric acid and precipitating the solution of silver nitrate so obtained with ammonium chloride. He also exposed some silver chloride in water to light, and found in the water the chlorine that had been separated from combination with the silver.

Scheele also exposed paper coated with silver chloride to a solar spectrum, and found that violet light had more effect than any other in darkening the silver compound. Some four or five years afterwards, Senebier timed the darkening effect of the various parts of the solar spectrum when projected on silver chloride—violet 15 seconds, green 37 seconds, red 20 minutes, and so on.

In 1795, Lord Brougham, then a youth seventeen years of age, sent to the Royal Society a paper, from which, Brougham afterwards stated, the secretary deleted a suggestion to receive the image produced by means of a hole in a shutter on a surface of ivory rubbed with silver nitrate, that the picture might be rendered "permanent." This appears to be the first suggestion to apply photography to pictorial purposes—and a very crude suggestion, as the result would be a "negative." It is stated that Wedgwood obtained some of his results as early as 1791, in which case he had results four years earlier than Brougham's suggestion.

In 1801, J. W. Ritter found that the darkening effect of the spectrum on chloride of silver extended beyond the visible spectrum (the ultra-violet) and in 1802 Wollaston confirmed this observation.

In 1802, a paper by Thomas Wedgwood (son of the great Wedgwood) and Sir Humphrey Davy was read at the Royal Institution on copying paintings done on glass, and making profiles by means of nitrate of silver. Davy found that chloride of silver was better than the nitrate, and that leather was better than paper. The materials used were not sensitive enough to be affected within a reasonable time by the image of a camera obscura, but some photographic prints were got by means of the

solar microscope. These experimenters failed to find a fixing reagent, although they sought for one. It is stated that Wedgwood obtained some of his results as early as 1791. This is certainly the first known attempt to produce photographs as we now understand the word—to produce photographs for their own sake, that is, as records of the things photographed.

In 1810, T. J. Seebeck observed that when the solar spectrum was projected upon moist chloride of silver on paper, some approximation to the natural colours was produced.

In 1812, Bernard Curtois discovered iodine.

In 1814, Joseph Nicéphore de Niepce began to experiment with photographic processes, using ferric chloride and silver chloride among other things. He eventually coated metal plates of various kinds with a film of bitumen, exposed them in the camera for some hours, and dissolved away the unaffected and still soluble parts of the film with oil of lavender. He endeavoured to darken the exposed parts of the metal, corresponding to the shadows of the subject, by the application of iodine and other substances, and some of his plates he etched with acid. In 1827, Niepce submitted some of his specimens to the Royal Society of London, but was refused a hearing, because he declined to give the details of his process. There seems to be no doubt that Niepce was the first to fix a photograph, or "heliograph," as he called it.

In 1819, Sir John Herschel described the hyposulphites and the solvent power of the alkaline hyposulphites upon chloride of silver.

In 1824, Louis Jacques Mandé Daguerre began

experiments, hoping to make permanent the pictures produced by the camera obscura which he used in his business as a scene painter, etc.

In 1826, A. J. Balard discovered bromine.

In 1829, Niepce and Daguerre entered into partnership.

In 1833, Niepce died. Daguerre continued the work, and from using iodine to stain the surface of his silver plates was led ultimately to the invention of the Daguerreotype process.

William Henry Fox Talbot is stated to have begun his researches in 1833, and in 1839 he stated that several pictures of a country house which he then showed had been taken in the camera in 1835.

Daguerre continued to work with much perseverance, and in 1838 attempted to form a company to work the process that he had discovered. He received but little encouragement, so at last he laid the matter before the French savant Arago, who was delighted with it and described it at the French Academy. Through Arago's influence, Daguerre received from the French Government a pension of 6,000 francs per annum, and a pension of 4,000 francs was awarded to the nephew of Niepce, on condition that they surrendered their rights in the process.

The year 1839 is the most important of any in the history of photography. From that time photography was a practical art. The difficulties that had seemed insuperable were overcome, and, although photography now is very different from what it was then, the differences are in degree rather than in kind. The fact that Daguerre had discovered the key to the art that so many had sought for in vain was known and discussed. Some

scientific men proceeded to sum up the possible methods by which the described results could be obtained, and so to get at the secret for themselves; and others who had been at work upon the subject brought their results forward.

The Daguerreotype process was patented in England on August 14th, 1839, and five days afterwards it was publicly explained in Paris, and given free to the world (except England).

In this year also, Fox Talbot described his process of "photogenic drawing," in which he used paper impregnated with common salt and sensitised with nitrate of silver, and fixed the image with a saturated solution of common salt. He produced both negatives and positives. He also substituted bromide of potassium for common salt to get the sensitive surface.

Sir John Herschel recommended hyposulphites for fixing. He exhibited at the Royal Society photographs made by himself, one of which was a picture of his telescope, and taken in a camera.

The Rev. J. B. Reade showed photographs that he had produced some year or two before by following up the method of Wedgwood and Davy. His supply of white leather falling short, he applied an infusion of galls (whence we get gallic acid and pyrogallol) to render nitrate of silver on paper more sensitive to light, and he fixed with hyposulphite of soda.

And Mungo Ponton pointed out that paper soaked in a solution of bichromate of potash and dried was changed by exposure to light, and that the chromium compound produced by light could not be washed away.

In 1840, Sir John Herschel used the terms "positive"

and "negative," as they are now understood photographically, "to avoid circumlocution." He used glass plates to receive and support the deposit of sensitive silver compound.

J. Goddard introduced bromine to be used in addition to iodine in sensitising the Daguerreotype plate, so very considerably reducing the exposure necessary to get a satisfactorily developable image.

In 1841, Joseph Petzval invented the lens that bears his name, and Voigtländer constructed it. By means of this lens, exposures were reduced to one-tenth of that necessary with the ordinary lenses used previously.

Fox Talbot patented his calotype process, in which iodide of silver was used on paper, and great sensitiveness was obtained by means of a solution of gallic acid with nitrate of silver, and the scarcely visible image produced by exposure was developed with more of the same solution. One minute's exposure with an aperture of f/15 was sufficient for a building in sunshine.

Antoine J. F. Claudet patented the use of coloured media, preferably red, through which the "dark room," which was till then really dark, was illuminated.

In 1842, Sir John Herschel described methods of printing with iron salts, including the production of prints in Prussian blue.

In 1844, Robert Hunt introduced ferrous sulphate as a developing agent.

In 1848, Niepce de St. Victor, nephew of the elder Niepce, introduced the albumen process, in which glass is coated with albumen that contains iodide of potassium, and the film is sensitised by dipping it into a solution of nitrate of silver (the silver bath). Herschel, eight

years before, had used glass plates to support the sensitive salt of silver, but with no film on the glass to hold the silver compound in position. The younger Niepce used a film (the albumen was afterwards replaced by collodion and then by gelatine), and produced the sensitive salt in the film as previous workers had on paper.

In 1851, Frederick Scott Archer introduced collodion, which was first suggested for photographic purposes by Le Grey.

In 1852, Fox Talbot described photo-etched plates, prepared by coating the plate (or lithographers' stone) with a mixture of gelatine and potassium bichromate, exposing under a negative, washing, and etching.

In 1854, *The Art Journal* gave an impression from a woodcut, engraved from a photographic impression on the wood.

In 1858, *The Photographic News* also gave a specimen.

In 1864, B. J. Sayce and W. B. Bolton used collodion emulsions.

And in 1871, R. L. Maddox used gelatine instead of collodion.

Many other historical details are given in subsequent chapters in connection with the subjects to which they refer.

This sketch of the early history of photography will perhaps be accepted as showing that it cannot be rightly said of any individual that he was the first photographer, or that he discovered photography. It was a case of slow development, as with most other arts and branches of knowledge. Many workers contributed to the progress—some less and some more. The position of photography at the present time would probably have been but little

different if any one of those concerned in its development had never existed.

There is, however, one whose contribution has often of late been belittled, who stands in quite a peculiar position. Daguerre was the first to lay before the public a practically useful and acceptable process. It was he who brought photography to the notice of the world and set it in a position from which it has never fallen back. Before the publication of his process, photography was only an art that a few workers were hoping to set upon a satisfactory basis. From 1839 it has been a practical method of record-making. Moreover, Daguerre was a man alone. How much he owed to the elder Niepce will perhaps never be known, but it seems highly probable that if Daguerre had never lived the Daguerreotype process would have remained unknown, and, instead of photography assuming a sudden practical importance, its gradual development would have continued until it slowly forced itself into the position that it was destined to occupy.

CHAPTER III.

PRELIMINARY CHEMICAL MATTERS.

The chemical action of light is universally known, though perhaps not often recognised. In our houses, it is usual to draw down the blinds to prevent the fading of the curtains and carpets; and the bleaching action of light was usefully employed before chlorine compounds in the preparation of cotton fabrics. Shortly before the Christian era, Pliny observed that yellow wax lost its colour by exposure to light. The destruction of colour, however, is not characteristic of the chemical action of light, for it has already been shown that chloride of silver is darkened by exposure, and that the green colouring matter of plants, the chlorophyl, is not produced in the roots which are below ground, nor in the plant at all if it is grown in the dark. Light causes the separation of chlorine from its compound with silver, but it causes chlorine to combine explosively with hydrogen if the two gases are mixed and placed in the sunshine. Hence, light must not be regarded as either a maker or a destroyer of compounds, as bleaching or producing colour. It is simply a force, and the change that it causes depends entirely upon the circumstances of the case. When it brings about a chemical change, it disturbs the stability of what it acts upon, and the resulting substance may be darker or lighter, it may be more or less complex, than the original.

Whether chemical action is produced by light, as in

photographic printing, or by other substances (they are called "reagents" in chemical language), as in developing, or whether it takes place spontaneously (the cause not being very obvious), the change or reaction proceeds according to the same general rules.

All substances must be either compounds or elements. Every compound can be decomposed, that is, pulled to pieces, and can be built up from its constituents; but the elements cannot be decomposed. If, for example, a few of the crystals of chloride of gold were heated to redness, this compound would be decomposed—that is, the gold and the chlorine would separate from one another; but whatever is done to a piece of iodine, or of silver, it is impossible by any known means to get anything whatever but iodine from the iodine, or silver from the silver. They may be ground up, melted, or volatilised, but the iodine always remains iodine, and the silver is always silver.

An element cannot suffer chemical change; when it enters into a chemical action, it must combine with something else. When a silver plate is sensitised for the production of a Daguerreotype it is exposed to the vapour of iodine, and the sensitive film is produced by the combination of the silver and the iodine. In this case, two elements combine to form a compound.

There are circumstances, however, that sometimes make it inadvisable to use the simple element when it is desired to get a compound containing it. If an over dense negative is to be reduced by changing a part of the silver image into chloride of silver, that hyposulphite of soda may dissolve it away, this change could be produced by applying the element chlorine. But chlorine

acts very vigorously in combining with other things, and would probably spoil the negative. The silver, moreover, can very readily take chlorine from the compound of chlorine with iron, called ferric chloride or perchloride of iron, leaving the iron with less chlorine; and as this compound is very much less likely to injure the negative, it is a preferable reagent to the simple chlorine. An element will often form a compound by taking what it combines with out of another compound.

Compounds invariably have very different properties from the elements of which they are composed. Sulphate of iron, for instance, contains the tough metal iron, the yellow sulphur, and gaseous oxygen, but the compound is not tough, nor yellow, nor gaseous. Pyrogallol is a compound of carbon, oxygen, and hydrogen; and, although each of these elements can be easily got out of it, so long as they remain joined together their individual characters are entirely lost—the compound bears no resemblance whatever to any of its constituents.

Elements. There are seventy-eight elements known at the present time, but the greater number of these are not of sufficient importance to the photographer to make it worth while to introduce them here. It is the custom of chemists to indicate the elements by their initial letters, or by the initial letters of their Latin names, sometimes adding a second letter to avoid confusion. And these "symbols" do not stand merely for the elements, but for a definite proportion by weight of each; for example, the two symbols which together constitute the "formula" of hydrochloric acid, HCl, indicate not only that the compound consists of hydrogen and chlorine, but also that it consists of these elements in the proportion of

1.008 part by weight of hydrogen to 35.45 parts by weight of chlorine.

The proportional weights assigned to the elements are termed the "atomic" weights, that is, the proportional weights of the atoms, and the symbols are taken as standing for the atoms. In the older tables of atomic weights, hydrogen was set down as the unit. It is, however, more convenient to calculate the atomic weights on the basis of oxygen—16, rather than hydrogen —1. For the practical purposes of the photographer, these and other small differences may be safely ignored. In the following table, the most recent determinations of the atomic weights are given, and in a second column more simple figures that may be used in almost every case without introducing appreciable error.

SYMBOLS AND ATOMIC WEIGHTS OF ELEMENTS.

Name.	*Symbol.*	*Atomic Weight.*		*Name.*	*Symbol.*	*Atomic Weight.*	
Aluminium	Al	27.1	27	Lithium	Li	7.03	7
*Ammonium	Am	18.072	18	Magnesium	Mg	24.36	24.5
Barium	Ba	137.4	137	Manganese	Mn	55.00	55
Bromine	Br	79.96	80	Mercury	Hg	200.0	200
Cadmium	Cd	112.4	112	Nitrogen	N	14.04	14
Calcium	Ca	40.1	40	Oxygen	O	16	16
Carbon	C	12.00	12	Phosphorus	P	31.0	31
Chlorine	Cl	35.45	35.5	Platinum	Pt	194.8	195
Chromium	Cr	52.1	52	Potassium	K	39.15	39
Copper	Cu	63.6	63.5	Silver	Ag	107.93	108
Gold	Au	197.2	197	Sodium	Na	23.05	23
Hydrogen	H	1.008	1	Strontium	Sr	87.6	87.5
Iodine	I	126.85	127	Sulphur	S	32.06	32
Iron	Fe	55.9	56	Uranium	U	238.5	238
Lead	Pb	206.9	207	Zinc	Zn	65.4	65.5

Every compound has a definite composition which can be expressed in most cases by a very simple formula. Thus, table salt or chloride of sodium is expressed as NaCl, and this formula, in conjunction with the above table, shows at once that this substance contains 23.05 parts by weight of sodium and 35.45 parts by weight

* As ammonium consists of two elements, nitrogen and hydrogen (NH_4), it is not an element but it is convenient to include it because it behaves like an element

of chlorine. Corrosive sublimate, which is written $HgCl_2$, contains 200 parts by weight of mercury, combined with twice 35.45 (that is, 70.9) parts by weight of chlorine. The proportion between the constituents of any given compound does not vary, but commercial preparations vary by being mixed with more or less of foreign matter which may have been not entirely removed in the manufacture, or which may have been produced by the decomposition or change of a part of the preparation.

Mixtures, however, are totally different from compounds. Sugar and salt may be ground up together in any proportions whatever. Two or more gases, such as nitrogen and oxygen, can be mixed in any proportions, and the same often applies to liquids, such as water and alcohol.

Such mixtures as those just instanced are readily prepared, but when it is desired to mix a solid with a liquid there are difficulties that have to be overcome. Sand will hardly mix with water, it soon settles down; but fine mud will remain in suspension for a considerable time. It is possible to get gold in such a fine state of division that it will remain for years before it settles down from the water in which it is suspended.

An "**emulsion**" is a milk-like liquid, having solid particles of such a degree of fineness in it that the ordinary methods of separating solids from liquids are almost ineffectual. Ordinary filtering media allow emulsions to pass through them, and the solid matter subsides very slowly.

However fine the particles of an emulsion are, they can be separated from the medium that holds them, and they are still solid, but when a solid substance is "**dis-**

solved" in a liquid, the most refined methods of filtration entirely fail to effect a separation. A dissolved compound is not chemically combined with its solvent, for the proportions of the two may be varied within certain limits, but the union is something closer than that of a mere mixture. The dissolved substance may generally be recovered by evaporating away the solvent, or by changing the solvent in such a way as to rob it of its dissolving power. Collodion, for instance, is a solution of what is called soluble gun-cotton in a mixture of alcohol and ether, and the gun-cotton may be recovered in the solid condition, either by evaporating off the alcohol and ether or by adding water, because both alcohol and ether are easily volatilised, and when mixed with sufficient water they cannot dissolve the gun-cotton.

It is often desired to obtain one constituent of dissolved matter in a solid form, the nature of the solid being quite a secondary matter so long as it contains the particular constituent; for example, the silver in waste solutions. In such cases, it is convenient to "precipitate" what is wanted by adding something that will make an insoluble compound with it, as, for silver, the sulphide of sodium, which produces the black insoluble sulphide of silver.

CHAPTER IV.

THE AIR, OXYGEN AND ITS COMPOUNDS, ETC.

The air, being invisible, is too often neglected when it does not make itself obtrusive by its movements. It would often be better for photographic operations if the air could be excluded, but in practical work this is impossible. It is necessary to consider its effects, therefore, and to take such precautions as may be necessary that it may not so interfere as to render one's work useless.

But if fresh air is sometimes detrimental because of its action upon the chemical substances employed, air vitiated by combustion or respiration is even worse. Photographers too often, in excluding light from their dark rooms, exclude the outer air as well. By so doing all who work in such rooms suffer by partial suffocation, which dulls their intellect, if it does not perceptibly injure their health, and photographic materials therein will generally deteriorate much more rapidly than in a well-ventilated apartment.

Combustion and respiration vitiate the air in a similar manner, using up its oxygen and producing carbonic acid gas and water. Although these products are heavier than air when they are cold, being hot when liberated they are lighter than the air, and ascend. The accumulation of foul air at the tops of rooms indicates the method of efficient ventilation; it is here that an exit should be provided, while fresh air is introduced at a lower level

in such a manner as not to agitate and mix with the upper layers of unwholesome gases. The higher a room is, the more space is provided for the foul air, and ventilation becomes less urgent. If sensitive materials must be kept in places where gas is burned and where people breathe, they should never be stored higher than about six feet from the floor, so that anyone walking in the apartment inhales the worst air likely to gain access to them. Neglect of these simple precautions has given considerable trouble to manufacturers, dealers, and photographers.

It is impossible to burn gas, or any ordinary combustible, in a way that will prevent the production of carbonic acid gas and water or reduce the amounts of these resulting from the combustion of a given quantity of the substance burned. No stove, therefore, should be used for heating unless it has an efficient chimney to carry off the products of combustion. It would be well if all flames used for lighting were similarly provided for, and this may become essential if the room is small or the ceiling low, unless the general ventilation of the apartment is very effective.

It is easy to show that the oxygen of the air, that is, the active part of it, forms only about one-fifth of its total bulk. The other four-fifths are nitrogen, which simply dilutes the oxygen. If a wet medicine phial has a few iron filings introduced into it, is shaken so as to spread them over its inner surface, and is then placed in an inverted position with its mouth under water, it will be found that the water will gradually rise in the bottle, until in a day or so it will be about one-fifth full of water. The water that rises into the bottle occupies

the space that was filled by the oxygen, and the oxygen has combined with the iron.

Developers absorb the oxygen of the air, especially when they are spread out into a thin layer as in a developing dish, and the compounds produced are worse than useless, because they are often dark coloured, and liable to stain the gelatine. Whatever developer is used, a sufficient quantity must be taken to allow for this deterioration during development.

The air always contains carbonic acid gas, normally about .04 per cent., but this amount is much increased in ill-ventilated rooms. This gas is subsequently referred to.

The water or moisture that is present in the air often causes the photographer much trouble in other ways than by the leakage of rain through skylights, or their breakage by hail or snow. The amount of the invisible vapour of water in the air is being constantly augmented by the evaporation of water from the wet ground, as well as from the surface of oceans, seas, rivers, etc. That a considerable quantity of water is really present in the air may be proved by putting a few pieces of ice in a tumbler of water. The glass will be cooled, and will cool the air that is in immediate contact with its outer surface, and the cooled air, not being able to hold as much water as it could at a higher temperature, will deposit water in the form of drops on the surface of the glass.

The hotter the air is, the more water it is able to take up, and as combustion and respiration produce water and liberate heat, the air of inhabited rooms often contains an excessive quantity of water. A cold lens or lantern slide brought into such a room will generally

become bedewed and useless for a time. Wiping off the moisture is of but little use in such a case, as, if the article remains cold, more moisture will deposit upon it. The moisture is condensed because the surface is cold, and it is only by warming it up to or above the temperature of the surrounding air that the annoyance will be obviated.

There are some substances that take up water with such eagerness that they will absorb moisture from the air with which they are in contact, sometimes to such an extent that the solid substance becomes moist, or even dissolves in the water it has absorbed. Carbonate of potassium and chloride of calcium are such compounds, and on account of this property they are called "deliquescent." Substances that absorb water from the air obviously "dry" the air. Strong sulphuric acid absorbs water vapour with greater avidity than either of these salts, but it is not always convenient to use. The paper prepared for platinum printing will give good results only when kept carefully dry, and this is accomplished by storing it in boxes that have chloride of calcium below perforated false bottoms. The chloride of calcium is mixed with asbestos, and tied up in muslin to prevent the fine particles from getting on to the paper.

Oxygen is more abundant than any other element. It has already been shown that the air consists chiefly of oxygen diluted with four times its bulk of nitrogen. Besides being present in the air, it constitutes eight-ninths by weight of water, and is doubtless the element present in the greatest quantity in the solid part of the earth's crust. Flints are more than half oxygen. This gas is

needed in an almost pure condition for the production of the limelight, and for other purposes in artificial illumination.

Oxygen is generally purchased ready prepared in steel cylinders, into which it is compressed by the manufacturers. At Brin's works, oxygen is obtained from the air, after removing the carbonic acid gas from it, by pumping it into heated retorts charged with dry barium oxide. Under these circumstances oxygen is absorbed, peroxide of barium being produced, while the nitrogen of the air passes away. The supply of air is then stopped and the pressure within the retorts reduced by pumping machinery, when, without changing the temperature, oxygen is evolved and collected in a suitable holder. This cycle of changes goes on continuously.

For the preparation of oxygen on the small scale, chlorate of potassium is the most convenient substance to use, and by simply heating to a little above the temperature at which it melts, it breaks up into potassium chloride and oxygen. The chemical equation is written thus—

$$KClO_3 = KCl + 3O,$$

and signifies that one molecule of the salt yields three atoms of the gas. The weight of the molecule of the chlorate, found by adding together the weights of its constituent atoms, is 122.6, and the weight of the three atoms of oxygen is three times 16 = 48. These figures, 122.6 and 48, show the proportion that always exists between the weight of the chlorate of potassium and the weight of the oxygen gas producible from it. The method of discovering the volume of any given weight of any gas is described in connection with hydrogen.

In preparing oxygen for practical purposes, it is necessary to mix the chlorate of potash with about half its weight, more of less, of the black oxide of manganese (sometimes called simply manganese). The amount of oxygen is not changed by this addition, but its evolution is rendered much more rapid, and the decomposition takes place at a lower temperature. The part that the manganese takes in the reaction is not certainly understood. If much of the gas is required a metal retort should be used, and in all cases the exit tube should be of large size, and care be taken that it does not get stopped up.

It should be noted that neither the potassium chlorate nor the manganese must be dirty from the presence of ordinary dust or anything that will burn. It is safer to heat a little of the prepared mixture first in an iron spoon or glass test tube, and if any appreciable sparkling takes place, the mixture must be rejected as dangerous.

Oxygen is a very little heavier than the air. Combustible things burn in it much as they do in the air, but more vigorously and rapidly, producing a higher temperature, because of the absence of nitrogen, and, therefore, more luminosity. A match with only a spark upon it bursts into flame when plunged into the gas. The greater brilliancy of combustion when oxygen is used instead of air has often been taken advantage of in the arranging of artificial lights for photographic purposes.

When substances are burned they are not lost, but new bodies are produced by their combination with oxygen. When the material burned is an element, the product is simply an oxide; and if a compound such as tallow, wax, or coal is burned, we may consider that each element

is acted upon as if it were alone. Coal, for example, gives carbonic anhydride (or carbonic acid, CO_2) from its carbon, water (H_2O) from its hydrogen, and sulphurous anhydride (or sulphurous acid, SO_2) from the sulphur that may be present.

Oxides, anhydrides, bases, acids, salts. The non-metals, except hydrogen, generally produce by their burning substances that are soluble in water and form acids when they are dissolved. Such a compound of oxygen is called an "anhydride." Metals, when they burn, produce what are called "oxides" or "bases," and these, if soluble in water, have properties that are the reverse of the acids. They change red litmus paper to blue, while the acids change blue to red; and they are slimy or soapy to the taste, instead of sharp and penetrating. These properties are termed "alkaline," and are exemplified in ordinary washing soda.

If an anhydride and a base are brought together they generally combine, and the distinctive properties of both are lost in the resulting compound, which is called a "salt." Sulphuric anhydride, SO_3 (which can be produced from sulphurous anhydride, SO_2, by adding more oxygen), will combine with the oxide of sodium to form the salt called sodium sulphate (or sulphate of sodium, or sulphate of soda). The salt has none of the distinctive properties usually associated with acids or alkalies, and its characteristic taste is referred to as "saline." The change that takes place during its production in this way is expressed chemically thus—

$$SO_3 + Na_2O = Na_2SO_4.$$

If the acid is used, that is, the anhydride plus water,

instead of the anhydride, the water involved is eliminated as the salt is produced—

$$H_2SO_4 + Na_2O = Na_2SO_4 + H_2O.$$

And if, instead of the oxide of the metal, we use the compound produced by adding it to water, that is, its "hydrate," we have this water also eliminated—

$$H_2SO_4 + 2NaOH = Na_2SO_4 + 2H_2O.$$

Or, again, if the acid acts upon a compound of the base with another acid, such as sodium carbonate, the carbonic acid or anhydride is eliminated—

$$H_2SO_4 + Na_2CO_3 = Na_2SO_4 + CO_2 + H_2O$$

This last is a very common method of producing salts, because carbonates are generally cheaper and more convenient to handle than oxides or hydrates.

There are some acids, such as hydrochloric acid, HCl, that have no oxygen in their composition, and that, therefore, cannot be built up of an anhydride and water. But all acids agree in containing hydrogen, and if we speak of a salt as an acid with its hydrogen replaced by a metal, we have a description that is universally applicable.

Every salt can be made to furnish an acid and a base. All salts are not neutral to test paper. Carbonic acid, for instance, is so weak an acid that it cannot neutralise the alkalinity of the soda when it joins with it to form sodium carbonate. This compound, however, is none the less a salt, for it has its acid and its base.

An acid and a base can very rarely exist side by side; they will combine to form the corresponding salt. If citric acid is added to restrain an alkaline developer, it

is not a case of simply adding a restrainer, as when bromide of potassium is added, but as the acid combines with some of the alkali to form a salt, that is, a citrate, the amount of free alkali has been reduced as well. But two or more acids, or two or more alkalies, can exist side by side, each as if the other was not present.

CHAPTER V.

CONCERNING HYDROGEN, THE COMBINING POWER OF THE ELEMENTS, AND CERTAIN PROPERTIES OF GASES IN GENERAL.

WATER contains eight-ninths of its weight of oxygen; the other ninth is hydrogen.

Hydrogen is a gas, and it is the lightest substance known. Its lightness is exceptional and characteristic. The chemical formula of water is H_2O, and the hydrogen can be set free from this compound by passing steam through a red-hot tube containing iron filings or nails. The change that takes place is represented thus—

$$3Fe + 4H_2O = Fe_3O_4 + 4H_2.$$

The oxide of iron produced is black, and forms a closely adherent film upon the surface of the metal. When carefully produced, this coating is usefully protective to the metal beneath, and ornamental ironwork and culinary apparatus are sometimes treated with steam at a high temperature, the oxide produced serving instead of enamel or paint. This black oxide is the most stable of all the oxides of iron; it will not readily react with acids to form salts.

But it is far more convenient to get hydrogen from hydrochloric acid by the action of zinc. The metal will decompose the acid alone in the gaseous condition, thus—

$$2HCl + Zn = ZnCl_2 + H_2,$$

forming zinc chloride and hydrogen; but it is better to

use the aqueous solution of hydrochloric acid (that is, the "hydrochloric acid" of commerce), and to add this, a little at a time, to the zinc, after covering it with water in a suitable generating apparatus. The water dissolves the chloride of zinc produced, and so keeps a clean surface of metal for the acid to act upon.

Hydrogen will burn readily in the air, combining with the oxygen in the air to form water (H_2O).

$$2H_2 + O_2 = 2H_2O.$$

This equation indicates the proportion that exists between the volume of hydrogen and of the oxygen with which it combines when it burns, because an equal number of molecules of any gas occupy an equal space under uniform conditions of temperature and pressure. Or, in other words, the volume of a gas, irrespective of its composition, is proportional to the number of molecules of the gas, if the temperature and pressure remain unchanged.

It is shown in the above equation that two molecules* of hydrogen combine with one molecule of oxygen; therefore, two volumes (pints, litres, etc.) of hydrogen will combine with one volume (pint, litre, etc.) of oxygen when it burns. This combination is gradual and safe when the hydrogen burns from a jet, but if the gas is mixed with the oxygen or air that it requires for combustion and a fire is put to the mixture, the whole bulk of gases burns almost simultaneously, the high temperature produced by the burning is developed suddenly instead of gradually, and an explosion results.

Of all the gases that the photographer is likely to

* The molecules of simple gases consist generally of two atoms.

have to deal with, perhaps hydrogen is the most likely to lead to accidents, and as coal gas contains, roughly speaking, about half its volume of hydrogen, it is not very far wrong to say that whatever precautions are necessary in dealing with hydrogen are also necessary in the case of coal gas.

Diffusion. Hydrogen is not only exceptionally light, but in the movements of its particles it is far more agile than any other substance. If it were attempted to fill a vessel made of unglazed earthenware or plaster of Paris with hydrogen by passing the gas into it, the operation would be unsuccessful, because the gas would rapidly escape through the minute pores of the material. Under these circumstances, as the hydrogen passed out of the vessel the air would pass in, so that a mixture of gases would be obtained in the vessel, and perhaps an explosive mixture. Minute holes or pores in gas bags or holders lead to similar results when the gas is not under pressure, and are very liable to cause accidents. A gas holder or gas bag that is not certainly in perfect condition may be safely used for oxygen, because this gas is slower in its movements than hydrogen, and will be useful, or at least never dangerous, when mixed with even a large proportion of air.

This property that gases have of passing through porous substances is called " diffusion." The diffusion of gases takes place at a rapidity that is inversely proportional to the square roots of their densities or specific gravities. For example, in the case of hydrogen and oxygen, the densities are as one to sixteen, the square roots of these figures are one and four, and reversing these we get four and one as the relative rates of diffusion of hydrogen and oxygen.

VOLUMES AND WEIGHTS OF GASES.

Calculations concerning gases. As hydrogen is the lightest gas, it is convenient to take it as the unit of specific gravity for gases instead of air.* The proportional weights or specific gravities of the simple gases are then expressed by the same figures that indicate their atomic weights; that is, oxygen is sixteen times heavier than hydrogen, nitrogen fourteen times, and so on. And if the weight of a unit volume of hydrogen is known, the weight of the same volume of any other gas is easily calculated. As a matter of fact, one litre of hydrogen measured at 0° C. and at 760 mm. barometric pressure weighs very nearly .09 gram. To take an example of the usefulness of these figures, suppose it to be required to find what bulk of oxygen can be got from a given weight of potassium chlorate. It is known that the weight of potassium chlorate is to the weight of oxygen as 122.6 is to 48. If the calculation is made in grams, the bulk of gas is readily got by dividing the weight of oxygen by .09 multiplied by 16, the result being in litres. An alternative method of calculation that will often prove more simple in practice is founded on the fact that the number of grams of any gas represented by its molecular weight will occupy 22.44 litres at 0° C. and 760 mm. pressure. This, for example, shows at once from the equation—

$$Zn + 2HCl = ZnCl_2 + H_2$$

that 65.4 grams of zinc will liberate 22.44 litres of hydrogen.

If it is desired to work with English weights and measures, the following table will prove useful—

One ounce of hydrogen or sixteen ounces of oxygen	measure	558·4 pints, 69·5 gallons, or 11·3 cubic feet.

* The fact that the atomic weight of hydrogen is given as 1.008, oxygen —16 being taken as the standard, interferes in no way with the principles here set forth.

As an illustration of the way to use these figures, we will suppose that a gas holder or bag that has a capacity of three cubic feet is to be filled with oxygen, and it is desired to know how much potassium chlorate should be taken for the purpose. As 11.3 cubic feet of oxygen weigh 16 ozs., three cubic feet of the gas weigh 4.24 ozs., which is the weight of oxygen required. It has been shown above that the proportion between the weight of oxygen and that of the potassium chlorate required is as 48 to 122.6. Then, if 48 ozs. of oxygen are furnished by 122.6 ozs. of potassium chlorate, 4.24 ozs. of oxygen will be yielded by 10.83 ozs. of potassium chlorate. A calculation so made gives the weight required of the absolutely pure and dry salt, and when the operation is carried out perfectly and with no loss; therefore, to allow for contingencies, from 11 to 12 ozs. should be taken instead of 10.83 ozs.

Combining power of the elements. Hydrogen is also the unit in comparing combining power. Some elements have, atom for atom, a combining power equal to that of hydrogen; others have a greater, but none have less. Combining power is called "valency," or, less wisely, "atomicity." The valency of some of the elements is shown in the following table—

VALENCY OF ELEMENTS.

One.	Two.	Three.	Four.	Five.	Six.
*Ammonium	Barium	Aluminium	Carbon	Nitrogen	Manganese
Bromine	Cadmium	Chromium	Manganese	Phosphorus	Sulphur
Chlorine	Calcium	Gold	Platinum		Uranium
Copper	Carbon	Iron	Sulphur		
Gold	Copper	Phosphorus	Uranium		
Hydrogen	Iron Lead				
Iodine	Magnesium				
Lithium	Manganese				
Mercury	Mercury				
Potassium	Oxygen				
Silver	Platinum				
Sodium	Strontium				
	Sulphur Zinc				

* Ammonium is included because it behaves like an element.

COMBINING POWER OF ELEMENTS.

The occurrence of an element in more than one column shows that it forms more than one series of compounds. In such cases those compounds in which the metal has the lower valency are generally designated by the adjective termination "ous" to the metal, and those with the higher combining power have the termination "ic." Thus ferrous chloride $FeCl_2$, ferric chloride $FeCl_3$, mercurous chloride HgCl, mercuric chloride $HgCl_2$. It is customary with some to write two atoms of mercury in mercurous salts, and two atoms of iron in ferric salts, thus Hg_2Cl_2 and Fe_2Cl_6; but this does not interfere in any way with the proportions. The simpler method is sufficient, and equally useful.

Sulphur occurs in three columns in the table, showing its condition in sulphides, sulphites, and sulphates respectively. Some of the elements that occur in the table only once are similar to sulphur in forming more than one series of compounds, but those not represented are either rare or of no interest from a photographic point of view.

This table has many uses. If, for example, the formula of chloride of gold is wanted, it will be found that gold has either one or three times the valency of chlorine, and that, therefore, one atom of gold will be equal in combining power to either one or three atoms of chlorine, AuCl or $AuCl_3$; but chloride of sodium always has the composition represented by the formula NaCl, because both elements have an equal valency. The oxide of gold would be one and a half of oxygen to one atom of gold, but as fractions of atoms are impossible by the definition of an atom the formula becomes Au_2O_3. The formula of sulphuric acid being

H_2SO_4, the expression for any sulphate can be obtained by replacing the hydrogen of the acid by an amount of the metal that is of equal combining power—K_2SO_4, or $CaSO_4$, because one calcium or two potassium atoms are equivalent in combining power to two hydrogen atoms. And so examples might be multiplied.

CHAPTER VI.

WATER, PEROXIDE OF HYDROGEN, AND OZONE.

WATER (H_2O) is the most important of all the compounds that contain hydrogen, and is produced whenever this gas is burned, whether it is alone, or combined with other substances as in ordinary fuel. Water can easily be separated into its constituent elements, namely, two volumes of hydrogen to one volume of oxygen. Pure water, however obtained, has invariable properties under uniform conditions; it is neither acid nor alkaline; it is colourless, except in layers of considerable thickness when it transmits blue light; it is tasteless; it boils at 100° C. (212° F.), and solidifies to ice at 0° C. (32° F.). Water when freezing expands by about one-eleventh of its volume, and as it is impossible to prevent this expansion any closed vessel filled with water is burst when the water is frozen. To prevent accidents to water pipes in the cold weather, it should be seen that there is room for this increase in bulk on freezing, unless the freezing can be prevented. Water vaporises at all temperatures; even ice and snow give off vapour when the air is below the freezing point, but, other things being equal, it vaporises more rapidly the higher the temperature.

Gelatine plates, carbon tissue, prints, etc., etc., are dried by the evaporation of the water from them. A high temperature favours drying, but a high temperature without ventilation is useless, for at any temperature below that of boiling water, air may be "saturated"

with moisture. This moist air must be removed to allow drier air to come and carry off its load of moisture. The hotter the air is, the more water it can hold before becoming saturated.

Water combines with many substances, often liberating much heat as it does so. The slaking of lime is a familiar example; here the lime (CaO) combines with water to form the hydrate of calcium (CaH_2O_2). Blue vitriol, or sulphate of copper, is found as blue crystals which contain water ($CuSO_4, 5H_2O$). If the crystals are moderately heated, they lose their water, and the residue is neither blue nor crystalline. This water is called "water of crystallisation."

Water is the most universal and useful solvent, and is never pure, because it dissolves a certain proportion of whatever it comes in contact with. The natural sources of water are supplied from the clouds, and even rain-water is not pure; it dissolves from the air as it passes through it oxygen, nitrogen, carbonic acid, and other gases in less proportion, besides small quantities of saline matters. As ordinarily collected, it has also whatever it can gather as it passes over roofs and gutters on the way to its tank. River water contains, in addition, a modicum of earthy matter of a nature determined by the soil over or through which it has flowed. If the soil is purely sandy, the amount of matter imparted to the water is infinitesimal, but gypsum (that is, sulphate of calcium or sulphate of lime, $CaSO_4$) is soluble in five hundred times its weight of water. Chalk or limestone (that is, carbonate of calcium or carbonate of lime, $CaCO_3$) is not appreciably dissolved by pure water, but if carbonic anhydride (CO_2) is also present it forms with the calcium

carbonate the soluble bicarbonate of lime ($CaCO_3, CO_2$). The carbonic anhydride is rarely lacking; a little is taken up from the air, and more is furnished by decaying vegetable matter. Of other substances sometimes present, but generally in smaller quantities, may be mentioned magnesium bicarbonate and common salt. Some natural waters contain exceptional substances in notable quantities, such as iron, sulphuretted hydrogen, or saline matter; these are generally distinguished as mineral waters, and obviously are unfit for use in photography.

The calcium and magnesium salts that are taken up by the water are the chief substances that make it "hard," so called because such water does not freely lather with soap. Any hardness due to the presence of bicarbonate of lime, and most of that due to bicarbonate of magnesia, can be got rid of by boiling to drive away the carbonic anhydride that has made these salts soluble, and so precipitating the carbonates. The chief constituent of boiler incrustations and the "fur" of kettles is carbonate of lime. Hardness that can be got rid of by boiling is called "temporary hardness." The carbonate of lime can also be removed on the large scale by adding lime to the water, and then allowing the precipitate of carbonate of lime to settle down. This is Clark's process. The lime combines with the carbonic anhydride of the bicarbonate of lime, and changes the whole into the insoluble carbonate of lime thus—

$$CaCO_3, CO_2 + CaO = 2CaCO_3.$$

Hardness due to sulphate of lime and to other compounds that are not thrown out of solution by boiling is called "permanent hardness."

Water also generally contains a small quantity of organic matter taken up from decomposing animal and vegetable substances, or introduced by sewage or other drainage water that accidentally, or of set purpose, has gained access to it.

All the non-volatile impurities of water are left behind by distillation, and water so prepared is the purest that can be got in any quantity. Distilled water should be used for solutions of oxalates (ferrous oxalate developer) and for nitrate of silver. But ordinary tap water may be used even in these cases if the injurious matters present are got rid of by adding a little of the oxalate or of the soluble silver salt, as the case may be, to the water, and allowing the precipitate formed to settle down. The action of the nitrate of silver should be allowed to take place in a glass vessel and in the light, so that organic matter may be removed, and it is well to add a little barium nitrate with the nitrate of silver, as this gets rid of sulphates, which are sometimes undesirable. The purified water should be tested, to see that an excess of the reagent is present, by adding a drop or two of a solution of calcium chloride to a small quantity of the water to which the oxalate was added, or a little common salt in the case of the nitrate of silver; if a turbidity is not produced, the water has not had enough of the reagent added to purify it.

The storage and conveyance of water need care, for soft water attacks lead and zinc to a dangerous extent. Hard water may be kept in contact with these metals, because the sulphate and carbonate present soon form a protective coating which practically stops the solvent action; but distilled water should not be allowed to

come into contact with anything but glass, good earthenware, or tin (that is, "block tin," not the "tin" of the whitesmith, which is tinned iron).

Peroxide of hydrogen is water with a double proportion of oxygen (H_2O_2), and is sometimes convenient as a source of oxygen that may be mixed with aqueous solutions, and has not the disadvantage of being either acid or alkaline. As purchased, it is always acid, because the presence of a little acid renders it more stable. It cannot be obtained in a pure condition—that is, unmixed with water—and the strength of commercial preparations is expressed by the number of volumes of oxygen that are liberated by boiling a unit volume of the liquid. That ordinarily sold is called ten or twenty volume, but the solution is very liable to lose strength, so that it can never be depended on unless it has been recently tested. A more reliable, purer, and far stronger solution has recently been introduced into commerce. It contains thirty per cent. of the peroxide, and is stored in bottles coated inside with paraffin wax, and closed with a plug of paraffin, as contact with glass leads to a slow decomposition.

A very dilute solution has been recommended for decomposing the last traces of hyposulphite of soda that remain in photographic films after the usual washing, but it is of very little, if any, use for this purpose. It oxidises about one-third of the hyposulphite into sulphate, and even after acting for many days the amount of sulphate produced is not more than about the half of what would result from a complete oxidation. The other product of the reaction is sodium trithionate, and this changes gradually into other complex compounds containing sulphur, which are as troublesome and probably

as dangerous as the hyposulphite itself. Moreover, the ordinary solution of hydrogen peroxide is always deteriorating, and it is not improbable that after a week or two it will have decomposed to such a degree as to have reduced its strength to a quarter or even a tenth of that of the original preparation. And the photographer has no indication whatever of this deterioration. If, therefore, it were satisfactory in its action, it would prove a very unreliable substance in ordinary practice. It is better not to depend upon it at all. (See Sodium peroxide.)

Oil paintings that have become discoloured or dingy through a part of the white lead having changed into sulphide of lead by the action of impure air can be restored by the application of peroxide of hydrogen, as it will change the black sulphide into the white sulphate of lead, thus—

$$PbS + 4H_2O_2 = PbSO_4 + 4H_2O.$$

When peroxide of hydrogen is mixed with certain other substances that are oxidisers, a mutual decomposition ensues, and oxygen gas is evolved. Oxide of silver, permanganate of potassium, and black oxide of manganese are decomposed in this way.

Ozone is a condensed and peculiarly active form of oxygen always to be avoided as detrimental to sensitive surfaces, and also to apparatus, by reason of its corrosive action. It is produced by electric discharges under certain conditions, and it is well to exclude all electrical apparatus from photographers' store rooms or dark rooms, except perhaps incandescent lamps, and the wires that lead to them.

CHAPTER VII.

CARBON AND SULPHUR WITH THEIR COMPOUNDS.

CARBON is one of the most unalterable of things, for it cannot be melted or volatilised except in the voltaic arc, and then very slowly, and it appears to be quite unaffected by exposure to atmospheric influences.

The diamond, which is the hardest substance known, and graphite, which is so soft that one's skin or soft paper is hard enough to act as a file upon it, are both essentially carbon. Charcoal, lampblack, soot, etc., are other less pure forms of carbon. Animal charcoal has a still greater proportion of matters that are not carbon, and is obtained by heating bones or animal refuse with exclusion of air. It is variously known as bone black, animal black, ivory black, etc.

These various forms of carbon have many uses. An uncut diamond, conveniently mounted so that one of its edges projects, forms the usual instrument for cutting glass. A fragment of a diamond mounted, with a sharp corner projecting, is useful for writing upon glass.

Graphite is commonly called "blacklead," and everyone is familiar with its use in coating (blackleading) ironwork, and in lead pencils. Amorphous carbon has a more extended application as a pigment. Ground up with diluted negative varnish, it may be applied to almost any surface to give a coherent, dull-black coating, and by revarnishing with uncoloured varnish a brilliant black surface is obtained. Metal articles are preferably

warmed before treatment. Starch-paste may be used as a medium instead of varnish for blackening other than metallic surfaces, such as the insides of cameras. The tinctorial matter of ordinary printers' ink is lamp-black. In carbon printing, too, carbon is used, and, as nothing is less amenable to change under ordinary circumstances, it may be regarded as permanent. It is, however, customary to modify the tint by adding other pigments which may not be so unchangeable. And the character of the substance that holds the pigment to the paper or other surface, or in which the pigment is embedded, must also be taken into account in considering the permanence of a "carbon" print.

Lampblack is the commonest form of amorphous carbon. It is prepared by burning pitch or resin in such a manner as to produce much soot. There is always more or less of oily matter that condenses with the lampblack. Its presence is not generally harmful, but it can be got rid of by heating the black to a red heat in a vessel suitably covered to exclude air and prevent loss by combustion.

It is stated that the soot from an ordinary gas flame is grey; that that got from the tip of a benzene flame is brown; and that bone black is the blackest of these forms of carbon.

Animal charcoal is an efficient and innocuous decoloriser, useful especially in bleaching lac varnishes, for it is not safe to employ lac bleached in the ordinary commercial way, lest it should be contaminated with the acid used.

Carbon combines with oxygen in two proportions, forming carbonic oxide (CO) and carbonic anhydride (CO_2).

OXIDES OF CARBON.

Carbonic oxide is produced when ordinary fuel burns with an insufficient supply of air, or when the combustion is retarded, as is generally the case in coke and gas stoves. If the gas flames impinge upon any substance, such as iron or asbestos, which is often provided to increase the amount of heat radiated, carbonic oxide is sure to be produced. And as this gas, even in small quantity, is highly poisonous when inhaled, no heating stove should ever be fitted without an efficient chimney. And this precaution is even more than usually necessary in a small room.

Carbonic oxide is a combustible gas that burns with a blue flame producing its own volume of carbonic anhydride.

$$CO + O = CO_2$$

Carbonic anhydride (CO_2) (also called carbon dioxide and carbonic acid) is the product of the complete combustion of carbon, and is not poisonous in the ordinarily accepted sense of the word, but is, on the contrary, very essential to our well-being. An undue accumulation of this, as of any other gas, is injurious, and should be guarded against by good ventilation. The unpolluted air contains about four parts of carbonic anhydride in 10,000 volumes, and respired air from three and a half to four per cent. It is produced by the combustion of carbon, by respiration, fermentation, decay, and by the action of an acid upon a carbonate.

An acid and a carbonate can rarely exist together; they will act upon each other with effervescence, because of the liberation of the gas under consideration. The base of the carbonate forms its corresponding salt with the acid used; for example, hydrochloric acid and

sodium carbonate produce sodium chloride, carbonic anhydride, and water, thus—

$$2HCl + Na_2CO_3 = 2NaCl + CO_2 + H_2O.$$

Carbonic anhydride is soluble in its own bulk of water. When dissolved in water, it has the chemical properties of an acid, though of a very weak acid. Ordinary soda water is little more than a solution of carbonic anhydride in water under pressure, and the taste of it does not even remind one of an acid, though it can turn blue litmus paper halfway towards red. It combines eagerly with caustic alkalies, not neutralising them, but reducing their caustic nature. It is an active agent in the rusting of iron, for polished steel will remain untarnished for years in an atmosphere, however moist, if carefully freed from carbonic anhydride and other acid substances.

Sulphur. The compounds that sulphur enters into are among the most useful that the photographer has at his disposal, and it is only by those who are ignorant of the facts of the case that this element is invariably regarded as an enemy. It occurs widely distributed in the free state, in combination with metals, and in many other compounds, of which both albumen and gelatine are examples.

Sulphur itself is a yellow brittle solid which burns without difficulty, and is of no immediate use to photographers. Its compound with hydrogen, sulphuretted hydrogen (SH_2), is occasionally useful, but must be rigorously excluded from any apartment where sensitive material is stored, and from silver prints either in a finished condition or at any stage of production. The

ordinary albumen silver print when subjected to the influence of this gas rapidly fades to the yellow colour that is so familiar. The sulphides of sodium, potassium, and ammonium give off sulphuretted hydrogen copiously when any acid is added to them

$$(SAm_2 + 2HCl = SH_2 + 2AmCl)$$

and are decomposed in a similar way slowly by exposure to the air, because of the carbonic acid gas present. These substances, if the photographer requires them, should therefore be carefully guarded. The characteristic odour of rotten eggs, that is, decomposing albumen, is due to sulphuretted hydrogen.

Sulphurous anhydride (SO_2) (also called sulphur dioxide and sulphurous acid). When sulphur burns, it produces sulphurous anhydride (SO_2), a heavy gas with an odour that was better known when matches were tipped with sulphur. Water dissolves about thirty times its volume of sulphurous anhydride, and gives a liquid that has acid properties. This solution is referred to when sulphurous acid is prescribed for developers. It is one of the most uncertain of preparations, varying in strength as at first obtained, and rapidly changing afterwards, getting weaker by the loss of some of the dissolved gas, and also by absorbing oxygen from the air and becoming sulphuric acid, thus—

$$SO_2 + O + H_2O = H_2SO_4.$$

The comparative amounts of sulphuric acid in two or more samples of sulphurous acid may be roughly estimated by taking a small quantity of each sample, adding to each, with agitation to mix thoroughly, an equal quantity of hydrochloric acid, about twenty times as

much water, and a solution of barium chloride in small quantity, but until the maximum turbidity is produced, The turbidity is proportional to the amount of the sulphuric acid present. The comparative strengths of the odour of burning sulphur from the mixtures so prepared will furnish a rough guide as to the strengths of the original samples.

Sulphurous anhydride can easily be liquefied by cooling it with ice and salt. It can be obtained commercially in "syphons," somewhat similar to those used for aerated waters, and this is by far the most convenient and certain way to get this compound and the preparations obtainable from it. It would be very undesirable, however, for anyone not accustomed to chemical operations to have to deal with liquefied sulphurous anhydride.

CHAPTER VIII.

SULPHURIC, HYDROCHLORIC, AND NITRIC ACIDS.

SULPHURIC ACID and sulphates are the most stable of the compounds of sulphur. The acid is produced in a dilute form by the spontaneous oxidation of sulphurous acid as already noted, and a somewhat similar method of preparation is pursued commercially. Sulphurous anhydride, obtained by burning sulphur, is mixed with air, steam, and a small proportion of nitric acid fumes, in a large leaden chamber that has a shallow layer of water upon its floor. The sulphurous anhydride, steam, and oxygen of the air, combine to produce sulphuric acid. The nitric acid readily gives up some of its oxygen to some of the sulphurous anhydride and steam, producing sulphuric acid and a lower oxide of nitrogen. This nitric oxide has the property of spontaneously combining with the oxygen of the air, and of at once parting with the oxygen it has combined with to the sulphurous anhydride and water, reforming nitric oxide which reacts again, and so continuously. One charge of nitric acid fumes would thus be sufficient for preparing any quantity of sulphuric acid if loss could be altogether avoided. The weak acid produced in the chambers is concentrated in leaden pans, and then in glass or platinum vessels as far as possible, to produce the "oil of vitriol" of commerce.

The photographer should always use the sulphuric acid known as "pure," and if this is obtained from a

respectable firm it may be relied upon. It should be colourless; a slight brown tint is probably due to a little dust. It must be kept in a properly-stoppered bottle, for it rapidly takes up moisture from the air that gets to it. It is a more powerful drying agent than chloride of calcium, but, being a liquid and highly corrosive, it is often not so convenient. The strong acid rapidly chars wood, paper, etc., and, as it is not volatile, it is dangerous to use it for clearing prints, etc., unless its application is followed by a thorough washing. Any dilute acid left in the paper remains; it keeps itself dilute because of its eagerness to combine with water, but its charring power is brought into play when it is concentrated by a gentle heat. Very weak sulphuric acid may be used as a secret ink, for writing done with it is invisible until it is warmed to concentrate the acid, when the paper is blackened wherever the dilute acid was put upon it. Parchmentised paper, or vegetable parchment, is made by plunging unsized paper into sulphuric acid mixed with a little water, and, after a few seconds, washing it thoroughly. It is stated that finished silver prints may be treated in this way without any injury to the picture.

It is necessary to exercise great care when diluting strong sulphuric acid, because of the violence of the combination of the two substances resulting in a considerable rise of temperature. If water is put into sulphuric acid the heating effect may be so great as to boil the water, or even to produce a spluttering that is almost equivalent to an explosion. Hence the acid should always be poured into the water in a thin stream, and the liquids should be kept gently agitated the whole time

with a rod of glass. If a white turbidity is produced by the dilution the acid used is not pure, but contains sulphate of lead derived from the vessels used in its manufacture.

Dilute sulphuric acid acts readily upon zinc and iron, and the hot strong acid corrodes all the ordinary metals; gold is not affected by it. Sulphuric acid is used in the preparation of hydrochloric, nitric, acetic, formic, oxalic, and citric acids, alum, corrosive sublimate, and many other common chemicals.

Hydrochloric acid (HCl) is prepared by warming together common salt and strong sulphuric acid—

$$NaCl + H_2SO_4 = NaHSO_4 + HCl$$

The hydrochloric acid escapes as a colourless gas, and is conducted into water to form the solution that is sold as "spirits of salt," "muriatic acid," or "hydrochloric acid." This solution fumes when exposed to the air, and contains generally about thirty-two or thirty-three per cent. of real acid, and never more than forty per cent. It is made weaker by heating, but if diluted with more than about its own bulk of water it loses a greater proportion of water than acid when boiled. It has practically no charring effect upon wood or paper, and, therefore, is a safer acid to use than sulphuric when either will serve. Dilute hydrochloric acid acts in the same way as dilute sulphuric acid in the majority of cases. It dissolves metallic zinc and iron, and most metallic oxides and carbonates, forming a chloride of the metal.

The hydrochloric acid used for photographic purposes should be what is known commercially as pure. It must be stored in a glass-stoppered bottle, and should not be

continually kept in a very light place, because light in the presence of air decomposes it slowly and gives free chlorine. The pure commercial acid is colourless. A yellow sample may owe its colour to iron, organic matter, or chlorine, and is unsafe to use except by one who has sufficient chemical knowledge to discover the cause of the colour, and to recognise its effect in any particular case.

Nitric acid (also called "aqua fortis," HNO_3) is prepared by the action of strong sulphuric acid upon potassium or sodium nitrate, and is a liquid. The strongest acid commercially obtainable has a specific gravity of about 1.5, but what is understood as strong nitric acid has a considerably less specific gravity, and contains at least some thirty per cent. of water. Nitric acid is very easily decomposed, giving up a part of its oxygen, the deoxidised residue of the acid showing as reddish fumes; it is therefore generally inferior to hydrochloric acid, except for purposes of oxidation and where soluble silver salts are concerned (hydrochloric acid would form the insoluble chloride of silver). When mixed with about four times its volume of hydrochloric acid, aqua regia is formed, which has the power of dissolving gold and platinum. The active agent of aqua regia is the chlorine liberated from the hydrochloric acid by the oxygen of the nitric acid—

$$HNO_3 + 3HCl = 2H_2O + Cl_2 + NOCl$$

The nitroxyl chloride (NOCl) that is formed at the same time is an orange-coloured gas.

Nitric acid acts upon most of the common metals, including silver, their oxides, hydrates, or carbonates,

producing nitrates; and its action upon the various forms of cellulose, such as cotton-wool and paper, is perfectly analogous. Pyroxylin or gun-cotton is a nitrate of cellulose, or a mixture of cellulose nitrates, and collodion is a solution of it in a mixture of alcohol and ether.

Nitric acid fumes when exposed to the air. It is colourless when pure, and has a very sharp, penetrating, and choking odour, something like hydrochloric acid. It should be free from hydrochloric acid, especially when it is to be used for preparing nitrate of silver, and this can be sufficiently proved by adding a little of the acid to four or five times its bulk of water, and then mixing with it a drop or two of silver nitrate solution. If no turbidity is produced, hydrochloric acid is absent.

CHAPTER IX.

THE PRINCIPAL COMPOUNDS OF POTASSIUM, SODIUM, AND AMMONIUM.

In reviewing the chemistry of the metals and their salts as concisely as possible from a photographic point of view, it will be convenient to consider the compounds of the two alkali metals, potassium and sodium, and of ammonium, simultaneously. Although potassium and sodium in the isolated form as metals have no practical interest to the photographer, one point about them is worth noticing, because it gives the key to differences in the properties of their compounds. Both metals decompose water when thrown upon it, and liberate hydrogen; but potassium acts with so much more energy than sodium that the liberated gas is ignited. On referring to the tables of atomic weights and valency, it will be seen that thirty-nine parts by weight of potassium are required to do the same amount of work in forming compounds, or to occupy the same place, as twenty-three parts by weight of sodium. Weight for weight, therefore, the former metal has less power than the latter, but it exerts its power with more intensity. A similar difference may often be traced in the compounds of these metals.

Potassium and sodium compounds are not volatile up to a red heat. Some are decomposed by heating, but the metals always remain in the residue. Ammonium compounds, on the other hand, are always either

volatilised or decomposed by heating them to a lower temperature than redness, and the ammonia is always lost. Hence ammonia used to be called the "volatile alkali."

The hydrates of potassium (KOH), **sodium** (NaOH), and **ammonium** (AmOH), are commonly called caustic potash, caustic soda, and ammonia respectively; and their caustic nature is shown by the rapidity with which they will disintegrate one's skin. The carbonates used to be called the "mild" alkalies to distinguish them from the caustic alkalies, and the old name very well describes the difference between them. Caustic potash and soda cannot well be purified, because there is no ready means of separating foreign matter from them and they absorb acid vapours of any description with great avidity. Caustic soda, generally speaking, is purer than caustic potash, and that prepared from sodium is the purest caustic alkali commercially obtainable. Caustic potash will often contain twenty per cent. or more of foreign matter.

Caustic alkalies dissolve grease, and hence are useful as detergents, but as they have a very decided action upon glass, they should be avoided or used sparingly for cleaning plates. Ammonia mixed with alcohol would appear to be preferable if we merely regard the preservation of the surface of the glass.

Sodium dioxide (Na_2O_2) is a yellowish powder of very considerable stability. It is prepared by heating sodium in a current of dry air. If a dilute solution of hydrogen peroxide were required, it would be more certainly obtained by dissolving sodium peroxide in the full quantity of water, and then slightly acidifying

the solution with hydrochloric or sulphuric acid, than by taking the ordinary commercial hydrogen peroxide from a bottle that has been previously opened. All such solutions should be kept as cold as possible during their preparation and storage.

Ammonia, as purchased, is a solution of gaseous ammonia (NH_3) in water. The specific gravity of the solution gets less as the amount of ammonia increases, and the ordinary full strength solution has a specific gravity of .880. It is advisable to dilute this with an equal bulk of water as soon as possible, as the more dilute solution loses ammonia less rapidly. The solution of ammonia absorbs carbonic acid from the air, but much more slowly than caustic potash or soda.

The carbonates of potassium and sodium are easily obtained pure, and are both crystallisable. The crystals contain water in very different proportions, but the "dry" salts can be purchased. "Washing soda" is crystallised sodium carbonate (Na_2CO_3, $10H_2O$); it contains nearly two-thirds of its weight of water, and by exposure to the air loses some of its water, and becomes opaque. It should be noted that sodium carbonate is commonly called "soda," and that what is generally sold by retail druggists as "carbonate of soda" (for medicinal and domestic purposes) is the bicarbonate, and useless as a substitute for the other. Sodium carbonate may be kept as a forty per cent. solution if it is desired to have a more concentrated solution than the usual ten per cent. Potassium carbonate when crystallised contains about one-fifth its weight of water (K_2CO_3, $2H_2O$), and by exposure to the air absorbs water, eventually getting pasty and wet.

In all formulæ where either of these carbonates is specified, it should be clearly stated whether the crystallised or dry salt is intended. Without this the formula is practically useless.

Carbonate of ammonia occurs in commerce as hard, irregular translucent lumps which smell strongly of ammonia. If an opaque and easily powdered layer is found upon the lumps it should be scraped off them; it is ammonium bicarbonate. This salt is not of a simple nature, and, in reality, is not what its name ought to signify. It consists of ammonium bicarbonate and ammonium carbamate in molecular proportions, and the carbamate gradually volatilises, leaving the bicarbonate as a white powdery mass. When dissolved in water, the carbamate soon combines with water, and forms the normal ammonium carbonate, and then the solution contains only the normal carbonate and the bicarbonate in approximately equal molecular proportions.

Tribasic sodium phosphate (Na_3PO_4, $12H_2O$) is obtained from the ordinary disodium phosphate (Na_2HPO_4, $12H_2O$) by adding caustic soda to its solution and evaporating to crystallise. The salt is permanent in dry air, and soluble in about five times its weight of water giving a solution that is strongly alkaline to litmus paper. For almost all practical purposes trisodium phosphate may be regarded as a simple mixture of the common disodium phosphate with caustic soda, as the third sodium atom is very loosely held by the phosphoric acid. On exposure to the air, for example, trisodium phosphate absorbs carbonic acid gas, forming a mixture of the ordinary phosphate and sodium carbonate—

$$2Na_3PO_4 + CO_2 + H_2O = 2HNa_2PO_4 + Na_2CO_3$$

Tribasic sodium phosphate is sometimes used as an alkali in developers, and, presumably, it is only one-third of the base that is available. It was introduced for this purpose in 1895 by Messrs. A. and L. Lumière and Seyewetz.

Sodium chloride (NaCl), also called common salt or table salt, is not pure unless specially prepared. If it has a tendency to get moist and clot together, it most probably contains magnesium chloride. Potassium chloride (KCl) is very similar to sodium chloride in its appearance and chemical behaviour. Ammonium chloride (AmCl), also called muriate of ammonia or sal-ammoniac, is more extensively used than either of the other chlorides. It is readily distinguished from them, as it gives off dense fumes when heated, and, if pure, it is entirely vaporised below a red heat. By sublimation it is freed from non-volatile impurities, and therefore the commercial salt is generally more pure than the chlorides of sodium or potassium.

Potassium bromide (KBr) is less liable to change than **bromide of ammonium** (AmBr), and is to be preferred on this account. Weight for weight, however, the potassium salt does not appear to be so powerful a restrainer as the other. Molecular proportions of each have perhaps equal restraining power, in which case five grains of ammonium bromide would be equivalent to approximately six grains of potassium bromide. This proportion must also be observed if one of the bromides is substituted for the other in preparing an emulsion. These salts are very soluble in water, and a fifty per cent. solution is easily obtained.

Potassium iodide (KI) should be quite white and dry, otherwise it is safer to reject it. By exposure to the air, it is decomposed with liberation of iodine which colours it brown, and carbonate of potassium is formed which absorbs moisture and makes the salt wet. Free iodine gives an intense blue colour when it is mixed, even in minute quantity, with cold starch-paste. Starch-paste is prepared by pouring boiling water on to a thin mixture of starch and cold water, until the starch loses its milk-white colour and the mixture thickens. A sample of iodide of potassium should be quite white and dry, and it should give no blue colour when dissolved and mixed with starch-paste and a few drops of dilute sulphuric or acetic acid. Iodine dissolves copiously in an aqueous solution of iodide of potassium, giving a dark brown solution. This is generally a more convenient preparation to use than the tincture, when a solution of iodine is required.

Sodium sulphite ($Na_2SO_3, 7H_2O$) can now be obtained commercially of excellent quality. By exposure to air, whether in the solid form or in solution, oxygen is absorbed and sodium sulphate is formed. Although this change takes place very much less readily than is usually supposed, the salt and its solution should be preserved in carefully-closed bottles which are opened as seldom as possible. It is convenient to prepare a forty or fifty per cent. solution of the crystallised salt, and fill small bottles with it, so that the bottle in use will not last very long nor be opened many times before it is exhausted. The crystalline lumps of the solid salt ought not to show much sign of changing to an opaque white powder. But it is a mistake to suppose that this powder

is sodium sulphate and therefore useless; it contains some sulphate, but after free exposure to the air for many days the product will still contain a considerable proportion of sulphite. The chief impurity to fear in sodium sulphite is the sulphate, and, if necessary, a good idea of the amount present may be obtained by dissolving half a dram in about an ounce of water, and thoroughly mixing with it about one dram of hydrochloric acid, and then a strong solution of barium chloride, a few drops at a time, until the maximum turbidity is produced (or two grams of the sample to thirty c.c. of water and five c.c. of hydrochloric acid may be taken). If two or more samples are treated in the same way, a very good idea of their comparative qualities may thus be obtained. The turbidity is due to sulphate of sodium in the sample, therefore the less of it the better; and the acid added liberates sulphurous anhydride, which has the characteristic odour of burning sulphur, by its action upon the sulphite, and the best sample, therefore, will give the strongest odour. The action of the acid is thus expressed—

$$Na_2SO_3 + 2HCl = 2NaCl + SO_2 + H_2O.$$

Sodium sulphite is generally slightly alkaline. An inferior sample may contain a considerable quantity of sodium carbonate. Litmus is not a serviceable indicator in this case, and phenol-phthalein should be used. This reagent will be reddened when added to the solution if the carbonate is present, and it invariably is. Two or three drops of concentrated hydrochloric acid or two or three grains of citric acid will be sufficient to acidify one if not two ounces of the solid salt if it is a good sample (or three grams of acid to 1,000 grams of the salt). A slight alkalinity in sodium sulphite may be disregarded.

Potassium metabisulphite ($K_2S_2O_5$) is an acid salt, and contains a very much larger proportion of sulphurous acid than sodium sulphite, namely, about two and a quarter times as much. Being acid, it is, like almost all acids, a good preserver of pyrogallol in solution, but it is very undesirable in developers, because it neutralises and so renders inoperative a part of the alkali added. The photographer, therefore, cannot tell how much of the alkali that he has put in is really available.

"**Acetone sulphite**" [$(CH_3)_2CO, NaHSO_3$] is the compound of acetone with acid sodium sulphite. It behaves like an acid sulphite, and has the same disadvantage in the developer as potassium metabisulphite. The presence of the acetone does not appear to be of advantage in any case. The compound is very soluble in water, and the solution on gentle warming begins to decompose, giving off acetone and sulphurous anhydride.

Sodium thiosulphate ($Na_2S_2O_3, 5H_2O$), also called sodium hyposulphite, or simply "hypo," is more stable than the sulphite. A solution of it should not be used until a day or so after it is made up, to allow a little sulphur that is generally liberated to deposit itself. Sodium hyposulphite, if clean, may be relied upon. It is decomposed by acids, with production of sulphurous anhydride and precipitation of sulphur, thus—

$$Na_2S_2O_3 + 2HCl = 2NaCl + SO_2 + S + H_2O.$$

Alum acts somewhat similarly. Ferric chloride or sodium hypochlorite oxidises it to sulphate without precipitation of sulphur, thus—

$$Na_2S_2O_3 + 8FeCl_3 + 5H_2O = 2HNaSO_4 + 8FeCl_2 + 8HCl.$$

Therefore, if any acid or alum is mixed with a solution of hyposulphite of soda, as some recommend in making a fixing bath, part of the salt is decomposed, and the fixing power of the solution is decreased.

The sulphides of potassium, sodium, and ammonium are of little photographic use; they are employed, though seldom, in intensification. In any form they give off sulphuretted hydrogen as air gains access to them, and as this gas is exceedingly harmful to sensitive surfaces the sulphides should be rigidly excluded from the general photographic operating room. These compounds change by oxidation, and an old sample will probably have no sulphide remaining in it. If fit for use, the smell of rotten eggs is evolved when any acid is added to them.

Potassium cyanide (KCN) is a white salt that may be got in crystals, but is generally sold in irregular lumps or in sticks. It is exceedingly poisonous, and any acid will decompose it with evolution of hydrocyanic (or prussic) acid, thus—

$$KCN + HCl = KCl + HCN.$$

The salt as purchased is rarely pure; it often contains as much as threequarters of its weight of potassium carbonate, but this is not of necessity detrimental. If white and clean and dry, it may be considered fit for use.

Ammonium thiocyanate (AmCNS), also called ammonium sulphocyanide, is a colourless, crystalline, deliquescent salt, and very soluble in water.

Potassium ferrocyanide ($K_4FeC_6N_6$, $3H_2O$), or yellow prussiate of potash, is of very little importance photographically. It is a permanent compound, and invariably obtained in good condition

Potassium ferricyanide ($K_3FeC_6N_6$), or red prussiate of potash, is an active agent in the production of "blue prints," and is useful as a reducer of negatives. The ferricyanide is not stable in solution, especially when exposed to light; it should therefore be dissolved only as it is wanted. The crystals are invariably covered with a loose powder or coating of the partially decomposed salt, but this is easily removed by washing them with water until they appear of a bright ruby red colour.

Potassium oxalate ($K_2C_2O_4, H_2O$) is distinguished from other oxalates of potassium which are acid by calling it neutral, although the commercial salt has an alkaline reaction. It dissolves in about three times its weight of water, even in the cold, and for some purposes for which it is used, if the presence of a small amount of alkali is likely to be harmful, it is advisable to add just enough oxalic acid to it to give the solution a very slight acid reaction. For making a solution of this salt distilled water should be employed; or, if hard water is used, the oxalate of lime produced from the lime salts present will need either to be filtered off or to be allowed to settle down.

Potassium persulphate ($K_2S_2O_8$), sometimes sold under the name of "anthion," is prepared by the oxidation of potassium acid sulphate by electrolysis, keeping the solution cold. It is a white salt sparingly soluble in water, requiring about fifty times its weight of water for solution.

Ammonium persulphate ($Am_2S_2O_8$) occurs as transparent crystals, and is very soluble in water, twice its weight of water being more than sufficient for complete solution.

These persulphates decompose slowly, giving acid sulphates, and generally the amount of acidity may be taken as an indication of the amount of decomposition. When they oxidise substances in solution, they become acid, thus—

$$Am_2S_2O_8 + H_2O = 2HAmSO_4 + O.$$

Sometimes their oxidising action is slow, as in the liberation of iodine from potassium iodide. Fabric moistened with the solution of a persulphate eventually becomes rotten.

CHAPTER X.

VARIOUS INORGANIC COMPOUNDS.

CALCIUM CHLORIDE ($CaCl_2$) is used chiefly for drying purposes, as in the canisters made for preserving platinum or other sensitive paper in. The commonest preparation that is usually sold is good enough for this purpose, and when it begins to lose its desiccating power it only needs heating nearly to redness to make it useful again, because the moisture, in attaching itself to the chloride of calcium, effects no chemical change in the compound, and is driven off at the higher temperature. A tin, copper, or thin iron dish, heated over a gas stove or a clear fire, is a convenient apparatus to use for this purpose.

Bleaching powder, or chloride of lime, sometimes incorrectly called calcium hypochlorite, is prepared by passing chlorine over slaked lime. It decomposes in a variety of ways by keeping, and an old or moist sample should be rejected. Its use in photography is due to the chlorine that it contains in an easily available form, and any acid, even carbonic acid, will liberate chlorine from it.

Alum is a double sulphate of aluminium and ammonium [$AmAl(SO_4)_2, 12H_2O$]. It is soluble in about eighteen parts of cold water, it has a strong acid reaction to litmus, and, indeed, acts generally like an acid, except that it hardens gelatine. It is preferable to buy the crystallised compound, as the powdered salt is often more difficult to dissolve.

Ferrous sulphate (also called green vitriol or copperas, $FeSO_4, 7H_2O$) forms green crystals, which, when fairly pure and clean, are remarkably permanent. Many years' preservation in a corked bottle will not appreciably affect them. This salt should be dissolved in cold water (twice its weight of water is sufficient), as heating with water causes a partial decomposition unless an acid is previously added. The solution is oxidised and so rendered useless by exposure to the air, with the formation of a rusty coloured precipitate. If an acid or an alkaline citrate has been added, the oxidation will take place, but no precipitate will fall.

The double sulphate of iron and ammonium ($FeAm_2S_2O_8, 6H_2O$) gives a solution that is perhaps more permanent than that of the simple ferrous sulphate, and is preferred by many as a developer for wet collodion plates.

Ferric chloride ($FeCl_3$), or perchloride of iron, is generally bought in solution. Strong solutions are reddish brown, and a well-marked yellow colour remains after adding a very large proportion of water. A solution that contains free hydrochloric acid has a lighter colour.

Ferrous oxalate (FeC_2O_4) may be obtained by mixing a solution of ferrous sulphate with a solution of oxalic acid and warming; a copious yellow precipitate of this compound is produced. It is practically insoluble in water, and soluble in alkaline oxalates. Potassium oxalate is preferred as a solvent, because a saturated solution of it dissolves more of the ferrous salt than either of the other oxalates. Ferrous oxalate, however, is more often made only as it is required, by mixing a solution of ferrous sulphate with a solution of a large excess of potassium

oxalate, so that the ferrous oxalate remains in solution. A solution of this salt in an alkaline oxalate has a well-marked red colour.

Ferric oxalate [$Fe_2(C_2O_4)_3$] is also sparingly soluble in water, but cannot be conveniently prepared by precipitation as it dissolves in acids. Like ferrous oxalate it is never used alone, but always as a double compound, its second constituent being generally oxalic acid, though an alkaline oxalate might be used instead. Ferric oxalate as commercially obtained is a solution of the salt in oxalic acid. It may be prepared by adding ammonia to a hot and rather dilute solution of ferric chloride, thoroughly washing the precipitated ferric hydrate, and then draining it as dry as possible. Finely-powdered oxalic acid is then put upon the gelatinous mass in small quantity at a time with vigorous shaking until after several hours almost the whole of it is dissolved; and the solution is then filtered. The preparation should be protected from the light as soon as the oxalic acid is being added. Ferric oxalate is the sensitive salt in paper prepared for the platinum printing process.

The double citrate of iron and ammonium is obtained from washed ferric hydrate prepared as above described. The amount of citric acid added nearly to dissolve the ferric hydrate must be known; an equal amount is taken, neutralised with ammonia, and then added to the iron solution. This double salt is chiefly used in preparing the paper that gives prints in Prussian blue.

Potassium permanganate ($K_2Mn_2O_8$) is obtained in small crystals of a dark purple brown colour, and is distinguished by its exceptionally great tinctorial power. A scarcely weighable amount will give a fine purple colour

to a pint of water. Reducing agents, such as sodium thiosulphate, either change it to the green manganate, or, if they are added in excess, to colourless compounds of potassium and manganese. A solution of this salt stains paper and such substances to a brown colour, because the permanganate gives up some of its oxygen to the organic matter, and forms brown manganese oxides. Hence it is used to intensify gelatine transparencies obtained as in carbon printing. The brown colour so produced is readily removed by a solution of sulphurous acid.

Chrome alum ($KCrS_2O_8$, $12H_2O$) is a dark violet-coloured substance, similar in chemical constitution to common alum, being a double sulphate of chromium and potassium. It is very effective in rendering gelatine insoluble, and a small proportion is sometimes added to gelatine preparations to confer the desirable amount of hardness.

Potassium bichromate ($K_2Cr_2O_7$) and **ammonium bichromate** ($Am_2Cr_2O_7$) are red salts, and one or the other is used in almost all the photo-mechanical processes and in carbon printing, as well as in other photographic operations. The use of the bichromates is founded on the fact that when a gelatine film is impregnated with one of them and exposed to light, the chromate is reduced to compounds analogous in effect to chrome alum, and thereby the gelatine is changed so that it is insoluble in hot water, and will not swell up in cold. Soluble compounds of chromium are poisonous, and especially injurious to some constitutions, causing great irritation, and even soreness of the skin. These and worse effects may result from the continued application of solutions to the skin, as in carbon printing, if the operator is sensitive, as some

are, but great care should be taken by everyone that the smallest sore place is protected from contact with any chromate.

Copper sulphate ($CuSO_4, 5H_2O$), **lead acetate** ($PbC_4H_6O_4, 3H_2O$), and **lead nitrate** (PbN_2O_6) are comparatively unimportant to the photographer, and the commercial preparations are invariably suitable when they are required.

Silver is a white metal. It is an interesting coincidence that this metal, which is the best known conductor of heat and electricity, forms compounds which are the most usefully acted upon by light. Many metallic compounds are decomposed by exposure to light, but it appears that silver alone gives compounds that are affected by an exceedingly small amount of light in such a way that some reducing agents (or developers), which alone cannot reduce the compound, are enabled thereby to cause a complete decomposition of the salt.

Silver nitrate ($AgNO_3$) is the chief soluble salt of silver, and it is consequently the starting point in the production of silver compounds in general. It forms heavy, colourless crystals, which contain no water of crystallisation. A crystal, if placed upon wet litmus paper, ought to redden it very slowly indeed, if at all, for actually pure nitrate of silver appears to be more inclined to show a slight alkaline reaction. To fit the compound for photographic uses, it is generally recrystallised two or three times, but the amount of purification effected by recrystallisation depends entirely upon the care with which the operation is performed, and a slight improvement secured in this way may be soon negatived by careless treatment afterwards. The small differences

in various preparations cannot be detected in any rough and ready manner; indeed, it appears probable that the photographic fitness of a sample of silver nitrate is a more delicate indication of its purity than any chemical test. Distilled water should always be used in making solutions of this salt, but if the only water that can be obtained is impure, whether it is called distilled or not, it may in the majority of cases be made serviceable by adding a small quantity of nitrate of silver to it in a clean white glass bottle, and exposing it to sunlight until the insoluble matter produced has settled down, and the supernatant water is quite clear. The nitrate of silver precipitates, or otherwise gets rid of those matters that are injurious to it, and the clear water may be poured off. Such purification, however, is comparative, and not absolute. If, for instance, the water is hard from the presence of carbonate of lime, then an insoluble carbonate of silver is precipitated, but nitrate of calcium remains in the water—

$$CaCO_3 + 2AgNO_3 = Ca(NO_3)_2 + Ag_2CO_3$$

and the nitrate of calcium, although it will not interfere with the nitrate of silver, may be more or less detrimental to the preparation for which the nitrate of silver solution is required. The following are the changes that nitrate of silver undergoes when its solution is mixed with the solution of various reagents:

Hydrochloric acid, or a soluble chloride, produces a white curdy precipitate of silver chloride (AgCl), which is soluble in ammonia, but unaffected by nitric acid.

Potassium bromide (KBr), or a soluble bromide, gives a yellowish white precipitate of silver bromide (AgBr),

soluble in a considerable quantity of ammonia that is not too weak, and insoluble in nitric acid.

Potassium iodide (KI), or a soluble iodide, gives a light yellow precipitate of silver iodide (AgI), insoluble in ammonia or nitric acid.

Sodium carbonate (Na_2CO_3) gives a grey precipitate of carbonate of silver (Ag_2CO_3), which is soluble in nitric acid with effervescence, reproducing silver nitrate.

Caustic soda (NaOH), or caustic potash (KOH), gives a brown precipitate of oxide of silver (Ag_2O), which is soluble in either nitric acid or ammonia.

Ammonia gives a precipitate of silver oxide, which dissolves if more ammonia is added.

Mercury, zinc, tin, iron, copper, lead, and other such metals, if introduced into a solution of silver nitrate, precipitate the silver in the metallic form. The metal used is at the same time corroded, and an equivalent weight of it is dissolved, thus—

$$2AgNO_3 + Hg = HgN_2O_6 + 2Ag.$$

Nitrate of silver may be heated in the solid condition until it melts without decomposition; but if any organic particles, such as dust, are allowed to gain access to it, the salt gives oxygen to the organic matter, and is itself partially reduced to nitrite of silver ($AgNO_2$). The pure nitrate will lose oxygen and become nitrite if it is heated much above its fusing point. The nitrite of silver shows itself in making a solution of the fused salt by remaining as a difficultly soluble powder, and the alkaline reaction of the solution is a further demonstration of its presence.

Mercuric chloride ($HgCl_2$), or corrosive sublimate, is the only compound of mercury that is much used by the

photographer. It is a white, very heavy compound, soluble in about fourteen times its weight of cold water, and more soluble in the presence of ammonium chloride. The commercial preparations are generally in suitable condition for use.

Uranium nitrate $[(UO_2)N_2O_6, 6H_2O]$ and the corresponding acetate are yellow crystalline salts that do not call for any special remarks.

Chloride of gold ($AuCl_3$) is a compound often talked about, but rarely seen. It is probable that the preparations that appear to be the cheapest are really the most expensive if the actual amount of metal is made the basis of the cost, and this is the only correct method of calculating the matter, as the gold itself is the only valuable and useful constituent. By dissolving gold in aqua regia, and evaporating and crystallising, the chloride of gold is obtained in combination with hydrochloric acid and water as yellow deliquescent crystals. This is the only commercial preparation that can with any propriety be called simply "chloride of gold." If common salt is added to the solution before crystallisation, the sodium chloride takes the place of the hydrochloric acid, and a compound is obtained of chloride of gold, chloride of sodium, and water. This preparation is the "non-deliquescent chloride of gold," and as it is more stable and not acid, it is probably more suitable for photographic uses. In no case, however, is the weight of a commercial gold salt an exact criterion of its value, but the weight of the actual gold itself.

Potassium platinous chloride, or potassium chloroplatinite (K_2PtCl_4), is a red crystalline salt easily soluble in water. It is obtained by reducing a solution of platinic

chloride by means of sulphurous acid gas and adding the required amount of potassium chloride. The crystals are obtained on evaporating the solution. This salt is used for platinum printing and for toning silver prints. For these purposes platinous chloride ($PtCl_2$) is preferred to platinic chloride ($PtCl_4$), because in depositing the metal there is less chlorine to be removed from it, and also because the withdrawal of chlorine from platinic chloride may result merely in the formation of platinous chloride with no deposit of metal. It is impossible to take any chlorine from the lower chloride without getting a corresponding amount of metal liberated. Platinous chloride is used in combination with potassium chloride because by itself it is insoluble in water.

CHAPTER XI.

VARIOUS ORGANIC COMPOUNDS.

GELATINE. If a bone is soaked in dilute hydrochloric acid for a few days, the mineral matter, which is chiefly phosphate of lime, will be dissolved away. The bone will appear much the same as before, but instead of being hard it will be tough and soft while still wet. The substance that remains is the organic part of the bone, and is called "ossein." When ossein is boiled in water, it does not suffer an appreciable change in composition, but it gradually becomes soluble, and the solution obtained sets to a jelly as it cools. This product is gelatine. Skin and hide also give gelatine when boiled with water, but unossified cartilage yields a jelly which has different properties, and is called "chondrin." Chondrin is present to a considerable extent in "size"; it is less adhesive than gelatine, and also differs from it in being made insoluble by nearly all acids, by alum and by iron salts, but not by corrosive sublimate. It is present in varying quantities in commercial gelatine, and to the least extent in those specially prepared for photographic purposes.

Isinglass is a variety of gelatine prepared principally from the swimming bladder of the sturgeon. Glue is an impure gelatine made from animal offal. The purer sorts of gelatine are prepared from selected materials, after they have been subjected to a prolonged cleaning process by means of alkali and sulphurous acid, by extracting them with steam, allowing undissolved matter

to settle out of the solution, cooling to gelatinise, and thoroughly washing the jelly to remove the acid. It is then remelted, and worked into the desired form for drying.

Gelatine varies even from similar tissues of animals of different ages, and it also varies according to the treatment that the raw material has undergone in its preparation. The chemical composition has been found by different analysts who have experimented upon gelatine obtained from different sources to be about as follows in parts per hundred—

Carbon	49	to 50	
Hydrogen	6.5	to 7	
Nitrogen	17.5	to 18.5	
Sulphur	·1	to .2	or more
Oxygen	24	to 27	

Gelatine should be colourless, transparent, hard when dry, inodorous, and when in solution tasteless, and neither acid nor alkaline. It sinks in water. When heated it melts and decomposes, giving off ammoniacal fumes, like most nitrogenous substances of animal origin, and when burnt away should not leave more than one to two per cent. of ash. If placed in cold water it swells very considerably, and absorbs from five to ten times its weight of water without very much dissolving. The swelled gelatine dissolves in hot water, and if the water used is not more than one hundred times the weight of the gelatine, the solution will gelatinise on cooling; but with 150 parts of water to one of gelatine the solution will remain liquid. By prolonged heating of the water solution, as in cooking emulsions, it gradually loses its gelatinising qualities, and the change takes place more quickly at a high than at a low temperature; but alcohol

will precipitate from such a solution gelatine that will gelatinise when boiled with fresh water.

Strong sulphuric acid and nitric acid change gelatine into entirely different substances which are readily soluble; hydrochloric acid that is not too weak dissolves gelatine; acetic acid causes it to swell up, makes it soft and transparent, and finally dissolves it. The acetic acid solution, though it does not gelatinise, retains the adhesive qualities of the gelatine, and is the foundation of some makes of "liquid glue." Slightly diluted nitric acid acts in a somewhat similar way to acetic acid. Dilute acids in general neither prevent the gelatinisation of gelatine, nor make it insoluble; nor do dilute alkalies, or even strong ammonia.

Moist gelatine exposed to the air decomposes, becoming first acid, and then alkaline from the production of ammonia. The development of an acid reaction is characteristic of gelatine, and acidity in a sample may indicate that putrefaction has begun, or, on the other hand, that the acid used in its preparation has not been thoroughly washed out. At a temperature of 90° F. the decomposition of moist gelatine may begin in twenty-four hours, but gelatine appears to remain unchanged if it is carefully kept dry.

Soluble gold and silver salts do not make gelatine insoluble, and such mixtures are readily acted upon by light. Nitrate of silver with gelatine is reduced on exposure, with formation of red-coloured products. Tannic acid ("tannin") gives a very insoluble compound with gelatine, and this reaction is so delicate that a solution containing so little as one part of gelatine in five thousand parts of water is rendered turbid by the addition of tannic

acid. The tanning of skins in making leather consists essentially of causing the tanning material used to act upon the gelatine in the hide, and change it into this insoluble compound, which is distinguished for its toughness and non-liability to putrefy. But if tannic acid is applied to a gelatine negative, it causes rapid frilling and blistering, unless the solution used is very weak.

Corrosive sublimate, platinic chloride, chrome alum, and chlorine gas make gelatine insoluble, and alcohol also precipitates it from aqueous solutions. Gelatine that has been soaked to swell in a solution of chrome alum will not dissolve, though the water it is put in is raised to the boiling temperature. Bromine and iodine combine with gelatine without rendering it insoluble. Ordinary alum raises the temperature at which it dissolves. Alum, alcohol, carbolic acid, salicylic acid, chloral, thymol, or zinc salts, in small quantities, or glycerine in considerable quantities, retard or prevent the putrefaction of gelatine.

Albumen, like gelatine, is extensively employed in photography as a medium for sensitive salts. It is preferably obtained from the whites of eggs, which contain about twelve per cent.; for though blood is a cheaper material and contains about seven per cent., its albumen is not so readily separated in an equally pure condition. Albumen from different sources does not appear to have exactly the same properties. It contains about one and a half per cent. of sulphur, which is readily changed into sulphuretted hydrogen by putrefaction, or by a few minutes' boiling with a weak caustic alkali. Albumen differs entirely from gelatine in being precipitated or made insoluble (coagulated) by heating its solution to

a little above 60° C., by the action of dilute acids, or of a solution of nitrate of silver. It is insoluble in alcohol, and weak alcohol added to its solution in water precipitates soluble albumen, while strong alcohol throws down the coagulated variety. It is not possible to detect any difference in composition between soluble and coagulated albumen, but when coagulation is determined by certain substances, as nitrate of silver, the product is a compound of albumen with the reagent used. White of egg is not a pure solution of albumen; it contains, among other things, a little alkali, which is necessary to make it readily soluble in water. Pure albumen may be prepared by adding sub-acetate of lead to the ordinary albumen solution, and so obtaining it as an insoluble compound with the salt, which may be purified by washing. The lead is removed by means of carbonic acid, followed by sulphuretted hydrogen. Albumen, when dry, forms a pale yellowish mass, which is easily powdered; it swells up in water like gelatine, but dissolves with difficulty unless a little alkali is added. Dry albumen may be heated to 100° C. without coagulation. Coagulated albumen dries to a translucent, brittle yellow mass, which will absorb about five times its weight of water. What is commonly called albumen contains a very similar substance, "globulin," which requires a higher temperature for its coagulation. It is stated that if the globulin is separated from white of egg, the albumen will crystallise from the solution. So far as it has been obtained, however, different samples of crystallised albumen vary slightly in their properties.

Asphalt, or mineral pitch, is also called Jew's pitch, or bitumen of Judea, because it is found upon the shores

of the Dead Sea. It is, in general, soluble in fats and oils, and also in solutions of alkalies and alkaline carbonates. By extracting asphalt successively with alcohol, ether, and chloroform, the parts dissolved vary considerably. The first is yellow, oily, strong-smelling, and very little, if at all, sensitive to light; the second is brownish black, brittle, nearly odourless, and sensitive; and the chloroform extract yields a residue that is black, brittle, odourless, most sensitive to light, and contains more sulphur than the others. By treating asphalt with additional sulphur, it is possible to increase its sensitiveness.

Cellulose $[(C_6H_{10}O_5)_x]$ constitutes the framework of plants. Elder pith, cotton, linen, hemp, unsized white paper, are very nearly pure cellulose, and may be further purified by successive and repeated treatment with dilute alkalies, dilute acids, alcohol, ether, etc., for cellulose is not affected by any of the more usual solvents. Cellulose is remarkably stable when pure, but readily decays when in contact with other decomposable substances as in rotting vegetable matter. Strong sulphuric acid dissolves cellulose and changes it into a sugar. But if the strong acid is mixed with a half to a quarter of its bulk of water, a few seconds' immersion in it of unsized paper, followed by washing in weak ammonia, gives what is called parchment paper. It is stated that a finished silver print may be treated in this way without injury to the tone, and that in the parchmentising, a slight contraction of the paper takes place which proportionately increases the sharpness of the print. Unsized paper plunged into strong nitric acid and then washed is so toughened that it may be rubbed between the hands under water without injury. Cellulose is soluble in a solution of oxide of copper in

ammonia, and by a very partial action of this reagent upon paper, enough of the paper is attacked to form a varnish that makes the sheet waterproof. This is the principle of the manufacture of Willesden paper. Messrs. Cross, Bevan, and Beadle find that when cellulose is treated with strong caustic soda solution, and the product is exposed to the vapour of carbon disulphide, a yellowish mass results, which when treated with water swells up enormously, and finally dissolves. The preparation can be purified, and yields with water a solution of extraordinary viscosity, which can be coagulated by warming or by the action of several chemical reagents, or by mere standing. The coagulum is, practically speaking, simple cellulose. This production of solid homogeneous cellulose appears likely to prove useful in many ways. Cellulose plunged into strong nitric acid, especially when mixed with sulphuric acid, is changed into the nitrates of cellulose, but in the preparation of these compounds the sulphuric acid doubtless acts in other ways than merely as an aid to the nitric acid. When the action of the acids is prolonged, a tri-nitrate is produced [$C_6H_7(NO_2)_3O_5$] which is the principal constituent of the explosive guncotton used in warfare; but when the acids are slightly diluted and allowed to act for a few minutes only, the dinitrate [$C_6H_8(NO_2)_2O_5$] appears to be the principal product. This last preparation is called pyroxylin. It is soluble in certain ethereal liquids, and a solution of it in a mixture of alcohol and ether constitutes collodion. Even strong hydrochloric acid does not affect cellulose, but chlorine, in the presence of water, destroys it: hence the bleaching of paper, or the materials from which it is to be manufactured, demands great

care, and it is necessary to neutralise the chlorine that remains with an "antichlor." The commonest antichlor is sodium thiosulphate, because it is the cheapest and most efficient of the available compounds, but its use should be avoided in making paper for photographic purposes.

Alcohol (C_2H_5OH). "Absolute" alcohol contains not more than one or two per cent. of water. "Proof spirit" contains approximately half its weight of water. "Methylated spirit" contains at least four or five per cent. of water, and one-tenth its volume of crude wood spirit or some similar liquid, and three-eighths of one per cent. by volume of an approved mineral naphtha added to make the alcohol nasty enough to be practically useless for the preparation of beverages. Methylated spirit becomes turbid when mixed with water because of the mineral naphtha, it is free from duty, and it is illegal to purify it. It is possible to get special permission to have methylated spirit without the mineral naphtha, and some samples of this kind are useful for many purposes, sometimes even for the preparation of sensitive silver compounds. In buying methylated spirit it should be seen that there is no gum in it, that it is not "methylated finish," or it will varnish any surface upon which it evaporates.

Ether [$(C_2H_5)_2O$] is an exceedingly volatile liquid, and its vapour is heavy and easily inflammable. It is dangerous to use ether, or liquids that contain it, in an apartment that has a naked flame in it without great care; and in small dark-rooms, tents, etc., a bottle containing ether should never be opened. What is called methylated ether has been prepared from methylated spirit.

Acetic acid ($C_2H_4O_2$) is prepared by the oxidation of alcohol, as in the manufacture of vinegar from fermented liquors, or by heating wood in closed retorts, when the watery part of the distillate contains this acid in considerable quantity. The acetic acid used in the arts is made by the latter method, and in its crude state it is called pyroligneous acid. Pure acetic acid is solid at temperatures below 15° C. (or about 60° F.), and commercial samples are generally described as being "glacial" or solid at a certain temperature. The higher this temperature the less water does the acid contain. An acid that contains twenty-one per cent. of water has a higher specific gravity than either a stronger or weaker sample. The specific gravity is not, therefore, a certain guide to the water present. Strong acetic acid is highly corrosive, and will blister the skin if allowed to remain on it.

Formic aldehyde (COH_2), or formaldehyde, is at ordinary temperatures a gas, and below —21° C. a colourless liquid of a specific gravity of about .82. The liquid aldehyde changes slowly at —20° C. (that is, just above its boiling point) into trioxymethylene, while at ordinary temperatures the change takes place rapidly and with a snapping noise. Formic aldehyde, therefore, at ordinary temperatures exists only as a gas, but it is very soluble in water, and its aqueous solution up to about forty per cent. is very fairly stable, though the aldehyde in a much more concentrated solution readily changes into trioxymethylene. It occurs in commerce as a forty per cent. solution, called "formaline," which is prepared by a secret method, and has a characteristic, pungent, and unpleasant odour. Gelatine soaked in a diluted solution is rendered less soluble, or even insoluble, in boiling water, caustic

alkalies, and acids. Formaline gives off the gaseous aldehyde freely, and gelatine films may be treated by supporting them over a layer of the solution.

In 1889, Messrs. Schwarz and Merklin observed that formic aldehyde when added to alkaline developers accelerated their action. In 1896, Messrs. Lumière and Seyewetz showed that this only takes place in the presence of a sulphite. Its action is strictly comparable to that of acetone, which is referred to below.

Trioxymethylene [$(COH_2)_3$], also called paraformaldehyde, and more recently metaformaldehyde, is a white crystalline substance that melts at 171° C. It volatilises even below its melting point, and the gas produced is simple formic aldehyde; but on condensing it, it combines with itself again to re-form the triple molecule. On evaporating an aqueous solution of formic aldehyde, a white solid residue is obtained, which is not trioxymethylene, but appears to be analogous to it, and may perhaps consist of two molecules of formic aldehyde combined together, or of hydrates of similar compounds. Trioxymethylene is insoluble in water, alcohol, or ether, but soluble in an aqueous solution of sodium sulphite. Messrs. Lumière and Seyewetz in 1903 pointed out its applicability in developers, and Messrs. Lumière at the same time introduced a white powder which they call "formosulphite," and is a mixture of anhydrous sodium sulphite one hundred grams, with trioxymethylene three grams, and a little potassium bromide. This mixture is soluble in water, and it is only necessary to add the developing agent to it to produce a complete developer.

Acetone [$CO(CH_3)_2$] is a limpid, very mobile liquid, which has a specific gravity of .8, and boils at 56° C. It

has an ethereal odour, evaporates quickly, and is very easily inflammable, burning with a luminous flame without smoke. It will mix with water, alcohol, or ether in all proportions. It combines readily with the acid sulphites of the alkalies, the compound containing one molecule of each substance [$CO(CH_3)_2$, $NaHSO_3$]. When added to a solution of a normal sulphite, it renders half the base of the sulphite available as alkali for development by combining with the rest of the sulphite. "Acetone sulphite" is considered in the previous chapter. The action of these substances in development is discussed later in the section on "Processes."

Sodium amidoacetate $\begin{pmatrix} CH_2(NH_2) \\ \\ CO.ONa \end{pmatrix}$ is the sodium salt of amidoacetic acid, also called aminoacetic acid. This acid is called variously glycocine, glycine, glycocoll, glycocol, sugar of gelatine, amido-glycollic acid, besides by the names already given. It is easily soluble in water and behaves both as an acid and a base—that is, it forms compounds with both bases and acids; but in its most characteristic reactions it behaves as a base—that is, as a derivative of ammonia. Its acid properties are scarcely recognisable. It has a sweet taste (it was called sugar of gelatine on this account, and because it is a product of the decomposition of gelatine by acids or alkalies) and has a very slight, if any, acid reaction to litmus. It dissolves silver oxide readily. It is a reducing agent, reducing a solution of mercurous nitrate in the cold. When ferric chloride is added to its solution, a deep red colour is produced, which is destroyed by acids and restored by ammonia. Being so exceedingly weak an acid, it will be

readily understood that its sodium salt is a strongly alkaline compound, and that it will replace the alkali in alkaline developers. Messrs. Meister, Lucius, and Brüning in 1903 introduced sodium amidoacetate for this purpose under the name of "pinakol salt N," which is a twenty per cent. aqueous solution of the salt. This salt dissolves silver oxide and other silver compounds that are insoluble in water, and, therefore, was proposed in 1903 by Dr. B. Homolka as a substitute for sodium thiosulphate in Farmer's reducing solution, as it may be mixed with potassium ferricyanide without appreciably acting upon it. Amidoacetic acid is often called glycine, but must not be confused with the developer so called, which is a phenol derivative of it.

CHAPTER XII.

ORGANIC DEVELOPERS.

THE number of organic substances that are known to serve for the purposes of development has very largely increased during the last ten years or so because of the systematic search for them and the principles of their constitution that appear to confer the developing power. The results obtained we owe chiefly to Dr. M. Andresen, Dr. J. Hauff, and the brothers A. and L. Lumière. Doubtless, the number of substances available might be enormously increased, and, indeed, a very large number that have never come into practical use have been proposed; but we shall consider only those that are specifically provided for photographic purposes, or are very nearly related to them. Their actual use as developers will be treated of in the section on "Processes."

The greater number of organic developers are derived from benzene (C_6H_6) or naphthaline ($C_{10}H_8$), or their derivatives, by replacing some of the hydrogen atoms by certain groups of atoms, namely, the hydroxyl (OH) and the amido or amino* (NH_2) groups. As these groups form compounds by themselves, it becomes of interest to note that they will develop the image on a gelatino-bromide plate.

* In chemical literature the word amido is not now used in this connection, but the word amino. Thus, what is commonly called paraamidophenol is called para-aminophenol. The word amido is reserved for those compounds in which the NH_2 group takes the place of the OH group in an acid. In this volume the older custom of using the word amido is followed, because it is incorporated in so many commercial names, that to vary the word at present would lead to confusion.

Hydrogen peroxide (H_2O_2), when made strongly alkaline with caustic soda or potash, was shown by G. A. Le Roy in 1895 to be able to develop, though not usefully. Hydrogen peroxide with caustic soda is practically the same as sodium peroxide—

$$H_2O_2 + 2NaOH = Na_2O_2 + 2H_2O.$$

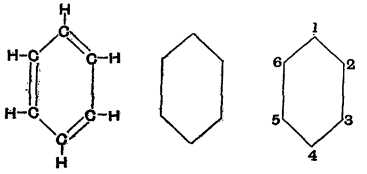
It is not surprising, therefore, to find that sodium peroxide itself will act as a developer.

Hydrazine (N_2H_4), the complete molecule of the amido group, in the presence of an alkali also has developing power, though it acts so sluggishly that it has been stated that it will not develop.

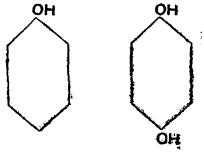
Hydroxylamine (NH_2OH), that is, the two single hydroxyl and amido groups united together, is a practical developer, having been suggested for this purpose as early as 1884 by Carl Egli and Arnold Spiller. The compound of the base with hydrochloric acid (NH_2OH, HCl) is a colourless, easily crystallisable, readily soluble salt, and when used as a developer it is mixed with a caustic alkali (potash or soda).

Thus the amido and hydroxyl groups when combined together or with each other have a developing power, though of a feeble kind. It is necessary that they or one of them shall be suitably introduced into another substance, such as benzene, in order to get a practically efficient developer. To express the conditions that it has been found necessary to observe in the introduction of these groups that the resulting compound shall have developing power, it is necessary to use the conventional methods of nomenclature. For the sake of convenience, benzene is generally represented as a "ring," and this is

usually contracted into a simple hexagon, and each angle has a number assigned to it, though the numbers are not generally written down.



The formula of a substituted derivative is indicated by the simple hexagon with the group or groups that replace the hydrogen, thus—



If the positions 1 and 2 are occupied by the replacing groups, the compound is called an ortho-derivative ; if 1 and 3 a meta-derivative ; if 1 and 4 a para-derivative. Any two adjacent positions are ortho, two opposite positions are para, and any two with one intervening are meta to each other. Thus, with regard to 1, 6 and 2 bear exactly the same relationship, and 5 and 3 are also alike. The positions 2 and 6 are called the ortho positions, 3 and 5 are the meta positions, and 4 is the para position.

Constitution of developers. It appears that the production of developers depends upon the following conditions.

1. There must be at least two groups introduced: either two hydroxyl or two amido groups, or one of each,

2. These two groups must be in the same benzene nucleus in such a compound as diphenyl ($C_6H_5 — C_6H_5$); and it is necessary that the second group shall occupy either the ortho or the para position. No meta-derivative has yet been found capable of acting as a developer.

3. If more than two such groups are suitably introduced, the developer tends to become more energetic; and if the extra group is an amido group, the developer may be fully efficient in the presence of sodium sulphite without the addition of any alkali.

4. If the hydrogen of a hydroxyl group, upon which the developing power of a substance depends, is replaced by a positive group (an "alkyl" group), such as methyl (CH_3), the developing power of the substance is lost. A similar replacement of one hydrogen of the NH_2 group weakens the developing power, and the replacement of both weakens it still further, leaving a very feeble developer.

5. The introduction of negative groups, such as CO.OH and SO_2OH, instead of other hydrogen atoms in the benzene nucleus, tends to diminish the developing power.

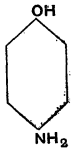
Phenol (C_6H_5OH) is the well-known carbolic acid—a white, crystalline, deliquescent substance of characteristic odour: It is not a developer.

Para-amidophenol ($C_6H_4.OH.NH_2$) is, like most of the following amido compounds, crystallised as a salt in combination with hydrochloric acid. The hydrochloride dissolves easily in water, and on adding an alkali to the solution it yields a white precipitate of the free base which dissolves on adding more alkali. Rodinal is a concentrated developer prepared by dissolving para-amidophenol in a solution of an alkaline bisulphite, and

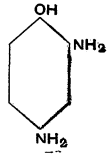
adding a caustic alkali until the precipitated base is redissolved. Unal is a mixture of the same ingredients in the solid form.

Glycin [$(C_6H_4.OH.NH(CH_2.CO.OH)$] is paraamidophenol, in which one of the hydrogen atoms of the NH_2 group has been replaced by the residue of acetic acid, as shown, or it may be regarded as amido-acetic acid, which is described in the last chapter, in which one hydrogen of the NH_2 group is replaced by the group $C_6H_4.OH$. Glycin is paraoxyphenyl glycin. It occurs crystallised as shining laminæ, which are difficultly soluble in water, and readily combines with mineral acids to form colourless salts. It is easily soluble in a solution of sodium sulphite and caustic alkalies or alkaline carbonates.

Amidol [$C_6H_3.OH.(NH_2)_2$] is diamidophenol, the two amido groups occupying the ortho and para positions. Its relationship to paraamidophenol is shown by the following formulæ—



PARAAMIDOPHENOL.



AMIDOL.

Both the amido groups in amidol are effective; therefore, it is a more powerful developer than paraamidophenol, and is efficient in the presence of sodium sulphite without the addition of any alkali. It forms colourless needles and dissolves readily in water, especially in the presence of sodium sulphite, and its solution soon darkens and becomes useless. It is better, therefore, and customary, to dissolve amidol only as it is required.

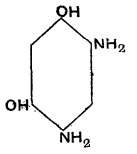
Triamidophenol [$C_6H_2.OH.(NH_2)_3$], which is like amidol but with another amido group in the other ortho position, forms needles which are easily soluble in water. With sodium sulphite it gives a yellow solution which is a powerful developer without the addition of any alkali.

Pyrocatechin [$C_6H_4(OH)_2$] or catechol, or oxyphenic acid, is orthodihydroxybenzene. It is a white crystalline compound very soluble in water, alcohol, and ether.

Kachin is the name given to a developer recently introduced, which appears to be pyrocatechin.

Resorcin [$C_6H_4(OH)_2$], or resorcinol, is metadihydroxybenzene, and is not a developer.

Diamido-resorcin [$C_6H_2(OH)_2(NH_2)_2$] has the formula



and is therefore the same as amidol, but with an extra hydroxyl group in the meta position. Being in the meta position, the additional group slows the developer, though it is efficient without alkali. The hydrochloride forms rhombic plates which are very easily soluble in water.

Hydroquinone [$C_6H_4(OH)_2$], or quinol, is paradihydroxybenzene. It occurs as white needles or long hexagonal prisms which are easily soluble in hot water, though with difficulty in cold. When silver nitrate is added to its solution in water, metallic silver is slowly precipitated, and in this reaction it shows its characteristic difference from pyrogallol, eikonogen, and some other developing agents, which very rapidly precipitate silver

under the same conditions. It is not a very energetic developer. It was introduced as a developer in 1880 by Sir William Abney.

Adurol [$C_6H_3Cl(OH)_2$ or $C_6H_3Br(OH)_2$] is either the monochlor- or monobrom-hydroquinone. It was introduced in 1899 by Messrs. J. Hauff and Co., who supply the chlorine derivative, and Schering's successors, who supply the bromine derivative. The two compounds are similar in their behaviour. They are white powders, more soluble in water than hydroquinone, and it is claimed for them that they are free from the disadvantages attending hydroquinone, such as the detrimental effect of a low temperature during development, the need of more alkali than developers generally require, the giving of a hard image, and so on.

Pyrogallol [$C_6H_3(OH)_3$], generally called pyrogallic acid, is a trihydroxybenzene in which the hydroxyl groups occupy the positions 1, 2, 3 respectively. It is therefore pyrocatechin with an additional hydroxyl group which is in the meta position with regard to one of the hydroxyls, and therefore might be thought to be of little if any advantage regarding the substance as a developer; but it is in the ortho position with regard to the other. Pyrogallol occurs generally as light feathery crystals produced by sublimation, but it can also be obtained in a more compact form as crystallised from solution. It is easily soluble in about two and a half times its weight of water, and its solution becomes brown, by the absorption of oxygen, when exposed to the air. If an alkali is added to it, the darkening on exposure is very much more rapid; but the addition of a sulphite retards it very considerably, even in the presence of an alkali. It reduces silver nitrate in

solution immediately, giving a black precipitate of the metal; but by the previous addition of a little acid, this action may be retarded as desired. Although pyrogallol combines with alkalies, like the other hydroxybenzenes, it is not what is commonly understood as an acid but belongs to the class of phenols. The common term pyrogallic acid is therefore a misnomer.

Tannic acid, gallic acid, and pyrogallol are simply related to one another. The active constituent of tanning materials, such as gall-nuts, is digallic acid ($C_{14}H_{10}O_9$) combined with glucose. By boiling it with dilute acids the glucose is separated, and the digallic acid takes up water, becoming gallic acid [$C_6H_2(OH)_3COOH$], thus—

$$C_{14}H_{10}O_9 + H_2O = 2C_6H_2(OH)_3COOH$$

When gallic acid is heated it volatilises, and the crystalline substance that condenses, which Scheele considered to be unchanged gallic acid, is pyrogallol [$C_6H_3(OH)_3$]. By the heating gallic acid loses carbonic anhydride, thus—

$$C_6H_2(OH)_3COOH = C_6H_3(OH)_3 + CO_2$$

It is not necessary to prepare gallic acid first, as the dried aqueous extract of gall-nuts gives pyrogallol when it is heated. If gallic acid is dissolved in glycerine, and the solution is heated to a temperature of 185° to 200° C., pyrogallol is produced, with effervescence due to the escape of carbonic anhydride, and if glycerine is desired in the developer, this may be a useful method for the preparation of pyrogallol.

Aniline ($C_6H_5.NH_2$) is amidobenzene, or phenylamine. It is an oil with strongly basic properties, combining with acids to form crystalline salts. It is not a developer.

Paraphenylenediamine [$C_6H_4(NH_2)_2$] combines with two molecules of hydrochloric acid to form the hydrochloride, a crystalline compound that is easily soluble in water. The amido groups, as the name indicates, are in the para position with regard to each other. Metaphenylenediamine is not a developer. Paraphenylenediamine when used as a developer is made alkaline with a caustic alkali.

Metacarbol, a developer introduced in America, is nothing but impure paraphenylenediamine.

Metol is a salt, generally the sulphate, of methylparaamidometacresol [$C_6H_3(OH)(CH_3)(NH.CH_3)$] according to Hauff, and of methylparaamidophenol [$C_6H_4(OH)(NH.CH_3$] according to Andresen. It is a white powder, easily soluble in water. By the addition of an alkali to the solution the base itself is liberated, and will crystallise out in long needles if the solution is strong enough.

Edinol ($C_6H_3.NH_2.OH.CH_2OH$) is the hydrochloride of metaamido-orthoxybenzyl alcohol. The formula given represents the free base. The hydrochloride is a yellowish white crystalline powder, which is soluble in twelve times its weight of water. It was introduced as a developer in 1901 as being intermediate between the so-called "rapid" developers, which start development of the whole image very quickly after their application to the plate, and the phenol developers, which are more slow to produce a visible effect, and develop the various parts of the image gradually according to the local amount of light action.

Paramol is the name at first given to edinol, but paramol is stated to be orthoamidometaoxybenzyl alcohol, not exactly the same as edinol.

DIPHENAL—EIKONOGEN—HYDRAMINE.

Diphenal is supplied as a brown solution, which only needs dilution to prepare the developer. It is an acid solution of diamidooxydiphenal ($C_6H_3.OH.NH_2—C_6H_4.NH_2$), the amido and hydroxy groups in the same benzene nucleus being in the para position. This substance is not soluble in a solution of sulphite and alkaline carbonate, though it is soluble in caustic alkalies. It is soluble in hot water, nearly insoluble in cold, and crystallises from water in long matted needles. It is easily soluble in alcohol. It develops in the presence of acids, and it appears that the commercial solution contains considerable proportions of both hydrochloric and sulphurous acid.

Eikonogen [$C_{10}H_5(OH)(NH_2)(NaSO_3), 2H_2O$] is the sodium salt of amido-βnaphtholsulphonic acid. It was introduced as a developer by Dr. M. Andresen in 1889, being one of the very earliest of what are often referred to as the modern developers. When pure it is white, but as supplied it is generally brownish; it can be recrystallised from a solution of sodium sulphite. It is rather sparingly soluble in water, but dissolves more readily in the presence of alkalies, especially on heating the liquid. Acids added to its solution precipitate the free acid in white needles.

Hydramine is not a simple substance. Phenols and amines will often combine, the phenol playing the part of an acid and the amine the part of a base. Messrs. Lumière and Seyewetz sought to combine the advantages of both classes of bodies, and in 1899 introduced this substance, which is a compound of hydroquinone and paraphenylenediamine crystallised together in the proportion of one molecule of each. It is a well-defined, definite compound, occurring as white flaky crystals, and is easily soluble in

either acids or alkalies. A simple water solution of hydramine will develop, but very slowly.

Ortol is a mixture of methylorthoamidophenol sulphate [$(C_6H_4.OH.NHCH_3)_2$ H_2SO_4] with hydroquinone [$C_6H_4(OH)_2$]. It is easily soluble in water.

Quinomet or metoquinone is a crystalline compound of metol and hydroquinone introduced in 1903 by Messrs. Lumière and Seyewetz as a developer. They state that it contains two molecules of metol to one of hydroquinone, and is prepared by mixing saturated solutions of these two substances and adding anhydrous sodium sulphite to saturation. The compound separates out as white scales, which are sparingly soluble in cold water.

Diogen occurs as a light impalpable powder. What it is does not appear to have been published, but it is stated to be closely related to eikonogen.

CHAPTER XIII.

THE TRANSMISSION AND INTENSITY OF LIGHT.

THE most generally accepted theory as to the nature of light regards it as the undulatory movements of a something that pervades all space, and whose particles, when transmitting light, oscillate in paths approximately at right angles to the direction of propagation of the wave. This medium is known as the "luminiferous ether." Although the nature of light is a matter of conjecture, we know with certainty in many cases what its *effects* are, and how to control those effects. We know that light travels from a luminous object, and the rate of its movement can be experimentally demonstrated, though the time occupied in passing over terrestrial distances is so small as to be inappreciable except by means of specially-made apparatus.

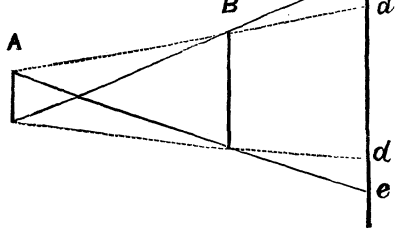


FIG. 1.—A, luminous surface; B, opaque object; C, screen upon which the shadow is cast.

Light travels through homogeneous media in straight lines, and, therefore, any opaque substance introduced into the path of light that emanates from a point produces a sharply-defined shadow. But it is practically impossible to get a luminous geometric point; and as all sources of illumination (except an individual star) have a sensible magnitude, they cannot give a sharp shadow. In fig. 1, *d d* mark the limits of the true shadow, but the full light falls upon the screen only beyond *e e*. The two spaces from *d* to *e* show a perfect gradation from darkness to full light, and are technically called the "penumbra." The extent and richness of gradation of the half-lights in photographic pictures is entirely controlled by the size and position of the surface that illuminates the object photographed, or, when more than one illuminant is employed, their relative sizes, positions, and intensities.

If a point of light shines through a hole upon a screen, the patch of screen that is illuminated will be of the same shape as the hole, but larger. The continuous lines in fig. 2 illustrate this. If the distance of the light from

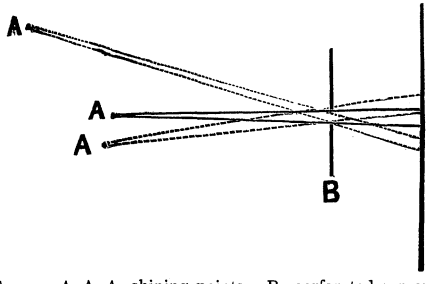


FIG. 2.—A, A, A, shining points; B, perforated screen.

the hole is many times the distance of the hole from the screen, the increase in size will be inappreciable, and may

be practically neglected.* Any number of shining points will act in the same way, and each quite independently of any other, as shown by the broken and dotted lines in fig. 2. Now, as everything whatever that can be photographed may be regarded as an infinite number of luminous points, some groups of points shining very feebly and others more strongly according to the brightness of the different parts of the subject, it is possible to get an image with a simple hole and a screen. As the hole must be small, it is technically called a "pinhole," and as pinhole photography has such great advantages, one might be tempted to think that if sufficiently sensitive plates were available, the use of lenses, with the numerous troubles they introduce, would be very much restricted; but a complete survey of the question reveals the error of such a notion. Though the pinhole gives an absolute "depth of definition," and no distortion, except that due to the projection of the image on a flat plate, it is impossible for it to give sharp definition. Further information concerning pinholes is given in a subsequent chapter.

The intensity of illumination in general, besides being proportional to the area of the opening through which the light is admitted, is, within moderate limits, inversely proportional to the area of the surface upon which it is received. Thus the intensity is diminished by withdrawing the surface upon which the light falls from the light source, it is inversely proportional to the square of the distance, as is very well known. But it is not so well recognised that the light intensity is dependent upon

* If a very small hole is used the patch of illumination will be notably larger than the hole, and the smaller the hole the larger the patch, because of "diffraction"—a phenomenon referred to in the chapter on "Spectacle Lenses and Pinholes." For information as to the nature and effects of diffraction, a treatise on "Light" should be consulted subsequently. It is not necessary to take it into consideration at present.

the angle that the pencil of rays makes with the illuminated surface. In fig. 3 the horizontal lines stand for a pencil of rays, and it is obvious that the screen indicated by the perpendicular line receives this pencil upon a smaller surface than an oblique screen placed in the direction of the dotted line. The intensity of illumination is inversely proportional to the extent of surface over which the light is spread ; or it diminishes with the obliquity of the pencil in proportion with the cosine of the angle which the incident

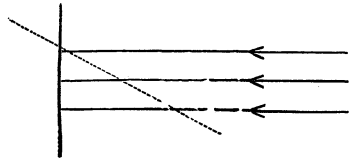


FIG. 3.

ray makes with the normal to the surface. This principle comes into action when the swing back of a camera is used, though so slightly as to be practically negligible. In photographic printing much time may be lost through not placing the frames " square " to the source of light ; and the loss in this case is aggravated by the reflection from the glass, which rapidly increases with the obliquity of the incident pencil. The light that passes through the lens in negative making falls obliquely upon the margins of the plate, and more obliquely the wider the angle included. The same law holds here also, and the oblique incidence of the light is one of the chief factors in the falling off of density that is so noticeable in wide-angle views.

There are many methods that serve to compare light intensities together, and there are three or four units that have been adopted, such as the standard candle,

the combustion of amylacetate or pentane under certain prescribed conditions. Photometry, however, is not of primary importance to the photographer, because it is chiefly concerned with artificial lights, and also because he has not so much to do with the visibility of light as with its effect upon the substances that he uses.

Many actinometers have been devised to measure the chemical power of light, and though each is, perhaps, useful, no one is of universal applicability, for obviously each measures only those kinds of light that affect it. The staining power of light upon chloride of silver is not equivalent to its decomposing action upon a mixture of dichromate of potassium and gelatine, and though the first is successfully used every day as a measure of the second in carbon printing, it is not an accurate indicator. A piece of ordinary silver paper may require twice as long exposure on one day as another before a standard tint is brought out, but it does not therefore follow that a gelatino-bromide plate must have twice the exposure to give an equally developable image. But even such an indicator, although it is far from being exact, is a very much better guide than the unaided eye; and the actinometers commercially obtainable associated with exposure meters, being provided with silver bromide paper especially prepared for the purpose, approximate much more closely in proportional sensitiveness to the ordinary plates used for negative making, and deserve a far more extended use than they enjoy. The chemical effects of different sorts of light, and the effects of aerial and other absorbents, are subsequently referred to in more detail.

Actinometers have been constructed in which the chemical effect has been allowed to proceed for a unit

of time, and the result has been measured, or the change has been allowed to reach a uniform result, and the time has been observed. Bunsen and Roscoe used a mixture of hydrogen and chlorine, and estimated the amount of hydrochloric acid formed. H. Draper used ferric oxalate, and noted the amount of carbonic anhydride given off by its decomposition. But paper prepared with a silver salt is the most convenient for practical purposes, and generally to be preferred on theoretical grounds because the silver salt is more closely related to the sensitive substance upon which it is required to estimate the effect of light. It is altogether a mistake to suppose that it is possible, as has apparently been supposed, to measure the chemical effect of light in any inclusive way. Obviously, the reagent employed measures only the light that affects it, and this is never the whole of the light that is able to produce chemical or photographic effects, nor, with different reagents, is it the same proportion of the whole.

CHAPTER XIV.

REFLECTION BY PLANE AND CONCAVE MIRRORS.

WHEN light impinges upon a surface of any sort, a part of it is invariably reflected. Most ordinary objects scatter the light in all directions, but polished surfaces, so far as they are perfectly polished, reflect regularly, that is, they simply change the direction of the pencils of light that impinge upon them, the incident and the reflected rays always making equal angles with the reflecting surface.

Any surface that is used to get regular reflection is technically called a "mirror," and, according to the shape of the mirror, whether flat or curved, so it is termed plane, convex, concave, cylindrical, parabolic, etc.

The commonest example of the plane mirror is the ordinary looking-glass. The plane mirror does not produce any true image, but as it bends the pencils of light in

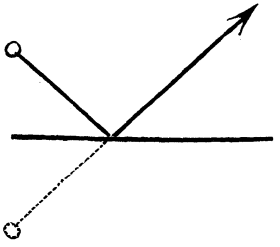


FIG. 4.

almost any direction, it enables one to see round a corner. The effect of a plane mirror is shown in fig. 4. The eye sees the ball and also a reflection of it, because the light

that emanates from the ball in the direction of the line towards the mirror has its direction changed, and enters the eye. If light from the same object reaches the eye in two distinct directions, the effect is the same as if there were two objects, for two images are produced upon the retina, and the eye knows nothing whatever of anything outside itself, but only interprets the light that enters into it. An image that does not exist in fact, but only appears to exist, is called in optical language a "virtual" image.

The effect of looking at an object by means of a plane mirror instead of directly, as when we use a looking-glass to view ourselves, is to cause a lateral inversion in the appearance of the object; the right-hand side becomes the left, and the left becomes the right. The same effect is produced by viewing a print or transparency through from its back. All photographs produced direct in the camera (daguerreotypes, collodion positives, etc.) are laterally inverted, and so also are single transfer carbon prints produced from ordinary negatives. Ordinary negatives are inverted laterally, but as a second lateral inversion takes place in printing on surfaces where the print is not removed from its support by transference, the print is not inverted. What is technically called a "reversed negative" is a negative reversed as compared with an ordinary negative, not reversed as compared with the object photographed. In optical language the image on an ordinary negative is laterally inverted, while that on a "reversed negative" is not inverted.

Where the process to be employed is one that naturally gives an inverted picture, the inversion can be corrected by producing a second inversion, and this is most conveniently done by photographing the reflection of the

object in a plane mirror instead of the object itself, and so producing a "reversed negative." The mirror is generally placed close to the lens, as the light is more concentrated there, and a smaller mirror is sufficient. The mirror used for this or any analogous purpose must have only one surface, that its effect may not be complicated by secondary reflections, and the surface used must be truly flat, or it will produce distortion of the image. It is customary to employ specially polished pieces of glass, coated with metallic silver on the front, the metal being polished. The glass is simply a convenient support for the silver, and is not used on account of its transparency. Ordinary looking-glass is quite useless, because its reflecting surface is at the back, and an oblique ray is partly reflected from the front surface of the glass, and this gives a faint image in addition to the chief image reflected from the back of the glass. But other secondary images are produced, for the light after reflection at the coated surface is partly reflected back again from the front surface of the glass,

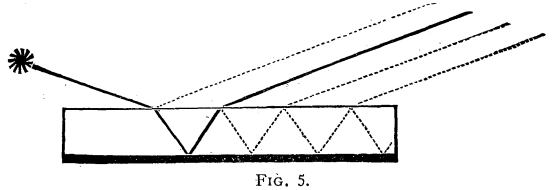


FIG. 5.

and so passes to and fro, giving a series of images which get fainter as the amount of light reflected is reduced. In fig. 5, the back of a looking-glass with its metallic coating is represented by the thick line, the passage of a ray is shown by the continuous line, and the broken lines indicate some of the reflections that produce false images. Several

images so formed may easily be seen by holding a lighted candle in front of a looking-glass, and looking at its reflection obliquely. The refraction or bending of the pencil of light as it enters the glass, is discussed in the next chapter.

A concave mirror causes the pencils of light that impinge upon it to converge. The law that the angles of incidence and reflection are equal applies to all reflecting surfaces, and it is therefore not difficult to trace upon paper the effect of any mirror upon the direction of any ray of light. In the figs. 6, 7, and 8, the arcs that stand

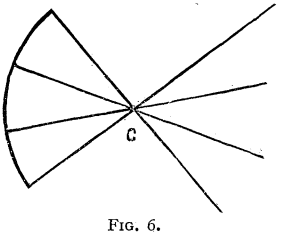


FIG. 6.

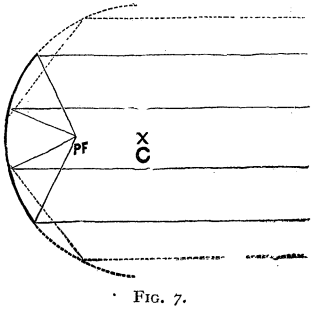


FIG. 7.

for curved mirrors are struck from the points marked C, and this point is called in each case the "centre of curvature" of the mirror.

CONCAVE MIRRORS—FOCAL POINTS.

If a luminous point is placed at the centre of curvature, the rays emanating from it travel in the direction of radii of the sphere of which the mirror is a part, and those

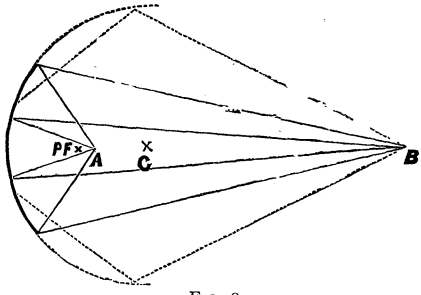


FIG 8.

rays that impinge upon the mirror are reflected back along their original paths to the luminous point, and add their effect to the light emanating in the opposite direction, as shown in fig. 6. This is the part that should be played by the reflector in optical lanterns, enlarging apparatus, etc. The size of the mirror should be such that when the condenser, the light, and the mirror, are properly placed, the diverging bundle of reflected rays fully covers the condenser. For such purposes the spherical concave mirror is what is theoretically required.

If the luminous point is moved to the position half-way between the centre of curvature and the surface of the mirror, the reflected light forms a bundle of approximately parallel rays, as shown in fig. 7 excluding the dotted lines; and, conversely, if parallel rays impinge upon such a mirror, they are brought to a point or focus half-way between the centre of curvature and the mirror, and this point accordingly is called the "principal focus."

It is a mistake to suppose that by putting a luminous point in the principal focus of a concave mirror there are only parallel rays opposite the mirror; the parallel rays produced by the mirror mix with the divergent rays emanating directly from the luminous point itself, and at a certain distance from the mirror, which may easily be demonstrated geometrically, the parallel and divergent rays are sensibly equal in intensity. Nearer the mirror than this the bundle of divergent rays is more intense, and further away it is less intense, than the bundle of parallel rays. And if the source of light, instead of being a theoretical point is an illuminant of sensible area, then each point of the illuminant will give its own bundle of parallel rays, parallel to a line drawn from the point to the centre of curvature. Therefore, even in the absence of spherical aberration, the reflected light from a practical illuminant always forms a divergent beam.

If light from so distant a source that the rays are practically parallel impinges upon a concave mirror, it is concentrated at the principal focus of the mirror, as shown in fig. 7, but this concentration is only approximate, though it is drawn as if it were exact so far as the unbroken lines go. The dotted lines of the figure show that if the curve of the mirror is continued, the concentration at the principal focus is not even approximate. This lack of focussing power is called "spherical aberration," and it is always present in spherical mirrors, though in a mirror of small angle* it may be practically neglected under certain circumstances.

In fig. 8 it is obvious that a point of light, such as B, that is further from the mirror than its centre of curvature,

* That is, a mirror that forms only a small portion of the sphere of which it is a part

has its light that impinges upon the mirror brought to an approximate focus at a point between the principal focus and the centre of curvature, at A. Conversely, a luminous point at A would have its light concentrated at B; and these two points, or any pair of points similarly related to one another, are therefore called "conjugate foci." Spherical aberration in this case is also shown by the dotted lines.

If one luminous point is reproduced, so to speak, by having a part of its light brought to a point in a different place, it generally follows that other luminous points will be correspondingly reproduced, and as a visible object may be regarded as an infinite number of luminous points, we have here all the conditions necessary to obtain a true image—true in the sense that it may be received upon a screen, and, therefore, may be photographically fixed upon a sensitive surface.

A camera with a concave mirror instead of a lens was used by some in the early days of the daguerreotype process, but such an apparatus is not readily amenable to modification, and allows much stray light to reach the sensitive surface. Moreover, as the sensitive surface, or a second mirror, must be between the object and the mirror, a considerable amount of light is stopped, unless the mirror is large as compared with the sensitive surface.

But in stellar photography the mirror has very many advantages over the lens. It can be made larger, and, therefore, to form a more brilliant image; by a slight modification of the curve, spherical aberration can be practically eliminated; and as it is absolutely free from chromatic aberration, the whole of the chemically active light is brought to a focus exactly where the visible image

is formed, an advantage that no practical combination of lenses can effect. As the light from stars is feeble, the stray light is not dangerously great ; and as the plate used to receive the image is not large, it does not cause, either directly or indirectly, an important barrier between the mirror and the object.

Convex mirrors do not produce real images, and as they are not useful in the practice of photography, we are not called upon to discuss their properties.

CHAPTER XV.

THE REFRACTION OF LIGHT AND THE FORMS AND PROPERTIES OF LENSES.

REFRACTION. When a ray of light passes from one medium to another of a different density, it is turned from its original path, it is "refracted," unless it impinges perpendicularly upon the surface that bounds the two media. The path of the light in the denser medium forms a smaller angle with the perpendicular to the bounding surface than its path in the rarer medium does; and for the same two media, the sines of these two angles bear a constant proportion to each other. In fig. 9 a ray of light is repre-

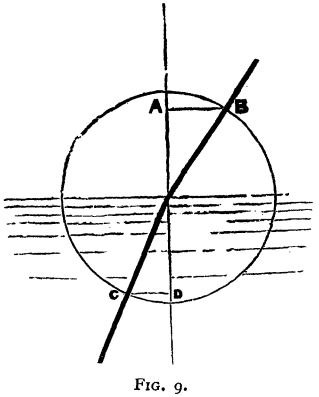


FIG. 9.

sented by the thick line, and the lines A B and C D are proportional to the sines of the angles of incidence and refraction respectively. The proportion between these

lines, when the media concerned are air and water, is approximately as 4 to 3, or for air and glass as 3 to 2. These proportions expressed as fractions are the "refractive indices," namely, $\frac{4}{3}$ or 1.33, and $\frac{3}{2}$ or 1.5. Refractive indices expressed in this manner are never more than approximate unless the light they refer to is exactly specified, because ordinary white light (or any light that is not homogeneous) is decomposed when it is refracted, the violet and blue being bent more out of the original direction than the yellow, and the yellow more than the red. The appearance which results from separating the constituents of non-homogeneous light is called a "spectrum," and in the spectrum of solar light there are certain narrow dark spaces (Fraunhofer lines) which serve as fixed points for convenient reference. Refractive indices for the D and E lines represent the effect upon the most visible part of ordinary light, and those for G may be considered as correct for the average of the active light that is most useful photographically.

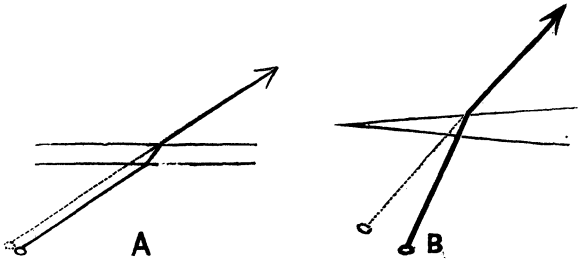


FIG. 10.

If an object is viewed through a plate of glass (or any similar transparent medium), so that the path of the light from the object to the eye is not perpendicular

to the surface of the glass, the object will appear laterally displaced, as shown in fig. 10, A. It is obvious that the greater the obliquity with which the light impinges upon the surface of the glass, or the thicker the glass, the greater will be the extent of lateral displacement.

If, however, the glass, or other such substance, has plane sides that are not parallel, the rays of light that pass through it will have their direction entirely altered, the refraction at both surfaces taking place according to the rule. The displacement of the beam of light caused by interposing such a medium in the path of the rays is always towards the thicker part of the medium, or the base of the triangle formed by continuing the two lines that represent the boundaries of the surfaces until they meet. It should be noted, however, that if an object is viewed *directly* through a dense medium with non-parallel sides, the *apparent* displacement of the object is towards the thinner part of the interposed substance, because we cannot but imagine that the light entering our eyes has come in a straight line.

In fig. 10, B, the passage of light through a prism is shown, and the apparent displacement of an object viewed directly is indicated by the broken lines.

If two prisms are placed base to base, light passing through them is concentrated, while if they are placed apex to apex the light is caused to diverge (fig. 11). If these two arrangements are made circular, so that the diagrams represent the plane obtained by cutting along any diameter, these two combinations are typical of the two sorts of lenses. The surfaces of lenses are always curved that they may be continuous, and for convenience in manufacture their surfaces are always spherical, although

a modification of the spherical surface might, perhaps, sometimes be introduced with advantage if it were practicable.

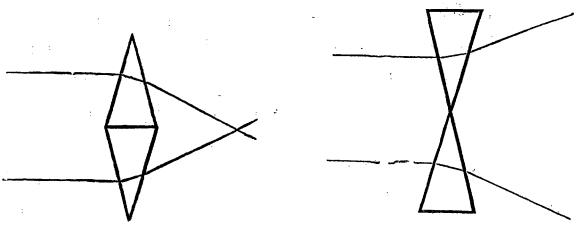


FIG. 11.

The forms of lenses. There are three forms each of converging and diverging lenses, the former having their greatest thickness in the middle, and the latter at their edges. These six primary forms are named respectively the double convex (if the two surfaces are not of equal curvature it is called a "crossed" lens); the plano-convex or convexo-plane, mentioning first the surface upon which the light is first incident; and the convex meniscus, also called a convexo-concave or concavo-convex positive or convergent lens; and the double

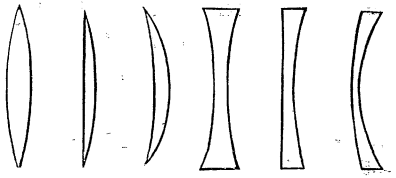


FIG. 12.

concave; the plano-concave or concavo-plane; and the concave meniscus, also called a convexo-concave or concavo-convex negative or divergent lens; and each of them is illustrated in fig. 12.

Focal points. Disregarding for the moment the spherical and chromatic aberrations from which such lenses suffer, the effects that can be produced by their means can be summed up in a useful and simple way. If a pencil of parallel rays of light is allowed to fall upon the surface of a converging lens, the light will be concentrated to a point at a certain distance from the other side of the lens (fig. 13). This point is the " focal point," or, more correctly, " the principal focal point," and its

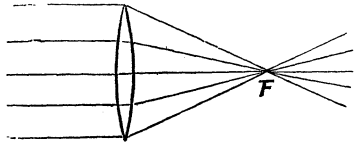


FIG. 13.

distance from the lens is the " focal length " or " focal distance " of the lens employed. In this, as in every other case, the refracting effect of the lens is the same whichever way the light travels through it, so that if a luminous point is brought into the principal focal point of such a lens, the diverging rays that impinge upon its surface will be transmitted as a pencil of parallel rays. It does not at all follow from this fact that an unsymmetrical lens (plano-convex, convex meniscus) will produce

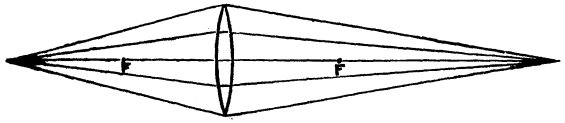


FIG. 14.

the same effect with either side towards a luminous object.

If the luminous point is moved further from the lens, the transmitted rays will converge to a point (fig. 14),

and when the luminous object is twice as far from the lens as the principal focal point, the point of light produced on the other side of the lens will be at exactly the same distance from the lens, if the lens is of symmetrical form. Any such pair of points are called "conjugate foci." Any number of luminous points will be simultaneously reproduced by the lens, and therefore any object will give rise to a corresponding image. The comparative linear sizes of the image and its object are proportional to the distance of each from the lens.

Concave or diverging lenses cannot cause a reconcentration of light that impinges upon them, and therefore they cannot form real images. They are used for photographic purposes only to modify the action of converging lenses.

Chromatic aberration. The images produced by lenses are formed by the refraction or bending of the light; and as the various constituents of ordinary light are not equally refrangible, each constituent produces its own separate image. In fig. 15 the bundle of parallel rays A is supposed

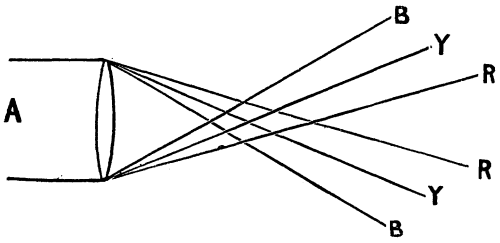


FIG. 15.

to consist of a mixture of red, yellow, and blue lights. By any given lens the blue is more affected than the yellow, and the yellow more than the red; hence, in this case,

the image is not simple, but consists of three points of lights of the three colours, and in the three positions respectively, as shown. If a screen is placed to receive the blue image of the point, it will be found that the blue is not pure, that it is surrounded by an orange yellow, and that this tint again is bounded by a red ring, if we assume that the brightness of the three colours is sensibly equal. The screen, in the position we are considering, receives a round patch of red light, and on this a smaller, that is, more concentrated and therefore brighter, round patch of yellow, and in the middle a thoroughly concentrated and therefore still more bright point of blue. The condition of affairs when the screen is removed to the focus of the red light is easily understood by the figure; the blue covers the largest space here, having spread out after being collected to a point at its focus

This experiment at once explains why the images produced by lenses that are uncorrected for chromatic aberration are fringed with colour, for the colour in the body of the image itself is scarcely perceptible on account of the smallness of the proportion of colour taken from it to form the fringe. It is clear, moreover, that if the screen that receives the image is placed in the focus of the actinic light, the image will show a red fringe to the eye, and that a blue tinted fringe indicates that the screen is further from the lens than the position where the brightest visual picture is formed.

This separation of light into its constituents is called dispersion, and Newton predicted that dispersion could not be neutralised without at the same time losing the effect of refraction. This, indeed, would be so if dispersion were always proportional to refraction, but, practically,

a prism of flint glass that gives the same amount of dispersion as a given prism of crown glass has a considerably less amount of refractive power. Thus it is possible by means of a flint glass concave lens practically to neutralise the chromatic aberration of a crown glass convex lens, and still to leave a residue of refracting power. This was shown to be possible by Hall in 1733, and in 1757 Dollond constructed achromatic objectives for telescopes. Perfect achromatisation with lenses is unknown, and when a combination of two lenses is used, it is only possible to get the foci of two parts of the spectrum to coincide exactly. Hence an achromatic combination made for ocular work only, if at its best, is not suitable for exact photographic purposes. A photographic lens should be so corrected that the focus of the mean of the photographically active rays coincides with that of the brightest of the visible rays, so that the lens shall properly "work" to focus." A sharper image can be obtained of the photographically active rays if the visible image is neglected, because then the available power of correcting the lens can be applied entirely to the actinic rays; and lenses have been so constructed for photo-astronomical work. With such instruments, however, focussing cannot be done in the ordinary way; the position of the actinic image must be determined, and the sensitive plate carrier must be fixed once for all in its proper place.

Spherical aberration. If a double convex lens with no diaphragm is attached to a camera, it will be found impossible to get as sharp definition as is generally desired in a photograph; but if, by means of suitably cut pieces of blackened card placed close to the lens, the light is allowed to pass only through its central part or its outer

part, it will be found possible to focus the picture, and it will be observed that the picture produced by the centre of the lens is markedly further from the lens than the picture produced by its outer part. This want of coincidence of the focal points of different parts of the lens in passing from its centre to its circumference is called "spherical aberration."

A plano-convex lens, with its convex side towards the distant object, or, better still, a double convex lens, the radii of the curved surfaces of which bear the proportion to each other of about one to six, suffers very little from spherical aberration. Such a lens so arranged is occasionally useful as a finder, because its aperture may be large and the image it gives proportionally bright; but the field over which it gives a good enough definition for practical photography is too small to be useful. By turning such a lens round with its most convex side towards the focussing screen, a larger field is covered, but the definition throughout is confused. The spherical aberration consequent on the position of the lens may be reduced by the use of a diaphragm. The ordinary single landscape lens of modern make is almost invariably of the meniscus form, because the field covered is still larger than with a plano-convex; but the spherical aberration is greater with the meniscus, and it is therefore necessary to use a smaller stop.

Spherical aberration can be corrected in combinations of lenses by the use of suitable curves, and lenses that are corrected so that they can be used with their full aperture are said to be "aplanatic," though this term is often employed in a very vague, if not an incorrect, sense.

CHAPTER XVI.

THE SPECTROSCOPE, COLOUR SENSITIVENESS, AND THE ABSORPTION OF LIGHT.

It has been shown that when light passes through a dense medium such as glass, whose opposite sides are not parallel, the path of the light is bent out of its original course; and also that whenever refraction is produced by a single medium, the constituents of the light are unequally refracted and therefore separated. A prism, as optically understood, is a piece of glass, or its equivalent, with its opposite sides parallel in one direction and inclined in the other direction; and a spectroscope in its simplest form is a prism and a screen with a narrow slit in it for the light to pass through before it impinges upon the prism, so that the separated constituents of the light may overlap to the least possible extent. By means of such an instrument, any light will give its own characteristic spectrum, and so reveal its exact nature to the scientific observer.

If a non-luminous flame is made yellow by introducing common salt into it, and this yellow light is examined by means of a small spectroscope, a yellow image of the slit is seen, and if then some potassium nitrate is introduced into the flame, there will be added a red image of the slit on one side, and a violet image, at a considerable distance, on the other side of the yellow one. The potassium compound gives out a mixture of red and violet light, and as the red is refracted less than the yellow, and the violet is refracted to a greater degree,

the three sorts of light are separated, and are each as clearly visible as if the others were not present. If we find in using the same instrument that another luminous body gives a yellow or red image of the slit, or gives a yellow or red light at the same place as the sodium or potassium compound, then we know that we have the same sort of light; for light from any source whatever, if equally refrangible, is similar in all its other known properties.

If a gas or candle flame is examined with a spectroscope, a band of colours similar to the rainbow is seen, and here there is no interval—all sorts of visible light are emitted by the flame, and the innumerable images of the slit overlap each other all the way. With the finest slit and most perfect instrument no gaps can be found, hence the light emitted is said to be of all degrees of refrangibility, and the spectrum produced is continuous. The spectrum of solar light is practically continuous, though hundreds of gaps of darkness occur, because these gaps are very narrow, and most of them immeasurably so. From the nature of the slit used, these spaces appear like lines, and they are called Fraunhofer lines, after the philosopher who first elaborately mapped them. These lines are made use of to indicate a definite part of the spectrum, or, in other words, a certain sort of pure or unmixed light. The lines A B C are in the red light, D is in the yellow, E in the green, F in the blue, G in the violet, and H in the extreme violet, as shown in fig. 16.

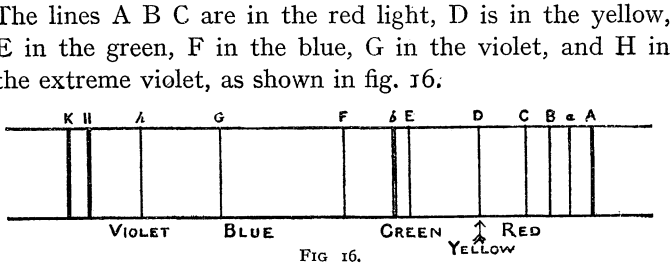


FIG 16.

If a continuous spectrum or the spectrum of solar light is allowed to fall upon a sensitive surface, the result will clearly show what sort of light most affects the sensitive material used. It will be found in most cases that where the red light falls there is little if any change produced, that yellow light has hardly more action than the red, and that the photographic effect is at its maximum where the violet or bluish violet falls, and that it extends on both sides of this centre, on the violet side beyond the visible light, getting smaller with more or less regularity. Thus, a large portion of the light that is photographically useful is invisible, and that which produces the greatest photographic effect has very little illuminating power, the brilliant yellow and green having very little action. Therefore, it is, and always will be, impossible to estimate photographic exposures by the eye alone with any exactness. An actinometer measures photographic activity by a photographic effect, and is therefore very much more reliable than the mere visibility of light, though, indeed, even it is not exact, because the proportional effects of different parts of the spectrum are not uniform when acting upon different sensitive substances, or upon the same sensitive substance under different conditions (printing out, developing, etc.)

Iodide of silver with ordinary development is sensitive to the ultra-violet and the violet; chloride of silver with development is affected chiefly by the ultra-violet, also by the violet, slightly by the blue, and very little by the green; while bromide of silver is chiefly affected by the violet and blue, very considerably by the ultra-violet, to a smaller extent by the green and yellow, and even slightly by the red, if the exposure is prolonged. As silver bromide

is sensitive over a wider range of colour than either of the other salts, it is the most suitable for the production of orthochromatic plates.

By means of spectrum analysis one can not only determine the nature of any given light, and the kind of light by which any given sensitive surface is affected, but also the absorbing effect of any medium that is only partially transparent, or transparent only to certain kinds of light. A very important use of absorbing media is in the construction of dark-room lanterns that are required to give the safest light for the manipulation of sensitive materials. This matter is treated of in the section on "Apparatus."

Other absorption effects sometimes demand considerable attention. In photographing interiors where the windows are glazed chiefly with yellow and red glass, a protracted exposure will be necessary, although the flood of light may appear such as to warrant a short exposure.

The moisture in the air is a great enemy to rapidity of exposure, and its effect is not only uncertain, but chiefly invisible, and therefore not to be estimated by the most experienced eye. In general language, nearly the half of the photographically useful light that reaches us from the sun on the best of days consists of invisible radiations, and the remainder have a very small illuminating effect. The air may therefore be photographically foggy when it is quite clear to the eye. and the visibility of a fog is always very much less than its effect in photography. However clear the air may be, it absorbs useful light, and therefore exposures must be shortened at high elevations, because there is less of the air intervening between the sun and the object; and the nearer the sun is to the horizon,

whether at early morning or late in the day, or in the winter, or in regions remote from the equator, the more must the exposure be lengthened, because the oblique rays have a greater distance of air to travel through.

The proportional photographic activity of the light at Iceland, Manchester, and Cairo, on the 25th March, for each hour during the day, as given by Professor Roscoe, is shown in the following table—

a.m.	p.m.	Iceland.	Manchester.	Cairo.
6 ..	6 ..	0. ..	0. ..	0.
7 ..	5 ..	.02 ..	.22 ..	1.74
8 ..	4 ..	1.53 ..	5.85 ..	20.12
9 ..	3 ..	6.62 ..	18.71 ..	50.01
10 ..	2 ..	13.27 ..	32.91 ..	78.61
11 ..	1 ..	18.60 ..	43.34 ..	98.33
Noon ..	..	20.60 ..	47.15 ..	105.30

Of course, these figures are only approximate, and normal conditions are assumed.

In this connection it is interesting to notice the value of the light that reaches the various planets :

Neptune ..	.04	Mars ..	137.1
Uranus ..	1.0	Earth ..	318.3
Saturn ..	3.5	Venus ..	608.9
Jupiter ..	11.8	Mercury ..	2125.0

Presuming other things to be equal, photographic exposures on the planet Mercury would only be about seven times as rapid as with us, while the equivalent of an exposure of one second with us is about a minute and a half at Saturn, five minutes at Uranus, and two hours at Neptune.

Many terrestrial substances exercise a very important absorptive effect upon the ultra-violet rays, and are therefore detrimental to photographic work when the available light has to pass through them. Dr. W. A. Miller made an extensive series of experiments in this

direction, and he found that while rock crystal was the most transparent to the ultra-violet rays, ice, water, white fluor-spar, and pure rock salt, in thicknesses up to .75 of an inch, were scarcely at all inferior to it. By passing the light examined through a space two feet long filled with either air, hydrogen, carbonic acid, carbonic oxide, or ammonia, there was no appreciable loss. But among a large number of other bodies examined, solids, dissolved substances, liquids, and gases, there is not one that does not stop a considerable proportion of photographically active light. The solar light, however, that reaches us is considerably reduced by passing through our atmosphere, and the majority of substances tested do not appreciably affect the solar light available under ordinary circumstances. Those given in the following table are the only ones likely to interest the photographer.

The last column indicates the extent of the ultra-violet transmitted, the ultra-violet of the solar spectrum being divided into ten degrees. The higher the figure, therefore, the less the absorption observed; but these figures cannot in any way be made to show the proportional diminution of photographic action, because the ultra-violet of the solar spectrum is not of uniform photographic intensity throughout its extent.

Material tested.	Thickness of layer.	Ultra-violet transmitted.
Solids.	*In inches.*	*In solar spectrum.*
Crown glass (greenish) ..	.74 ..	6.5
Flint glass	.68 ..	5.5
Faraday's optical glass (pale yellow) ..	.54 ..	1.5
Saturated solutions of solids.		
Hyposulphite of soda ..	.75 ..	8.5
Silicate of soda ..	,, ..	8.5
Nitrate of silver ..	,, ..	6.0

Material tested.	Thickness of layer. *In inches.*	Ultra-violet transmitted. *In solar spectrum.*
Solids.		
Cyanide of potassium (not quite pure)	.75	5.5
Ferrous sulphate	,,	5.0
Liquids.		
Nitric acid, s.g. 1.3 (colourless)	,,	6.5
Oil of turpentine	,,	4.5
Bisulphide of carbon	,,	2.5
Vapour of Bisulphide of carbon	24.0	1.5

The use of glass lenses, therefore, tends to uniformity of exposure under various conditions of the atmosphere, for their retarding effect only comes into play when the air is free enough from mist to transmit those extreme ultra-violet rays that glass absorbs.

PART II.—APPARATUS.

CHAPTER I

CAMERA CONSTRUCTION.

THE camera is an apparatus to support the lens and the sensitive plate, and, generally, to exclude all light from the plate except what passes through the lens. The quality and pattern of the instrument have no direct influence whatever upon the picture, but with a convenient camera the operator can adjust the position of his plate and lens with more rapidity, and perhaps with more certainty, than if he had only a makeshift apparatus. The various changes possible with any camera are, therefore, to be valued as conveniences, and when it is stated that any elaboration is indispensable, it simply means that without it the operator would be constantly hampered, and would often be losing time by having to devise means for gaining the desired end.

Camera bodies are most often made of the bellows form, and this has not only the advantage of portability and ease of adjustment, but the light transmitted by the lens that impinges upon the walls of the camera is reflected forwards or across the camera, rather than on to the sensitive plate. Sliding body cameras and solid body cameras, whether they fold like the old-fashioned instruments, or are rigid as in some patterns of hand cameras, allow the light that impinges upon their flat sides to

glance off on to the sensitive plate, especially at its edges. This should be guarded against by one or more diaphragms fixed at intervals within the camera, with rectangular openings large enough to allow light from every part of the lens to reach every part of the sensitive surface. A less efficacious method is to line the chamber with black velvet, so as to reduce the reflection from the sides as far as possible. For such purposes black velvet is much preferable to any black varnish or black mixture known.

Camera fronts. That part of the camera that carries the lens is always spoken of as the camera front. It is often necessary to raise the lens to get the upper part of a high building on to the plate, or to reduce the extent of foreground; and occasionally it is required to lower the lens when the photographer is obliged to occupy a high position. The camera front, therefore, ought always to slide upwards—say two inches or more for a whole-plate camera—and it is well if it will slide downwards about an inch for this size. A horizontal movement of the lens is very rarely desirable, unless only a part of the sensitive surface is to be exposed and the lens is wanted opposite that part; but if the camera is constructed so that it must be turned on its side for pictures taken with the longest direction of the plate vertically, then what is usually in landscape work the horizontal movement of the front becomes a vertical movement, and is a necessity.

This movement of the lens is a practical substitute for the impractical but fundamentally desirable ability to move the plate. The lens produces an image of much more of the subject than it is desired to photograph, and an image that much more than covers the plate. The fundamental desideratum is to be able to move the

plate until it receives exactly that part of the image that is to be photographed, but to do this would require an apparatus so cumbrous as to be practically impossible. The moving of the lens in the reverse direction is almost, though not quite, the equivalent of moving the plate. The disadvantage is so small and the practical gain so great that it is the method always adopted.

Any movement of the lens that places its axis at other than a right angle with the sensitive surface is to be guarded against. It is a waste of workmanship to attach the lens to a ball-and-socket arrangement, as has been done, and the notion that a swinging front is in any way a substitute for a swinging back is erroneous. However the back swings, the lens, in its normal position, points to the centre of the sensitive surface; but the front cannot be swung in any direction without upsetting this condition. A front that swings vertically is, however, useful in conjunction with the vertical swing of the back if the front and back are kept parallel, as the effect produced is that of an abnormal amount of rise or fall of the front; this is especially to be commended where the front is small, and the principle is well shown in many light modern cameras.

The back frame. For working under varying circumstances, it is well to have the back frame of the camera, that is, the part that carries the plate, to swing vertically (like a toilet-table looking-glass), except in the case of small hand-cameras. This is admitted by probably every maker; but the equal importance of having some means of knowing when the back frame is vertical is not recognised as it ought to be. It is true that anyone can carry a spirit-level, but this is a troublesome substitute

for a level fixed to the camera itself. It is important to notice that the level is for the purpose of indicating when the sensitive surface is vertical, and it is therefore preferable to fix it to the back frame of the camera; and a round level is generally more convenient and compact than two straight levels at right angles to each other. If no spirit levels are provided, an excellent substitute is a simple piece of string to which may be attached any weighty object, such as a pocket knife or a bunch of keys. Such a plumb line will readily show when the back frame is vertical in both directions, and is preferable to a small swinging index that may sometimes be seen suspended on the sides of cameras.

The vertical swing is used to keep the sensitive plate vertical when the camera is tipped up, as in taking very high subjects, that the vertical lines, as produced in the picture, may not converge. This movement of the plate throws the top and bottom of the picture out of focus, for the nearer the object is, the further off is the image from the lens, and the movement of the plate necessary to keep the vertical lines parallel brings the upper part of the sensitive surface nearer the lens, and it is this part that receives the image of the nearer part of the object. Thus definition is sacrificed for correctness of form, and to restore the lost sharpness a small stop must be used. It is well not to use the swing-back unless it is absolutely necessary to do so, especially with lenses that give a flat field.

If the swing-back is used in the other direction—that is, drawing the top part of the plate away from the lens—focussing is made easier, because the near foreground is delineated on the surface further from the lens; but this use of the swing-back always distorts the picture, pro-

ducing a perpendicular convergence that includes an undue proportion of the upper part of the subject. This aid to focussing has sometimes been recommended by skilled photographers in landscape work, but should be scrupulously avoided because of the distortion that results.

The horizontal swing is exactly comparable to the vertical swing used in the manner last described, and accordingly introduces distortion for the sake of ease in getting definition without having recourse to so small a stop in the lens as would otherwise be necessary. It is used in focussing a row of houses, trees, etc., that recede from the camera, but it has the very undesirable effect of dwarfing the distance, and so giving a somewhat similar result to what would be obtained by using a lens of shorter focal length at a point of view nearer the subject photographed.

Better advice cannot be given to the photographer than to keep his plate perpendicular and the lens axis at right angles to the plate, and to use the possibilities of deviating from these rules to the very least extent. When he is tempted to take advantage of the facilities for focussing just mentioned, he should bear in mind that he thereby distorts the representation of the view before him, and exaggerates those undesirable features already obvious, especially in small photographs, that make the picture deceptive. Although the picture is included within a parallelogram, the amount of subject represented as seen by the eye is bounded by lines which are parallel in one direction, but incline towards each other in the other direction. It should be noticed that in those cameras that have to be turned on the side for a vertical picture the horizontal swing becomes a vertical swing, and is therefore necessary.

It is well to have the swinging centres so fixed that their axes cross at the centre of the plate ; but it is often worth while surrendering this point for the sake of the portability that can be obtained by adjusting the back frame of the camera on the hinges at its lower part that also serves for closing the apparatus for carriage.

Plate carriers. The contrivance for holding the sensitive material, technically called the " back," has been modified in a great number of ways, but the book form of double-back continues to be the most popular, in spite of its defects and its competitors. Its two chief drawbacks are its cost and the fact that it slides into position. The evil of the sliding is not only that the camera may be moved as the back is being adjusted, but that the surface it slides against is difficult to keep so close fitting to the face of the double back that it can be depended upon to exclude light. The Sciopticon Company used to make a camera in which the back did not slide at all, but was pushed into a recess. This device perfectly obviated the trouble, but it appeared to be advisable to have a loose focussing screen, and this is certainly undesirable, especially for outdoor work.

Backs or plate carriers made of metal have some advantages over those of wood. They are more compact, cannot warp, and, if properly made, do not often get bent out of shape. But metal backs are often cheaply and badly made. It would be well if these fittings were standardised, so that any maker's back would fit and be in register in any maker's camera of the same size.

The weakest parts of camera backs themselves, so far as concerns the exclusion of light, are the openings where the slides are drawn out. This difficulty is greatly

increased when the slides neither fold back nor draw right out. It is only cheap apparatus that suffers from this defect, and it should be altogether avoided. If the back could be adjusted to the camera so that its slides were drawn downwards, the possibility of light gaining access to the sensitive plate would be very much reduced. When a double-back is opened for the removal of its plates, the plate that is at once exposed to view should always be the one indicated by the lower figure—that is, the odd number.

That small part of the back frame of the camera that receives the double-back is often detached and made square, so that it may be reversed in position for changing the plate from horizontal to vertical. To allow of this the camera must be made square. The larger front that is necessary gives a little more scope to the movements of the lens, and the longer baseboard a greater range in focussing. Therefore, the added weight and bulk may well be put up with for the sake of the many advantages.

Changing boxes. For carrying many plates it is as a rule best to provide the requisite number of double-backs. Changing boxes carry many plates, generally a dozen, and may be advantageous in connection with small cameras. The pattern that merits the most confidence is that in which the plates are one at a time lifted up into a light-tight bag, and put down by hand at the other side of the arrangement. Granting that a changing box is perfect in its workmanship and design, the principal points to regard in connection with it are that it is heavier than a double-back with its two plates, and may strain the camera or give an unequal distribution of weight; that the plates will probably have to be exposed in the order

in which they present themselves, so that it is not possible to have different kinds of plates to suit different subjects ; that if fewer plates are taken, the size of the box remains the same ; and that the movement of the plates is likely to stir up any dust that may happen to be in the apparatus.

Film carriers. Sensitive films are most conveniently exposed in roller slides. These contain two rollers, one that holds the fresh sensitive material and one that receives it after exposure, with a stretching board or its equivalent in front over which that part of the sensitive band that awaits exposure is drawn, and other minor parts that enable the operator to know when a proper quantity of the film has been wound to bring a fresh surface to the front. As early as 1854, A. Melhuish constructed a roller slide, but it was the Eastman Company in 1885 that popularised this form of apparatus. In their pattern the rollers are detachable, so that the receiving roller with its exposed film is removed bodily, and the film is introduced by slipping in a fresh roller with its charge already wound upon it by the maker.

Cut films are thicker than rollable films, and are carried very much like plates. To keep the surface flat, it is desirable that they be supported in a holder, and other things being equal, the best holders are those that grip all the four edges of the film. The function of a film holder is to keep the film flat during exposure.

Focussing the image. It is necessary to be able to alter the distance between the lens and the sensitive surface easily, smoothly, and exactly, and yet to retain the part moved with sufficient firmness to allow of the subsequent operations. Cameras for copying and indoor work in general are preferably made with the front fixed

and the back part to move, because the distance between the object photographed and the lens determines the size of the image produced, and it is very inconvenient to be unable to adjust the distance of the focussing screen from the lens without altering the distance between the lens and the object, and therefore the size of the reproduction. But in landscape work the distance of the nearest object from the lens is so considerable that an inch or two more or less makes practically no difference, and we may, therefore, focus by moving the camera front without disadvantage. This latter method also has much to recommend it, for cameras so constructed can be made lighter and more compact, which is an important consideration with the tourist photographer who carries his own apparatus; and the back frame of the carrier being fixed, it cannot be jarred from its proper position by the introduction of the dark slide, etc. This last advantage is the more important, because apparatus used out of doors is not unlikely to suffer somewhat by exposure, and get to work irregularly.

Focussing is generally done by means of a screen of ground-glass. Ordinary ground-glass is almost useless for the purpose, because the grain is too coarse to allow the details of the picture to be seen, and the finest ground surface that can be obtained will not permit of the sharp focussing sometimes desirable, as in copying subjects done in lines like engravings, and sometimes in photo-micrography. For this purpose no translucent screen will serve; the actual image itself must be employed in focussing, and to know whether the image is produced in the proper plane, a sheet of transparent glass that has its front side marked with very fine lines is introduced

in the place of the ordinary focussing screen, and a good focussing lens is adjusted so that the lines on the glass, as seen through the lens, are as sharply defined as possible. It only remains to get the image of the object before the camera at its maximum sharpness; for if the lines on the glass and the image are simultaneously sharp as seen through the same lens, they must be in the same plane. It is preferable to have the lines on the glass in groups, say of three, with intervals between the groups.

To get the advantage of this method of focussing without interfering in any way with the utility of the ordinary focussing screen, it is often recommended to cement two or three thin microscopic cover-glasses to the focussing screen by means of Canada balsam, after having drawn a few pencil lines on the spaces where the cover glasses are to be attached. The balsam entirely obliterates the dulness of the glass due to the grinding, and leaves only the pencil marks visible. But this method is not so satisfactory as it might appear to be.

Focussing screens of the finest quality can be made by taking two pieces of patent plate glass of suitable thickness, and working one on the other round and round with the finest elutriated flour of emery, well wetted, between them, until both are equally greyed all over. A focussing screen that shows no grain, even when magnified eighty diameters, can be prepared by inducing red fog in a gelatine plate. This is readily done by applying a ferrous citrate developer made alkaline with ammonia, and then fixing in the ordinary way. Coloured glass does not appear to be a sufficient barrier to the light to make visible the image that falls upon it, though one might imagine that glass flashed with a colour on one side would

be very similar to the glass with the coating of fogged film. To reduce the granularity of a ground-glass screen, it may be rubbed with any grease or vaseline in parts or all over, wiping off the excess. The simple ointment of the Pharmacopœia offers especial advantage for this purpose. When a screen so treated gets dirty, it may be cleaned off with a rag moistened with benzene, and re-treated.

Carey Lea's advice is to varnish a glass plate exactly as is usual in varnishing a negative, but first to add tartaric acid to the varnish that it may dissolve as much as possible, and to allow the excess of the acid to settle down. He states that such a film is exquisitely fine, yet not too transparent. The author has not succeeded very well with this method.

Temporary focussing screens for use in an emergency may be made by several methods. An ordinary dry plate may be exposed, developed until it is sufficiently grey, fixed, and dried. Such screens are not flat, because of the defects in the glass used in the manufacture of the plates. Other methods are by coating a piece of glass with a thin layer of starch, or by dabbing grease upon it; or a wet cambric handkerchief, if it can be stretched in position, may be made serviceable.

CHAPTER II.

THE CHOICE OF A CAMERA AND CAMERA STAND.

THE idea that the pictures produced by means of a camera are an indication of the value and efficiency of the instrument is very common, but quite erroneous. The simplest and cheapest box of deal or cardboard that will hold the lens and the sensitive plate in their right places and exclude extraneous light will give in every way as good a picture as the most expensive apparatus.

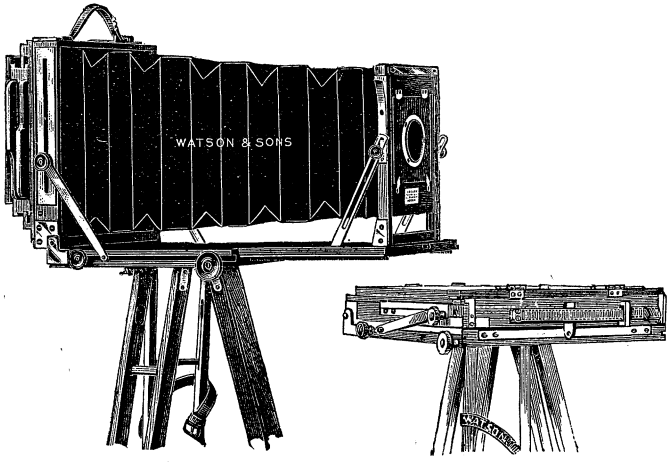
The best camera is simply the most convenient, but this is a very inclusive statement. It is not convenient to have a camera that shrinks or swells in a dry or moist atmosphere, or one that is likely to warp or crack. Hence the best workmanship, the finest wood, and the most perfect polishing, are well worth what they cost. It is not convenient that a camera shall fail to draw out far enough to give a picture with any lens that it may be desired to use; nor is it convenient to find that the long focus camera with its many possibilities, of the size required, is too heavy to be carried about.

It is impossible to suggest what pattern of instrument will be the most useful until it is known what work will be required of it, and what lenses are to be used. It may be taken for granted that no substantial advantage can be gained in one direction without a measure of sacrifice in another, and that all complications that are useless under the given circumstances are better absent.

Those who intend to take up photography as an

amusement, and travellers whose sole aim is to get the photographs they want with the least trouble and intend to send their exposed plates or films to a trade worker to be developed and printed from, will doubtless select a hand camera. Such instruments are treated of in a subsequent chapter. But he who follows photography earnestly and does his own work, whether it be landscape, portraiture, architectural work, the photography of flowers, or any of the other branches of the art except hand camera work pure and simple, will require a camera on a stand.

For general work out of doors, the type of camera that is almost invariably preferred, and with very good reason, is that exemplified by Watson and Son's "Acme," shown in fig. 17.



OPEN FIG. 17 CLOSED

But if extra weight is no disadvantage, the alternative pattern illustrated by the same firm's "Premier" camera,

fig. 18, may well be considered. Focussing at the back is a very great advantage, if not a necessity, for photo-

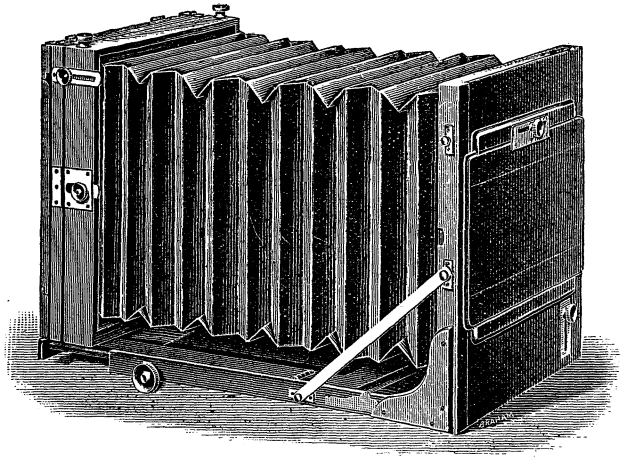


FIG. 18.

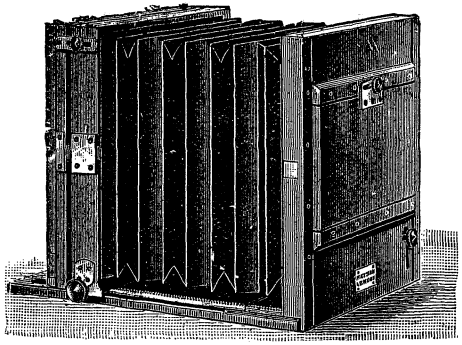
graphing near objects, that is, where the size of the image approximates to that of the object.

An excellent type of camera, though not so often used at the present time because of the limit of its focussing adjustment, and the fact that it is rather more bulky and heavy than the taper bellows, front-focussing camera, has a full size front and single baseboard, as shown in fig. 19.

The professional portrait photographer, of course, will use a camera of the type specially made to facilitate such work.

But whatever the pattern of the instrument, it is worth while to see that it is well made and reliable. A camera intended for honest work should be rigid in all

positions. When extended partially or fully, if the back is seized by one hand and the front by the other hand, there should be no looseness evident, but a sensible oneness,



OPEN. FIG. 13 CLOSED.

as if the back and front were permanently fixed with no means of adjustment. All movements must run smoothly, and this is especially to be looked to where the back or front slides on runners—a method of construction often adopted in extending baseboards or long-focus cameras. If such runners are made true by proper planing machinery, they will not cause any sticking or irregularity. The front and back of the camera in their normal positions should be parallel with one another, and the axis of the lens should be exactly at right angles to the focussing screen and opposite its centre. The inside of the camera should be black all over, including the brasswork, and it is well to look especially to the lens flange and the screws that pass through the front to hold the movable fronts in place, as these parts are often left bright. The balance between strength and portability is a matter that cannot be usefully discussed without practical examples,

but it may be stated that a light camera that is properly made will often be stronger than a heavier camera of inferior workmanship.

The register of a camera, that is, the correspondence in position between the surfaces of the focussing screen and of a sensitive plate that may be introduced in any of the backs or plate carriers, should be carefully tested, especially when lenses of large aperture are to be employed. There is no method of measuring with a rule that is so certain as the optical method. For ordinary purposes, a distant object, such as a signboard, a lamp-post, or a window, should be sharply focussed on the focussing screen, using the full aperture of the quickest lens at the disposal of the operator. The screen is then turned back, and each side of each double-back is by turn brought into its proper place, and a piece of finely-ground glass is held in exactly the position that the sensitive plate would occupy in making an exposure. If the image is well defined the register is correct. The same method should be pursued when greater exactness is desired, but transparent screens with fine lines on them should be used, and the focussing done by means of a good magnifier: To focus sharply and then expose and develop a plate is far more trouble and not so good a method, because the correction of the lens for chromatic aberration is included in the test.

There is great variety in camera stands, and those that appear to be cheaper often cost more in the end. It is useless to have legs of exceptional strength to a studio stand if they end in weakly castors, and stability in the fixed parts is wasted if the adjustable top that carries the camera is unsteady. However the top is secured, it

should show no signs of giving way when pressed with considerable force upon either corner; and this test should be repeated after varying the positions of the adjustable parts. Ball and socket arrangements are not to be recommended in any camera stands, except perhaps for very small and light hand cameras, because the support at that part is of necessity too small.

It is the habit of makers to supply tripods that are too weak and with tops that are too small. It is well to provide a tripod that is intended for at least the next size larger camera than is to be used. For working out of doors it will be found a great convenience to have the legs adjustable in length. The three-fold stand that Messrs. Watson and Sons supply with their "Acme" cameras, shown in fig. 20, is an excellent pattern. The lowest length slides, and is fixed in position by a screw bolt and fly-nut that binds it tightly between the two parts that form the middle section.

FIG. 20.

For quite small cameras of light pattern, there are many portable stands now provided that will be found convenient, if the camera is really light and not larger than quarter-plate size.

TESTING THE TRIPOD.

To ascertain whether a portable camera stand or tripod is fit for use, the largest camera that it is desired to carry should be screwed on to it, after placing the legs in the ordinary position. Then, on taking hold of the camera, it should feel as if it were one piece with the stand. The legs are generally attached to the tripod top by means of pins in the one and holes in the other, and sometimes the holes do not fit the pins. If the legs have sliding extensions, as much pressure should be brought to bear upon each leg as would suffice to drive it into the ground on average pasture land, and the sliding connection should remain firm. Other things being equal, the fewer the joints the firmer the tripod; but the other things so rarely are equal that the fewness of joints is of little value as an indication of stability. Some tripods that do not fold up at all are less firm than others that fold into about a quarter of their full length.

CHAPTER III.

EXPOSURE SHUTTERS.

THOSE shutters specially made for use in the studio to add to the convenience of the operator and to prevent the model from being distracted by the removal of a lens-cap are very desirable adjuncts to the camera; but, as they are simple in construction and their advantages are obvious, there is little to be said about them.

The need for shutters in general outdoor work has been very much over-rated by some photographers. For general purposes, it is advisable, as a rule, to make two or three seconds the shortest time of exposure, and, if necessary, to use a smaller stop than might otherwise give a satisfactory result. Two seconds can be timed with quite sufficient exactness after a little experience. An expert hand can expose for one second, half a second, or even a quarter of a second, without the assistance of machinery; but when the lens cap is taken off and replaced with so short an interval, there is likelihood of shaking the camera. It does not appear to be possible to give a hand exposure of less than a quarter of a second, and it is preferable for this, as well as for all shorter times, to use a shutter.

It is hardly possible to say what is the shortest exposure that it is well for a shutter to give unless the nature of the work to be done is clearly understood. Exposures of the one-thousandth of a second are desirable in some scientific experiments, and any longer time may be neces-

sary under certain circumstances. But if a shutter is wanted for general work, and is to be carried in case of need rather than for any pre-arranged purpose, then there is no doubt whatever that a range from one-fourth to one sixty-fourth of a second will be very useful and sufficient. If this must be curtailed, then, say, one-eighth to one sixty-fourth, or one-eighth to one thirty-second of a second. It is of little use to have an adjustable shutter unless the speeds under the given variable circumstances are known ; hence it is convenient to have a few definite exposures that can with certainty be reproduced. Reducing these to a minimum, the eighth, sixteenth, and thirty-second of a second will be found to be a useful series.

It is as impossible to construct a perfect shutter as a perfect lens, and it is therefore the more important to realise what is wanted, that minor considerations may give way to that which is more important.

The shutter, when in position and fully open, must have no part of it visible when the eye is brought to the place occupied by the extreme corner of the focussing screen when in its place as if a distant view were focussed upon it. Some shutters that work in front of the lens are made to fit the hood, but the opening in the shutter is even smaller than the lens itself. In most lenses the hoods are only just large enough to be out of the way of the light, and the opening in the shutter ought, therefore, to be as large as the ring that fits upon the hood. Otherwise, the edges of the plate have a less exposure than the centre, because the small opening in the shutter acts as a diaphragm towards them, and this evil, which cannot be altogether avoided, is needlessly exaggerated.

EFFICIENCY OF SHUTTERS.

The whole plate should be exposed simultaneously and equally, or if one part of it receives a little more exposure than another, it should be that part that needs most exposure, namely, the foreground. As large a proportion as possible of the exposure should be given with the full aperture, hence the opening and closing should always be as rapid as possible, and the duration of the exposure regulated by the interval. To regulate the speed of a shutter by simply slowing or quickening its action is bad in principle, though often very convenient in practice. There must be no jarring or jerking until the exposure is quite over. And, finally, a shutter should be small, that it may not catch the wind; light, that it it may not strain the lens mount or camera front; simple, that it may be easily repaired when necessary; and quickly fixed to or removed from the lens without needing any change whatever either in the camera or lens, unless the whole arrangement is designed for special work.

The efficiency of a shutter, expressed in its most simple and most useful form, indicates the proportion between the total duration of the exposure and the duration of a theoretical exposure that would give the same light effect on the plate if the shutter were fully open the whole time. Thus, if the opening and closing of the shutter occupied no time at all, the efficiency would be 1, or unit. If the whole time of the exposure is occupied in opening and closing the aperture, and the rate of movement of the shutter is uniform, the efficiency is $\frac{1}{2}$ or .5, because the same light effect would be produced by an exposure of one-half the duration if the opening and closing were absolutely instantaneous. It is obvious that no shutter can have unit or full efficiency, but the nearer to this the better.

The circumstances that govern efficiency are most simply illustrated by supposing a rectangular opening in an opaque material to pass in front of the lens at a uniform rate. Two examples are shown in fig. 21, in

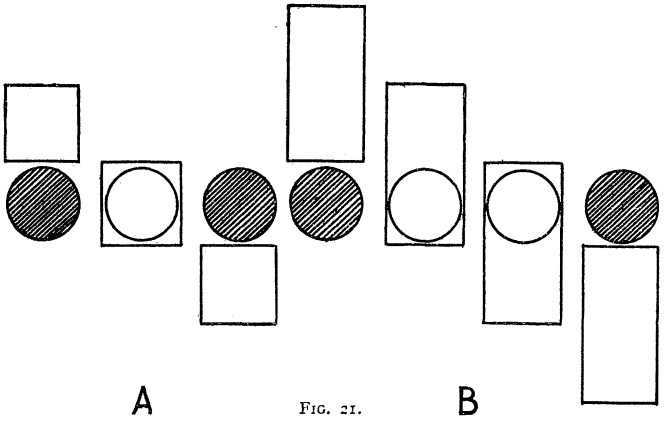


FIG. 21.

both of which the opening moves downwards. The relative positions of the lens and shutter opening are indicated by circles and rectangles respectively. In the first and last member of each series, the lens is shaded to indicate that it is closed. In A, the total duration of the exposure being two units, each being the transition from one stage to the next, the effective exposure is one unit only, because during the whole of the exposure the lens is either being opened or closed, an efficiency of .5. In B the total duration is three units, and the effective exposure is two units, because the added unit of actual exposure represents perfect efficiency, the lens being fully open the whole time of this additional unit of exposure. The resulting efficiency is therefore .66. If

the opening in the blind were three diameters of the lens in length, the efficiency would be .75, if four diameters .8, and so on, allowing always that the rate of movement is uniform.

Efficiency is increased by reducing the lens aperture. It will be readily seen that if the aperture were divided by four, that is, the diameter of the lens halved, then A in fig. 21 would give an efficiency of .66 instead of .5, and B .8 instead of .66. Suppose, for example, that the lens aperture is increased from f/16 to f/8, four times the light is admitted in unit time, and the exposure is therefore generally divided by four. But the shutter upsets this proportion. The efficiency at f/16 being .8 and at f/8—.66 the increase in light effect by putting in the larger stop, instead of being as one to four, is as .8 to 2.64, or one to 3.3. This must only be accepted as a rough indication of the effect of the shutter on proportional exposures, because actually the rate of movement of shutters is hardly ever uniform, as supposed in the examples, and the lens diaphragm is not close to the shutter. The equivalent exposure is the time that would produce the given effect if the lens were fully open, and no part of the time were required for the operations of opening and closing.

There are four positions for the shutter, namely, in front of the lens, behind the lens, between the combinations (that is, against the diaphragm), and immediately in front of the sensitive surface. Each position has effects of its own.

In front of the lens. Obviously, a shutter so placed may be easily attached and removed, and this is a considerable advantage, except perhaps in hand cameras.

In the best known shutters of this type, a rectangular opening in an opaque material is drawn across the lens. The old-fashioned drop shutter is now replaced by the more compact blind shutter that has been popularised by the Thornton-Pickard Co. The blind is carried on two rollers, one of which has a spring in it that is wound up sufficiently to draw the blind with its aperture across the lens when released. By increasing the length of the aperture the efficiency becomes greater, as already shown, but at the same time the exposure is lengthened, and to compensate for this the movement must be quicker. This sets the practical limit to efficiency. The movement may be quickened by having a stronger spring or a larger roller. The author devised and used with great satisfaction a roller blind shutter with a spring roller one inch in diameter, an opening three times as long as the maximum aperture of the lens, giving exposures from the one-sixteenth to about the sixty-fourth of a second, according to how much the spring was wound up. The practical limit to such increase of efficiency and speed is governed by the strength of the material of the blind and the shock to the apparatus.

Rotary shutters are often convenient and effective. In all such devices the limits of the aperture should be straight lines drawn from the centre of rotation. A round hole, or an elongated hole with rounded ends, is disadvantageous, as it reduces the amount of light that gets to the ends or edges of the plate, and offers no advantage whatever, except possibly in the manufacture. The obvious form of such a shutter is shown in fig. 22. The angle of the aperture may be increased or diminished by obvious devices, and with a constant speed of rotation

the relative exposure can be easily and definitely proportioned. Reducing this shutter to its smallest dimensions, it becomes merely a sector or fan-shaped screen that covers

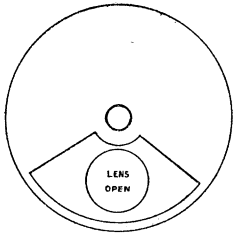


FIG. 22.

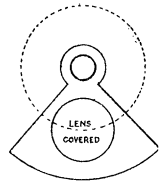


FIG. 23.

the lens, and flies round to re-cover it, as in fig. 23. The author had a shutter of this kind made many years ago by a watchmaker, and though in constant use ever since it gives perfect satisfaction. It is very efficient and uniform in action. The only friction is on the centre pin. There are two sectors, which when separated give a shorter exposure. The rotation is effected by a spiral spring, which pulls a cord wound on to a small drum at the centre. The sectors are very thin brass, and very light indeed.

Shutters have been made with two moving parts instead of one, an opening in each moving in opposite directions. This principle is wrong, as the lens is not uniformly exposed, the exposure beginning and ending in the middle. Thus the ends of the plate are robbed of light, and under-exposed. A double movement should never be used except at the diaphragm place.

Behind the lens. This position for the shutter has few advantages and many disadvantages in general outdoor work. It may be more convenient to change from one

lens to another; but the lens is rarely so firmly secured as when the shutter does not intervene between it and the camera front. The shutter will interfere with a lens that projects a little through its flange, the blind is generally further from the lens, and the shutter has to be carried, though it may be rarely needed. The aperture in the shutter limits the diameter of the lens that can be used, and this may be inconvenient when a new lens is obtained. In other matters the behaviour of the shutter behind the lens is much the same as when it is in front.

Between the combinations. This is a favourite position. A shutter here is best arranged to open from and close to the centre, so that it is practically an opening and closing diaphragm. If the efficiency is low, the definition of the lens is markedly improved, because a large proportion of the exposure is made with a smaller aperture than that of the fixed stop. Shutters of this kind are only suitable for hand cameras; they take the place of the ordinary mount, and become inseparable from the lens. Such shutters if good are very costly and very excellent; if cheap, they are not reliable. It is not unusual in a cheap shutter of this kind marked to give exposures extending down to one-hundredth of a second, to find that the two or three most rapid exposures are practically the same, and none of them shorter than about the thirtieth of a second.

Focal plane shutters. This is the common name for shutters that work immediately in front of the sensitive surface. They are roller blinds, of course of large size, with a slit that can be widened for longer exposures, and narrowed for shorter exposures. Very short exposures can be given with such shutters—that is, short so far as

any one part of the plate is concerned; but the total duration of the exposure is never very short, as the slit has to pass over the whole of the plate. If an exposure of each part of the plate of from the one-hundredth of a second to the one-thousandth of a second is required, probably this type of shutter is the best; indeed, it is the only commercial shutter that will give the shortest exposure mentioned. For near rapidly-moving objects it is serviceable. But it should never be used when a shutter at the lens is possible, because it distorts the image of the moving object. If the shutter moves downwards, and a man is photographed as he is running, the man's head is first photographed, then gradually his body downwards, and then his legs. But he is moving, and therefore the lower part of the image is in a more forward position on the plate than the upper. The man may be actually leaning forward, and the image may show him as if he were inclining backwards. If a man in a horizontal position is falling downwards, as sometimes in diving, he will appear stouter than he really is. Other effects of exposing a plate piecemeal can easily be discovered. It must be admitted that these distortions are not often obtrusive in photographs taken with focal plane shutters, but the effects cannot be avoided, and would be revealed by a critical examination of the picture. Therefore, such shutters should never be used when it is possible to use a shutter at the lens.

The estimation of the duration of the exposure given by the shutter used under the varying conditions possible is very desirable, indeed necessary, if the apparatus is to be used intelligently. The length of time occupied in giving the exposure is, as has been pointed out, always

longer than the equivalent exposure. If the shutter begins to close as soon as it is fully open, so that the whole time of exposure is occupied in opening and closing, the duration of the exposure may be assumed to be double the equivalent exposure. For example, the amount of light that reaches the plate, if equal to what would pass through the open lens in one-eighth of a second, would take a quarter of a second to get through. A good shutter that gives an exposure of a quarter of a second duration would give an equivalent exposure of nearly the same time, or, as compared with the first, nearly twice as much light, with no more blurring due to the movement of the subject.

The duration of the exposure, and the equivalent exposure, may be very different, therefore, and it is necessary carefully to distinguish between them. The duration of the exposure given by some shutters can be estimated by attaching a tuning fork to the moving part, and causing it to vibrate during the exposure, and mark its vibrations on a piece of smoked glass. Each complete vibration of an ordinary C fork is equal to about the 530th of a second, and with an A fork, such as violinists use, it is about the 440th. But if the fork adds its weight to the moving part of the shutter, and so alters its rate of movement, the result will not be the same as when the shutter is used in its normal condition.

Or, by calculating from the known rate at which a body falls, the duration of the exposure given by gravity shutters may be approximately found. Disregarding friction, which always retards movement, but will vary according to the particular circumstances in any particular case, a body falls inch by inch in the following fractional parts of a second—

1st	inch	in	$\frac{1}{14}$	or	.0714
2nd	,,	,,	$\frac{1}{36}$	,,	.0277
3rd	,,	,,	$\frac{1}{43}$	,,	.0232
4th	,,	,,	$\frac{1}{52}$	,,	.0192
5th	,,	,,	$\frac{1}{59}$	,,	.0169
6th	,,	,,	$\frac{1}{65}$	,,	.0154

A method of estimating the practical effect of the exposure given by any shutter is to photograph a body moving at a known rate, and to measure the distance it passes through during the exposure as indicated by the impression on the plate. The thing photographed should be white against a black background, and if possible in the sunshine. A clock without a pendulum, so that its minute hand moves rapidly ; a bicycle wheel with a piece of white paper attached, which can be timed to make one revolution in a second without much difficulty ; a white plate allowed to fall in front of a black background graduated in white, are examples of available means of getting what is desired.

Such tests as these are indefinite, as they do not give the whole duration of the exposure, but only the duration of the effective exposure. With a stronger illumination, the effective exposure will begin sooner and end later than with a weaker light, and therefore show a difference though the shutter behaves in exactly the same way in both cases.

When an exposure is being measured, care must be taken to have the image of the moving object as near the centre of the plate as possible, as the edges of the plate get less light, and with some shutters either the upper or lower part of the plate gets an excess of exposure. In the majority of cases it is only possible to get an average result, but it is always possible to select the most useful manner of performing the experiment.

An apparatus that gives more exact results than the methods referred to above consists in causing a sensitive plate to revolve at a known rate behind a small opening in an opaque screen, while magnesium ribbon is burnt in front of the screen. The shutter is fixed between the magnesium light and the screen. The proportion that the curved line produced on developing the plate bears to the whole circle is the proportion that exists between the time of one revolution of the plate and the exposure given by the shutter. If, for example, the plate turns round twice in a second, and a quarter of a circle is produced on developing the plate, it is obvious that the shutter allowed the light to pass for one-eighth of a second. A useful form of apparatus on this principle consists of a spindle revolving within a light-tight box, and carrying a plate on its end. A hole is made in the box immediately in front of the plate, and if this hole is made in a sliding piece, it is quite easy to get a dozen or more tests upon a plate three inches square. The plate may be rotated by hand with sufficient regularity, if a flywheel, which may be a wooden disc loaded with lead, is attached to the spindle, and the crank for turning it is kept very short.

FIG. 23A.

A simple shutter speed tester, devised by Mr. G. F. Wynne, was put upon the market in 1903 by the Infallible Exposure Meter Company. It consists of a heavily weighted pendulum, supported on two points, with an extension above that carries a polished convex button, as shown in fig. 23A. The system is arranged to make one semi-oscillation

per second, and its rate of movement is easily adjusted if necessary by a slight alteration of the weight at the polished button. This is caused to oscillate in front of a suitably divided sheet, and the whole arrangement is placed in sunshine and photographed, using the shutter to be tested. The polished button gives by its movement a streak of light, and the extent of this shows the duration of the exposure at a glance, as indicated by the divisions on the sheet behind the pendulum. The illuminant may be burning magnesium ribbon instead of sunshine, though not quite so advantageously. This apparatus is simple to use, and has no mechanism about it to get out of order. The accuracy of the results that it gives depends upon the care of the experimenter.

The question of the duration of the exposure that may be given when photographing moving objects, without showing a blurred image, is considered in the next section in the chapter on "Exposure."

CHAPTER IV.

HAND CAMERAS.

THE great rapidity of gelatine plates and the fact that they are always ready for use have made it possible to work with cameras without a stand or other fixed support, merely holding the apparatus in the hand. It is obvious that any camera in conjunction with a suitable shutter may be used in this way unless it is too heavy, but the advantage of the principle is especially manifest in a small apparatus made complete in itself, and that may be carried about without fatigue, and used with the minimum of delay in preparation.

The first hand cameras appear to have been described by Mr. T. Bolas in 1881, who gave details of several forms of what he called "detective" cameras, evidently with the idea that they would be found serviceable by the police force. He recommended that when used they should be supported upon some firm object, such as a gate or post, or even the ground, but added that the exposure might be given while the camera was held in the hand. Following up the idea of using a camera in public places without recognition, the earlier patterns of several makers were designed to hide the fact that the apparatus was of a photographic character. But, obviously, the more that were made, the less possible did it become to maintain the deception, and now, except in very few cases, the "detective" character of hand cameras is no longer a desideratum, and a simple and unobtrusive exterior is all that is aimed at.

TYPES OF HAND CAMERAS.

Some of the earliest hand cameras were merely a small landscape camera in a box with an opening for the lens, but this is a needless addition to the weight, and it is more usual now to arrange a simple box to carry the lens at one end, and the plates or film at the other. Many mechanical arrangements have been devised for changing the plates rapidly, but the use of double backs finds much favour. This plan has the advantage that the plates may be used in any order, and so adapted to each subject as it is taken. On the other hand, the loose backs are so many separate pieces of apparatus that are liable to loss and accident. Bag changing cameras carry the plates in sheaths one behind the other, a spring at the back serving to keep the front plate in its proper position. After exposure, the plate is drawn up into a bag that is just large enough for the purpose, and pushed down at the back of the bundle. This construction has the advantages of certainty in changing, the absence of mechanism to get out of order, and of the whole apparatus with its plates, being self-contained. But the plates must be exposed in the order in which they are arranged. This, however, is a very trivial drawback, because it is not usual to carry an assortment of plates with a hand camera.

For those who desire great portability, not only in the camera itself, but also in the stock of sensitive material carried for use in it, nothing can compare with hand cameras of the types popularised by the Eastman Kodak Company during the last twenty years, in which roller-supported films are used. Each roller occupies but little space, and contains film enough for a large number of exposures.

Finders. For exact work a finder is essential. By means of a sloping mirror within, the view may be reflected upon a focussing screen at the top of the camera, and the shutter may be so arranged that the mirror is moved out of the way immediately before the exposure is given. Twin-lens cameras are really two cameras in one, and the object can be seen on the screen of one while the plate is being exposed in the other. But full size finders such as these are bulky and weighty, and offer no particular advantage for a very large proportion of hand camera work. Nor is there any need for the finder to assist in the focussing, because this is generally better done by judging the distance of the object, and setting the camera according to a scale marked on it. The finder then becomes merely a device for showing what is on the plate, and it may be very much reduced in size. The image in a small finder can be made very brilliant, and this is a great advantage, because it obviates the need of looking very attentively at it. A distinction may be made between what is desirable for the taking of figures and views respectively, or, rather, the classes of photographs represented by these two types of subjects. In the one most attention is paid to the central part of the plate, and in the other to the boundaries; the photographer in the one case seeks to get his subject conveniently near the centre of the plate, while in the other he has to see that the view is really on the plate, and an error of even less than a quarter of an inch may prove disastrous. There are some finders that show only the middle part of the view, and for landscape work in general these are useless. A finder that shows the entire image, and indicates exactly where the view is cut off by the boundaries of the plate,

will obviously serve for every purpose, and except, perhaps, for some very special work, it is a finder of this character that most deserves recommendation.

A very common type of finder consists of a little box with a lens at the front, a sloping mirror within, and a piece of ground-glass at the top upon which the image produced by the lens is received. With such an arrangement, it is easy to mark off with opaque varnish exactly that part of the ground-glass that corresponds to the plate. The margins may then be blacked out with an opaque varnish, such as Berlin black. A finder of this type can be adjusted once for all to show exactly the image that is received by the plate, but it has the disadvantage that the image is not very bright, and as the ground-glass it falls on is exposed to diffused light, even when a shade is provided, it is not a satisfactory device.

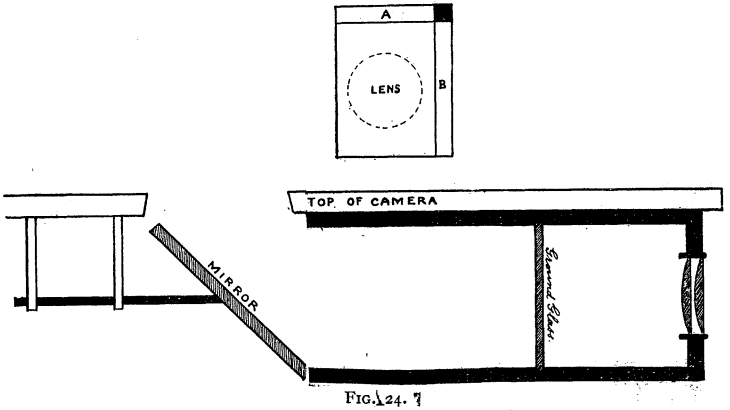


FIG. 24.

The author has modified this kind of finder, as shown in fig. 24. The lens has an aperture of f/2, and two lenses are used to reduce the spherical aberration, and so give

better definition. The ground-glass screen that receives the image is fixed in a long square tube, and therefore is absolutely protected from stray light. It is marked as shown in the upper part of the figure, the spaces A and B being the parts added to the image when the front of the camera is raised lengthwise or widthwise of the plate respectively. The lens aperture being large and the ground-glass thoroughly protected, the image is exceedingly brilliant; indeed, it often appears as if there were no ground-glass at all. The image is seen by means of a sloping mirror at the back end of the tube through a hole in the top of the camera. This mirror turns on a horizontal axis, and by turning it through 90° shows the view with the plate horizontal instead of vertical, the one finder serving instead of the usual two. This finder can be exactly adjusted to show what is on the plate, and never gets out of adjustment, the position of the mirror, obviously, having no effect upon the view on the ground-glass.

Clear-glass finders have no ground-glass in them. The simplest is a concave lens, but this is of no use at all unless the proper position for the eye of the observer is indicated, for the view seen through it will vary as the eye is moved. The most recent "clear-glass" or "brilliant" finders are made with convex lenses of high power, generally one in front to produce an image, and one behind placed horizontally through which the magnified image is seen, a sloping mirror being placed between. A rectangular screen, generally over the lens nearest the eye, limits the view. The first finder of this type appears to have been devised by Messrs. H. Hill and A. L. Adams in 1894.

This finder has been modified in many ways. A reflecting prism with one surface curved has been used instead of a lens and mirror. The lateral inversion of the image has been cured by an extra reflecting surface. But all such devices suffer from the defect of giving a different image as the eye is moved, and therefore are not susceptible of proper adjustment. Dr. Mercer, of New York, in 1897, suggested a diaphragm at each end of the optical arrangement to indicate the correct position of the eye, the openings in the two diaphragms coinciding when the eye was correctly placed. Messrs. C. and H. C. Beck, in 1898, showed the simple way of overcoming this difficulty. They put the limiting diaphragm inside the finder and in the same plane as the image; then, whatever affects the one affects the other equally. Whatever finder is used for views, it should be capable of adjustment by the user of the camera, so that the view on the finder may have exactly the same boundaries as the image on the plate.

Shutters. The principles of shutter construction are considered in the previous chapter. In hand cameras the shutter generally being an integral part of the apparatus it may occupy more space if desirable.

Focussing. Hand cameras intended for critical work should permit of focussing, otherwise objects at a certain fixed distance will always be the best defined. It is convenient to have a scale against the moving part, so that it may be set for objects at definite distances. The expression "fixed focus" or "fixed focus lens" implies an impossibility, and so far as it has any meaning must be regarded as a conventionalism, indicating that the camera will not allow of focussing adjustment, or that a

lens is of so short a focal length and so small an aperture that it may be used without great inconvenience on such a camera.

The following table, which is taken from a more extensive one calculated by Sir David Salomons, gives, for lenses of the focal lengths and apertures stated, the distances at which objects will be depicted with an equal amount of out-of-focus effect when the lenses are focussed for an object at a great distance. The actual amount of diffusion at the distances stated will be such that points in the object will be shown as discs one-hundredth of an inch in diameter without allowing for the imperfections of the lens. Obviously, the definition is sharper for objects at greater distances, and less sharp for objects nearer the lens.

Focal length of lens in inches.	Diaphragm apertures.				
	f/8	f/10	f/11	f/15	f/20
	ft. in.	*ft. in.*	*ft. in.*	*ft. in.*	*ft. in.*
4	17 0	13 8	12 5	9 2	7 0
4½	21 5	17 3	15 8	11 7	8 9
5	26 5	21 3	19 4	14 3	10 10
5½	31 11	25 8	23 4	17 3	13 0
6	38 0	30 6	27 9	20 6	15 6
6½	44 6	35 9	32 6	24 0	18 1
7	51 7	41 5	37 8	27 9	21 0

Levels are a necessary adjunct to a hand camera. If the finder image is seen through a rectangular opening in the apparatus, two spirit levels, at right angles to each other, at the extreme margins of the opening, will be well and conveniently placed, and better than a circular level.

Rising front. This is a very desirable movement, and if the plates are to be exposed in a vertical as well as a horizontal position, there should be a rise in both directions. For quarter-plate size, a movement of half an inch at least is desirable. Some makers cut the body of the camera across transversely, and make the one part to move on the other, but there is no need to do this because the half inch motion in both directions can easily be obtained within the camera without enlarging it for the purpose, by making a movable front somewhat after the style customary on field cameras. This rise is for general purposes so convenient that if it cannot be obtained, it would probably be found better to fix the lens once for all half an inch above the centre of the plate—it will probably be found better always to have the rise than never to have it.

Hand cameras have also been made for special purposes. As an example, we may refer to Marey's gun camera, by which a series of photographs of flying birds have been taken in order to determine the actual movement of the wings. The apparatus in this case is mounted on a gunstock, and the image of the object is kept upon the sensitive plate by sighting after the manner of taking aim with a gun. In such special cases some of the general principles already given may require modification.

The consideration of the use of hand cameras will be found under the general headings in other chapters, particularly in the chapters on the exposure of gelatino-bromide plates and the use of lenses.

CHAPTER V.

THE ILLUMINATION OF THE DARK ROOM.

SENSITIVE material must be handled, and it is convenient if the operator can see what he is doing when preparing it for exposure and during development, and so on. The safest light for this purpose is obviously that to which the material is least sensitive, that is, generally speaking, red, yellow, and green. Now, yellow is, optically, a mixture of red and green, in all cases except perhaps when the source of light is a non-luminous flame rendered luminous by the vapour of sodium, as when common salt is caused to colour the flame of a spirit lamp or Bunsen burner. It is better, therefore, to regard the light available for dark rooms as either a mixture of green and red (that is, yellow), or as red alone. An orange light consists of red and green, but with the green reduced in amount so that the red predominates. While an ordinary red will transmit the light down to, or nearly down to, the Fraunhofer line D, a deep red may transmit light only down to the line C. Of course, any number of intermediate effects may be produced.

It is not only desirable to get the best kind of light, but also to take care that there is not too much of it, for it is more correct to describe sensitive materials as much less sensitive to red and green than to blue and violet, rather than as insensitive to the one and sensitive to the other. Indeed, by reducing an essentially unsafe light sufficiently it may be made safe, as, for example even,

quick plates may be put into camera backs in a room brilliantly lit by moonshine without fogging them, if care is taken to keep out of the direct rays of light. A candle with no coloured medium may be used if it is hidden under some article of furniture, so that the only light getting to the plates is that reflected from the ceiling and walls of the apartment. But such methods of work are uncertain, and not advisable except as makeshifts.

Printing-out papers, carbon tissue, and platinum paper may be cut up, developed, etc., in a room lighted as usual by daylight, if yellow blinds are drawn over the windows. If yellow blinds are not available, care must be taken that the ordinary light is dull enough. With this exception it is better to discard daylight altogether, because it is so variable. If a window exposed to daylight is made safe for gelatino-bromide plates when the daylight is at its best, eighty per cent. of good useful light may be wasted on a dull day. It is impossible to have confidence in any arrangement that utilises daylight for such purposes.

Artificial lights may be either a candle, a paraffin oil lamp, a gas flame, or an incandescent electric lamp. If paraffin oil or gas is used, there should certainly be a small part of the coloured medium that is transparent, so that the condition of the flame may be ascertained, and the regulation of the flame should be from the outside of the lantern. In either case, or when using a candle, there must be ample ventilation.

An excellent form of lantern is illustrated in fig. 25. The three sides have grooves into which two pieces of glass slide, and between the glasses any coloured media may be placed. The lantern sides should be at the very least

four inches wide. A similar lantern of triangular shape should measure at least eight inches in the side.

It is desirable that the coloured sides of the lantern be changeable, if it is to be used for general purposes. For the manipulation of bromide paper and lantern slides a very much brighter and more pleasant light is allowable than for ordinary plates, while isochromatic and other specially colour-sensitised plates will need extra precautions. Thus those who work with this variety of materials will find it convenient to have three kinds of coloured sides to their lantern, and those who use red sensitive plates will require an additional screen.

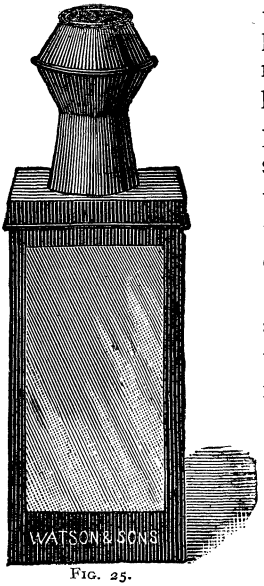


FIG. 25.

There are many ways of getting light suitable for the three kinds of work referred to above. For example, using plain colourless glasses, one or two thicknesses of yellow fabric between them will give a splendid light for bromide paper, two or three thicknesses of yellow and one of orange fabric will give a light suitable for ordinary plates, and by adding a thickness of red fabric it will serve well for isochromatic plates. As to the many possible alternatives, a few will be sufficient to indicate their character. For the first light, a yellow glass and a colourless ground-glass may be used; for the second, a sheet or two of yellow fabric may be added to these, or four

or five thicknesses of yellow fabric may be put between plain glasses; and for the last, a sheet of ruby glass may be used instead of the red fabric. Coloured papers also are useful, but generally they transmit less light than the fabrics in common use. The chief warning necessary is that ruby glass should never be used alone, because it transmits an amount of blue light that is useless for illuminating purposes, and dangerous to the plate.

A diffused light has many advantages over a direct light. If of reasonable size, the whole surface of a diffusing screen gives light, and under many circumstances the plate being developed will actually be better illuminated than when the lantern side is transparent. If a candle is used, the light will be more uniform as the position of the flame varies. The light coming from a larger area than the direct flame will cast smaller shadows, and this will cause the general illumination of the working bench to be better and more agreeable, and also the glare of the light will be diminished. Although so many lanterns are provided with nothing but transparent sides, the transparency is in almost every way a disadvantage.

A still more important matter is the disposition of the arrangement so as to get the best light with the least risk to the plate. Of course, no absorption by such media as are useful for lamps is absolute. Yellow media absorb the blue and transmit the green and red (which together form yellow), but they do not absorb *all* the blue nor transmit *all* the other colours. The medium transmits all light to a certain extent, but blue to a very much less extent than the green and red. Suppose, for example—calling the green and red together as yellow, as, indeed, they are—that of this yellow medium—

1	thickness	transmits	$\frac{1}{2}$	of the yellow and	$\frac{1}{8}$	of the blue.
2	thicknesses	will transmit	$\frac{1}{4}$	,, ,,	$\frac{1}{64}$	,, ,,
3	,,	,,	$\frac{1}{8}$	,, ,,	$\frac{1}{512}$	,, ,,
4	,,	,,	$\frac{1}{16}$	,, ,,	$\frac{1}{4096}$	,, ,,

Suppose, now, that the illumination obtained when four thicknesses are used is inconveniently small, and it is desired to get about a double intensity of light. By removing one thickness of the yellow medium the increase is obtained; indeed, a little more, because of the increase of the blue, but this, in the case supposed, is so little that, so far as the eye is concerned, it may be disregarded. But doubling the light in this way gives eight times as much of the blue or harmful light. By using two similar lamps the light is also doubled, but the blue constituent is multiplied by two only instead of eight; the factor of safety remains the same instead of being diminished to one-fourth. This, therefore, is the more advantageous plan, so far as the character of the light is concerned.

Instead of using two lamps, the light may be doubled, without altering the factor of safety, by doubling the illuminating power or brilliancy of the flame in the one lamp. But the heat generated by the combustion will soon set a practical limit to advance in this direction. Very much the same increase may be obtained, again without altering the factor of safety, by merely increasing the size of the side of the lamp, if a diffusing medium is used, because in such a case it is the surface of the coloured medium, and not the flame itself, that is the practical source of light. If, for example, the translucent side measures 6in. × 3in., and it is increased to 8in. × 4½in., the effective illumination will be very nearly doubled. In all these cases the illumination is doubled, and the danger of it to the sensitive plate is doubled (or still further increased) also.

DESIDERATA IN DARK ROOM LANTERNS.

It is possible to increase the illumination without increasing the risk of fogging the plate. Referring again to the table just given, and supposing that the existing conditions are represented by the third line, three thicknesses of medium being employed : by taking an extra thickness and increasing the brilliancy of the light within by eight times, the amount of blue, or dangerous light, remains the same, while the amount of yellow, or safe light, has been increased four times, the eight-times increase being halved by the extra thickness of medium.

It must be remembered that the cases given as examples are hypothetical, and suppose that the plate is not affected by yellow light. Even ordinary plates are affected to a certain extent by light of all colours, but this does not affect the general principles described.

Therefore, we come to the conclusion that it is advantageous in dark-room lanterns to use diffusing or translucent coloured media rather than transparent media. That the sides of the lantern, that is, the coloured media, should be large. That the light within should be brilliant. That the depth of colour, or number of sheets of the medium, through which it has to pass should be considerable.

CHAPTER VI.

THE FORMS OF LENSES. THE FIRST EPOCH.

IN the earliest days of photography, before special lenses were to be obtained, it was usual to employ telescope objectives. But these lenses were ill-suited to the purpose, though their performance in a telescope might have been unexceptional, because the image viewed through the eyepiece of a telescope is smaller than the objective itself, while the picture produced in the camera is often required to cover a comparatively large area. The rays that pass obliquely through the objective in a telescope are not utilised, but in the camera the oblique rays generally form the greater part of the image.

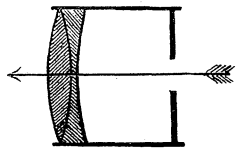


FIG. 26.

To increase the covering power, the objective was turned round, and a diaphragm was put in front of it (see fig. 26*). But with this assistance the image produced is not perfect enough over a sufficient area to satisfy modern requirements. The diaphragm obviously diminishes the light, and it also distorts the image, as will be subsequently shown. With such an arrangement,

* In all the figures the arrows indicate the direction of the light in passing from the object to the image; that is, the arrows point *into* the camera.

also, the image of a flat object is curved, like the inside of a saucer, and the chief of the light which acts photographically is brought to a focus at a considerable distance within the visible image.

In these and in other ways the existing lenses were faulty when applied to the new art. The chief corrections desired were a larger aperture for the sake of rapidity, a larger and flatter field, the chromatic aberration corrected in an especial way, namely, the most intense of the photographically active rays brought to focus at the same point as the most intense of the visible rays, and distortion reduced to a minimum, or completely eliminated.

The larger the aperture, other things being equal, the smaller the field, and so it has been found convenient to perfect lenses in two directions—some with a small aperture, and therefore slow in action, but covering a large field; and others with a large aperture, and consequently rapid, but producing a comparatively small picture. The first are classified as view lenses, the second as portrait lenses, while a lens of medium properties is called a universal lens, or a view and group lens. There is nothing scientific in these distinctions. Under certain conditions a view lens is superior to a portrait lens for taking portraits, and portrait lenses have often been used for taking views. By common consent, lenses whose apertures are about one-sixth of their focal lengths are called universal, or portrait and group lenses; if the aperture is much less than this it is a view and group, or simply a view lens; if appreciably larger it is a portrait lens.

Petzval's portrait lens. The first improvement on the telescope objective arranged as already described, was by Professor J. Petzval, the invention of whose portrait

combination initiated the first epoch in photographic optics: This lens was constructed by Voigtländer, of Vienna, under Petzval's instructions, in 1841. It is shown in fig. 27. The

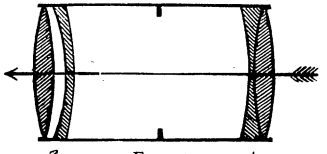


FIG. 27.

focal lengths of the posterior and anterior combinations are as three to five, and the combinations are separated a distance about equal to half the equivalent focal length of the whole lens. The chief point about this lens is the great gain in rapidity secured by shortening the focal length and using the full aperture without a diaphragm. The focal length is shortened by having two combinations instead of one, and the spherical aberration is so cured by means of the separated back combination that a diaphragm is rendered unnecessary. The multiplication of surfaces, six instead of two, causes loss of light, and also adds to the diffused or false light in the camera.* It is stated that Andrew and Thomas Ross (father and son) worked out a photographic objective with separated combinations, a device suggested by Thomas Ross to gain in flatness of field, and that this lens was constructed by them shortly before the Petzval lens was introduced.

Grubb's aplanatic lens. In 1857, T. Grubb introduced

* It was intended to give some idea at least of the angle of view of each lens, that is, the proportionl extent of field covered, but this is found to be quite impossible except by an actual test of every instrument. Thus the author has two lenses of well-advertised makes, one stated to cover 9 by 7 and the other 12 by 10. The 9 by 7 will cover 12 by 10, while the 12 by 10 lens will only cover 10 by 8; and taking the same apertures and fields, the 9 by 7 lens is far superior in definition throughout the field. On the other hand, the maker of this 12 by 10 lens does not always overstate the covering power of his lenses, for the author has another of his make which he calls 5 by 4 that will cover 8½ by 6½.

his " patent aplanatic " lenses. He gets a deeper separating curve between the components of the single lens by making the crown lens a meniscus, and putting it in front instead of behind the flint lens, as in fig. 28. By means of this deeper separating curve he claims that the " spherical

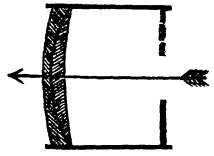


FIG. 28.

aberration is nearly corrected," and that, therefore, a diaphragm with a larger aperture may be used than was possible with the old form of view lens.

Dallmeyer's single lenses. In 1860, J. H. Dallmeyer introduced his quick-acting single lens for stereoscopic pictures, modifying the curves as shown in fig. 29, that it may work with an aperture of f/10, and yet not suffer to a practically injurious extent from spherical aberration. W. Wray, since 1886, has issued a series of single

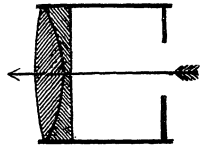


FIG. 29.

lenses suitable for all the ordinary sized plates, of which fig. 29 may be taken as a general representation. Rapidity is here also the especial feature, the series having a maximum aperture of f/10, except the larger sizes, which work at f/8. This last aperture, however, does not give what is commonly called a sharp picture, and is useful

chiefly in large direct portraits. The introduction of a certain obvious amount of spherical aberration, with its concomitant loss of sharpness in the picture, is sometimes desirable in order to gain what could be got in no other way so well. This matter is referred to subsequently.

The single landscape lens was further modified in 1864 by J. H. Dallmeyer, who uses two crown glass

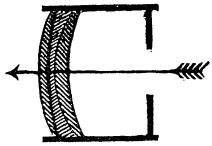


FIG. 30.

meniscus lenses of focal lengths as one to three, and cements the flint lens between them, as in fig. 30. This gives an additional surface for correction of the aberrations, so that it is possible to get a better correction of the oblique pencils, and it also has the minor advantage that the softer flint glass is protected on both sides. The lenses of this series have maximum apertures varying from f/13 to f/20.

In 1886, Dallmeyer issued another series of single landscape lenses of somewhat similar construction to those last described. They differ in including a smaller angle

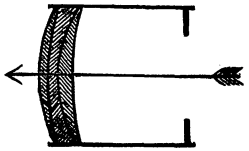


FIG. 31.

(that is, for the same covering power they have a longer focal length) and in working at about twice the rapidity,

i.e., f/11.3. The diaphragm is larger, of course, and it is placed further from the lens to give greater flatness of field (fig. 31).

The anterior convex meniscus is of extra light flint instead of crown, and the anterior surface of this lens is less curved than in the wide-angle lens.

In 1888, the same optician introduced another landscape lens, in which the back component is curved in the opposite direction from the other two, as shown in fig. 32.

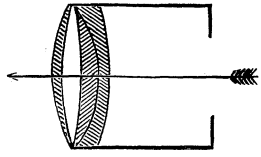


FIG. 32.

The two anterior lenses are cemented, and form a combination of very long focal length. This lens is intermediate in rapidity between the two last described, the maximum aperture recommended when good definition is desired being f/14. The especial feature of this instrument is that it is free from curvilinear distortion, and is, therefore, suitable for taking architectural subjects, for copying, etc.

Petzval's orthoscopic lens. The desire for a lens to cover a large field stimulated Professor Petzval to work out another lens particularly adapted to landscape work. In 1858, Dietzler, of Vienna, issued the new lens under Petzval's directions, for Voigtländer and Petzval had disagreed since they had worked together at the portrait lens. Petzval's fame secured an immediate and warm reception for the new instrument, and it was copied by many opticians of repute, who christened their productions

variously as orthoscopic, orthographic, caloscopic, etc. Fig. 33 shows the lens as made by the American optician, Harrison. It will be observed that Petzval has adhered to his first principle of a separated back combination,

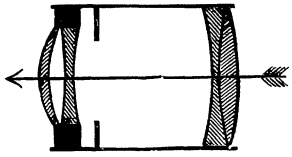


FIG. 33.

but in this case the combination is negative or diverging, and therefore makes the focal length of the whole lens longer than that of the front combination. After experience with this lens, the foremost landscape photographers of the day pronounced it not so useful to them as the single landscape lens, and found that it required a smaller stop. The orthoscopic lens gives pin-cushion distortion, but only to a slight extent as compared with the opposite, barrel-shaped distortion of single lenses with the diaphragm in the front.

Convertible lenses. In 1859, Derogy advertised a photographic objective, giving in the one instrument three portrait and three view lenses, the necessary changes being made by means of bayonet joints. This *multum in parvo* method was also adopted by Jamin, Melhuish, Darlot, the Sciopticon Company, and many others. The method of interchanging the combinations of various lenses in order to get a variety of focal lengths with the minimum of weight and cost, was possible with Ross' portable symmetricals. In many of the anastigmats and other lenses of modern introduction, this system has been extensively adopted.

Sutton's water lens. In 1859, Thomas Sutton patented his panoramic water lens (fig. 34) for use with long curved plates. It was achromatic, and from its spherical form would transmit oblique rays almost as perfectly as the central pencil. The opening in the diaphragm was elliptical, so that light falling upon it obliquely was more fully

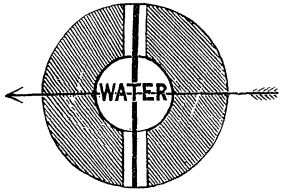


FIG. 34.

transmitted, and two projecting wings in front reduced the aperture to a circular one for axial rays. Illumination over the large angle was thus approximately equalised. Besides the obvious drawbacks to lenses containing fluids, such as leakage, there is the impossibility of preserving the temperature of the liquid uniform, and a change in temperature means a change in refractive power. In 1861, T. Ross bought the patent rights of this lens and issued copies to the public. Other fluid lenses, as they are called, have been constructed.

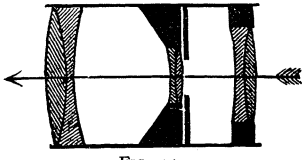


FIG. 35.

Dallmeyer's triplet. In 1860, the celebrated triplet of J. H. Dallmeyer was constructed. This was the first lens attaining to any degree of appreciation that was

specially adapted for views and copying, and gave a picture free from curvilinear distortion (see fig. 35). Its three combinations are each achromatic, and the central combination, which is diverging or negative, serves to flatten the field. By removing the central combination the focal length of the whole lens is reduced, and its aperture, originally f/15, is enlarged sufficiently for portraiture.

The need for a non-distorting view lens was by this time fairly appreciated by opticians, and within the next six years this want was provided for so well that the following five and twenty years passed without bringing any improvement of note.

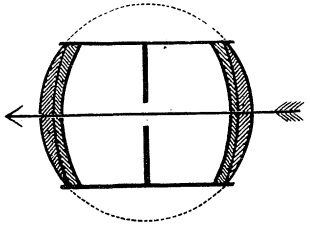


FIG. 36.

Harrison's globe lens. In the same year C. C. Harrison, of the firm of Harrison and Schnitzer, of New York, patented his "globe" lens, so called because the outer surfaces of the combinations form parts of the same sphere, as shown in fig. 36. This lens is a symmetrical doublet, and suffers much from spherical aberration and from flare.

Ross's actinic doublets. In 1864, Ross's "actinic doublets" were introduced (fig. 37), the first non-distorting doublet including a wide enough angle for average views that enjoyed any degree of popularity. This lens is not symmetrical, and it is free from flare. It was made in three series—rapid, medium, and wide angle.

Steinheil's periscopic. C. A. Steinheil, in 1865, introduced the "periscopic" lens, a non-achromatised, symmetrical doublet, as fig. 38. This lens included an angle of 90°, and was an improvement on the "globe,"

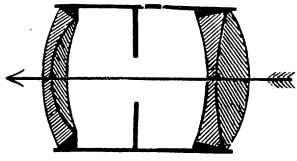


FIG. 37.

being about one-quarter the diameter for the same field, because the lenses were brought nearer together. It was, however, not free from flare, and its defining power was much complained of. Obviously, focussing cannot be done as usual with a lens not corrected for chromatic aberration, and to get over this difficulty the inventor

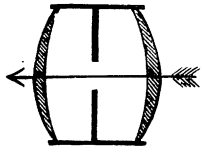


FIG. 38.

stated that no focussing was necessary, as near and distant objects were equally clear, and the plate-holder should be adjusted once for all. Deceptive statements of this sort had been made before, and so far as there is any truth in them, they apply equally to all good lenses of the same aperture and focal length. The periscopic lens was not a step forward towards perfection, except in so far as it appears to have been the starting point for notable developments by the firm of Steinheil. The periscopic is still employed, especially on cheap non-focussing hand cameras.

CHAPTER VII.

THE FORMS OF LENSES. THE SECOND EPOCH.

In 1866, we have the beginning of the second epoch in the history of photographic objectives; for just as the Petzval-Voigtländer portrait lens has been copied by every optician who caters for photographers, so has the symmetrical achromatic doublet, working at about f/8, been imitated; but with, perhaps, this difference, that each imitator deems it necessary to give a new name to his production, and so, as far as he is able, to introduce it to the world as a new instrument.

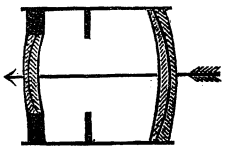


Fig. 39.

Steinheil's "aplanats" and Dallmeyer's "rapid rectilinears" were the first lenses of this character introduced. It appears that both opticians worked simultaneously in the invention of these lenses, and that Steinheil was the first to issue them to the public. Dallmeyer's lens was preceded a few months by his wide-angle rectilinear doublet, working at f/13 to f/17, which has its posterior combination of smaller size than the front combination, that its reflecting power may be diminished, and any tendency to flare reduced (see fig. 39). The nature of the rapid lens is sufficiently indicated by fig. 40:

Steinheil also introduced large angle aplanats, in which the combinations are of smaller diameter, thicker, and very much nearer together.

The rapid rectilinear of Dallmeyer soon began to replace his triplet, but it was not till 1874 that Ross introduced his portable and rapid symmetricals, and left his actinic doublets as instruments of the past.

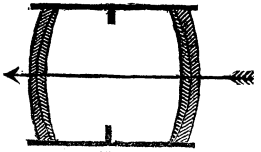


FIG. 40.

The apertures chosen by Steinheil and Dallmeyer, f/7 and f/8 respectively, have proved to be the most useful for the general work that such lenses are constructed for; but in January, 1870, Mr. Dallmeyer exhibited a lens of similar construction, and of aperture f/4, at the London Photographic Society, to show that by reducing the angle of view included, this form of lens could be made as rapid as the ordinary portrait lens. Mr. Dallmeyer considered that this pattern was not the best for general portraiture. Voigtländer, however, has since then introduced two series of rapid symmetrical doublets, his "euryscopes," working at f/6, in 1877, and his "portrait euryscopes," with an aperture of f/4, in 1886. These more rapid lenses have met with considerable favour, and are now made by many opticians.

Dallmeyer's portrait lens. At the same time that J. H. Dallmeyer obtained a patent for his wide-angle rectilinear lens, 1866, he got protection for a modification of the Petzval portrait lens, in which the flint component

of the separated back combination was put behind instead of in front of the crown, and the latter was a meniscus instead of a double convex lens. The new form is shown in fig. 41. But the chief point was that the back flint might be moved backwards to a certain and definite extent, thus introducing, when required, a definite and exactly reproducible amount of spherical aberration. This he called "diffusion of focus," a very good and perfectly descriptive term, although it has been much cavilled at.

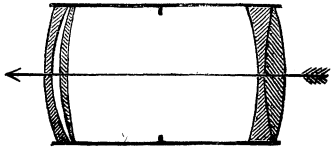


FIG. 41.

Diffusion of focus. The convenience under discussion was specifically asked for by some of the most eminent photographers; it was hailed by them when they got it as a new power, and it is still employed by those who know what they want, and find this a means of getting it. Before Dallmeyer introduced this form of lens, inferior instruments were sometimes much valued, because they possessed the desired property; but in such cases the effect was due to carelessness, it was uncertain in amount, and could not be regulated. Dallmeyer gave the possibility of getting a certain and regulatable amount that might be reproduced exactly at any time.

The advantages of the introduction of spherical aberration have been denied, but the fact that many photographers of high repute appreciate it is a complete practical answer to this objection. Its occasional use-

fulness was pointed out by Petzval in 1859, that is, by a mathematician who was neither optician nor photographer. Indeed, he gave directions for getting a certain amount of spherical aberration with his orthoscopic lens.

The effect of the introduction of positive spherical aberration is illustrated in an exaggerated manner for the sake of clearness by *b* (fig. 42), *a* showing a lens of the same focal length, and free from aberration. The fully

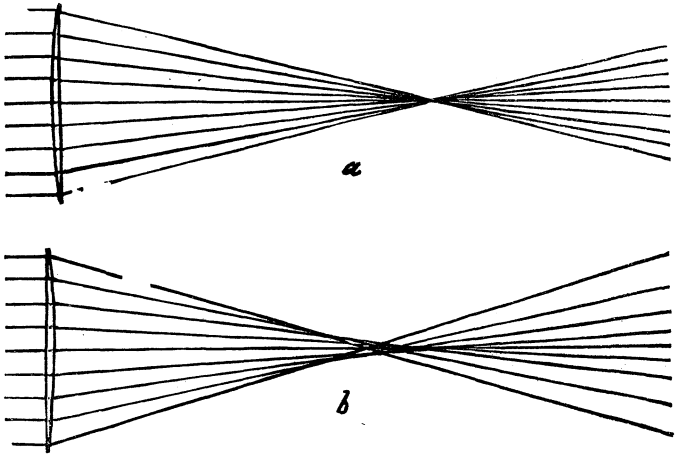


FIG. 42.

corrected lens gives theoretically a sharp focal point, and represents points of objects out of focus by evenly illuminated discs. With lenses of large aperture, that is, portrait lenses, this contrast in defining power for objects in different planes is occasionally very objectionable, and some photographers are in the habit of putting the whole image out of focus, therefore increasing the lack of definition in every part, to get rid of the small area of painful sharp-

ness in the picture. But it will be observed that when spherical aberration is present the sharp focal point is got rid of, and that the amount of aberration determines the degree of softness of outline in the image. Under these circumstances, however, the points of objects out of focus are no longer represented by evenly illuminated discs, but by discs which have a concentration of light at their outer part for objects nearer the lens than the plane focussed for, and discs with a central concentration of light for objects further away than the plane focussed for. In the first case the aberration narrows the pencil of light, giving depth of definition somewhat after the manner of a diaphragm reducing the lens aperture, but the outward concentration of light is a disadvantage. In the other case, however, the central concentration confers a persistence of the image as it is thrown out of focus that is sometimes remarkably great, the halo round the image increasing in extent as the object is moved more and more out of focus until the central concentration of the light dies away. It is impossible to demonstrate geometrically how much gain in depth of definition may thus be realised, because it is impossible to state where the image leaves off and the halo begins on the one side, or how much the outward concentration of light affects definition on the other. It seems very probable that the depth of definition in the presence of spherical aberration will vary according to the character of the object photographed.

Spherical aberration is present in all practical forms of single lenses and in many doublets, and it is reduced to a negligible amount (that is, negligible for ordinary work) by the use of a diaphragm. The diaphragm reduces

the aperture, and so lengthens the necessary exposure, but rapidity can be gained at the expense of sharpness of definition by enlarging the diaphragm, at the same time increasing the spherical aberration. Lenses of the type illustrated in fig. 29 may have their apertures enlarged to f/8, but with this aperture the definition is nowhere sharp, though sharp enough for large portraits.

Other portrait lenses than those already mentioned have been introduced from time to time with more or less success.

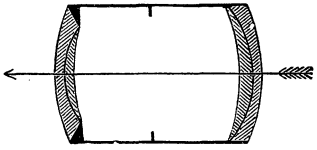


FIG. 43.

In 1874, Steinheil described a portrait lens that had both its combinations cemented, and the inner surfaces of both of nearly equal curvature, as shown in fig. 43. In 1878, Voigtländer made lenses in which the ordinary back combination of the Petzval lens was replaced by a cemented combination so constructed that both com-

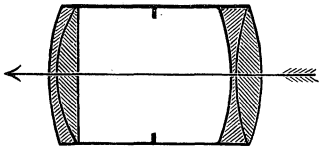


FIG. 44.

binations had outside surfaces of equal curvature. Each combination was of the same focal length, which was one and a half times the focal length of the whole lens. The general form of the instrument is given in fig. 44.

The maker claimed for it that it avoided distortion of the image, and that it was more rapid in action and gave more depth of definition than the original Petzval. However, in spite of this improbable combination of improvements, this construction was soon abandoned.

Steinheil's antiplanets. The greatest departure from the rules ordinarily observed by opticians in devising photographic lenses until the introduction of the modern

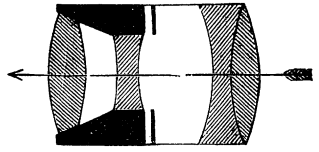


FIG. 45.

anastigmats, was made by H. A. Steinheil in his "antiplanet" lenses for portraiture and views which were introduced in 1881. These are shown in figs. 45 and 46 In both cases the anterior combination has a shorter focal length than the whole lens, and the posterior combination is diverging. The back and front combinations both

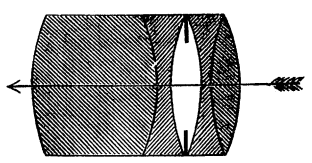


FIG. 46.

suffer greatly from spherical and chromatic aberrations, but to an equal extent in an opposite sense, so that they form a properly corrected whole. It is claimed by the inventor that by means of this principle a better definition is secured at the edges of the field. The maximum aperture of the portrait lens was f/3, and of the view lens f/6. It

is claimed for the antiplanets that they were the first lenses containing an element for the correction of astigmatism. In 1894, the thick anterior combination was replaced by a triple cemented combination, a crown positive meniscus between two flint glass lenses, the anterior double concave and the posterior double convex.

CHAPTER VIII.

THE FORMS OF LENSES. THE THIRD EPOCH. THE ANASTIGMATS.

ONE of the chief desiderata in a photographic objective is the power of defining equally well all over a flat field. The lenses referred to in the previous chapters are characterised by a more or less rounded field, and if it were flattened it would be at the expense of defining power towards the edges of it because of astigmatism.

Astigmatism. This fault may be pictured to one's self by imagining a lens held with its axis horizontally, as usually when fixed on a camera, and a bundle of rays passing through it in a sloping upwards direction. If then a thin vertical section of the bundle of rays were isolated, they would be found to come to a focus nearer the lens than the focus of a thin horizontal section of the rays. The practical effect of this is that the image of a point or dot is lengthened into a line which is vertical or horizontal according to the position of the focussing screen, the figure in the intermediate position being somewhat diamond shaped. Another practical effect of astigmatism is that the image of lines crossing each other cannot be obtained simultaneously sharp. Astigmatism, therefore, makes it impossible to get good definition far away from the centre of the plate unless a very small stop is employed.

It is the curing of astigmatism, or the reduction of it to an almost negligible quantity, that characterises

what is conveniently regarded as marking the third epoch in the development of photographic objectives. In 1881, Professor Ernst Abbe and Dr. O. Schott began a series of costly experiments, in which they were assisted by the German Government, in order to reduce the limitations hitherto imposed upon opticians by the small variety of optical glasses at their disposal. The now celebrated optical glass works at Jena, conducted by Schott and Gen., are the practical outcome of these investigations. By the employment of other than the usual constituents, this firm is able to offer more than a hundred varieties of glass, many with new and specially valuable properties, and it is by the judicious employment of a selection of these that recent improvements have been effected.

In all previous achromatic combinations the positive element has a lower index of refraction than the negative. By the use of the new barium silicate glasses it has become possible to construct an achromatic lens in which the positive element has a higher index of refraction than the negative, and such a combination gives astigmatism of the opposite character to that of the other. By combining two such achromatic combinations the astigmatism of the one is neutralised by that of the other. There are, of course, very many ways of taking advantage of this principle.

Zeiss's anastigmats. Carl Zeiss, of Jena, was the first to put upon the market lenses embodying this improvement, constructing them according to the calculations of Dr. Rudolph. Towards the end of 1890 he introduced the first series of his anastigmats, the most rapid of which is shown in fig. 47, and had a maximum aperture of f/7.2. Two slower series, made especially for copying, had

apertures of f/12.5 and f/18 respectively, and were unsymmetrical doublets, each combination consisting of two lenses cemented together.

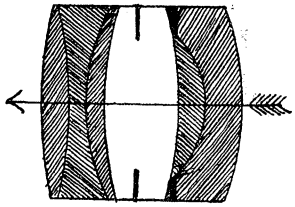


FIG. 47.

Of the different kinds of anastigmats introduced about 1890 and 1891 by the firm of Carl Zeiss from the calculations of Dr. Paul Rudolph, at least three are not now made, while several others are made to special order only. These and other lenses, although they were made and sold commercially, must be regarded now rather as experiments in lens construction under the new conditions rendered possible by the use of the new Jena glasses.

At the same time Zeiss introduced an apochromatic triplet of an aperture equal to f/6.3. In this the two outer lenses are simple condensing crown glass meniscus lenses, and between them is a triple cemented combination which corrects the aberrations of the others. The middle lens of the central combination is a borate flint. The lens is symmetrical. The term "apochromatic" signifies a better correction for colour than "achromatic," the improvement consisting in eliminating the secondary spectrum. Three parts of the spectrum instead of two are made to coincide. Such lenses are especially valuable for working with colour sensitised plates and yellow or red screens, without being less applicable to work done

under ordinary conditions. Several other series of anastigmats have since been constructed. The chief practical characteristic of these lenses is good definition over a larger field than usual, and the fact that lenses of large aperture when stopped down become excellent wide-angle lenses.

Ross's concentric lens. The "concentric" lens was first introduced to the public at the Photographic Society in May, 1892, by Ross and Co., though its construction had been worked out by Dr. Schroeder about three years earlier. The uncemented surfaces of each combination are concentric, and the cemented surfaces are flat (see fig. 48). With an aperture of about f/22 this lens gives

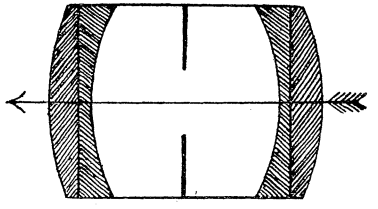


FIG. 48.

equally sharp definition over a large and quite flat field, and in this it surpasses any lens previously made. But if the aperture is enlarged, spherical aberration interferes with the definition, and the want of correction of this aberration is a weak point. But as there is no need to use a small aperture to gain defining power at the edges of the plate, this lens is often in practice more rapid than many that have a far larger maximum aperture. The distance apart of the combinations is very great for a wide-angle lens, and this tends to reduce the illumination towards the edges of the field.*

* In some drawings of this lens, it is represented with its combinations placed much nearer together than here shown. The figure given is drawn from an actual lens, except only the line showing the cemented inner surfaces in each combination.

Goerz double anastigmat. The first anastigmat that established itself in popular favour, and this by its marked superiority over any lens that preceded it, was the "double anastigmat," made by the firm of C. P. Goerz from calculations by Dr. E. von Hoegh. It is symmetrical, each combination is anastigmatic in itself, and consists of a flint between two crown glass lenses which differ as already explained, and with its full aperture of f/6.8 it gives sensibly equal definition over a flat field of about 70° (see fig. 49).

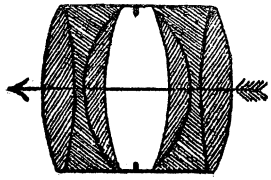


FIG. 49

It is also made in a wide-angle series with an aperture of f/11. This lens was first shown in this country in June, 1893, at the Photographic Society.

The universally acknowledged success of this lens, coupled with the experiments above referred to, appears to have settled, for the time at least, the general superiority of an anastigmat of the symmetrical doublet type as compared with the unsymmetrical doublets that Messrs. Zeiss had hitherto introduced. Other symmetrical (or sometimes nearly symmetrical) anastigmats were introduced by other makers, and for a short time there was much discussion and legal proceedings with regard to patent rights and priority. Most of the lenses immediately following are now made on the "satz" or convertible or interchangeable system, so that the single combinations may be used as "single" lenses, and may

be screwed into the same mount in similar or dissimilar pairs forming doublets, three different single combinations giving three different doublets according to how they are paired, or a total of six different focal lengths.

Voigtlander's collinears. The "collinears" were introduced by Messrs. Voigtländer and Son in 1895 (or quite at the end of 1894). The first series issued had an aperture of f/6.3, and its general form is indicated in fig. 50. In this lens the middle element of each combination has

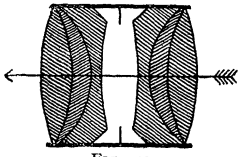


FIG. 50.

the lowest refractivity, and in this it differs from the Goerz double anastigmat, in which the middle element has a refractive power intermediate between that of the two exterior elements. The collinear is now made in three series with apertures from f/5.4 in the smaller members of the most rapid series to f/12.5 in a wide-angle series. Apochromatic collinears, f/9, are also issued.

Steinheil's orthostigmats. The "orthostigmats" of Steinheil, introduced in 1895, were similar to the Goerz double anastigmat, and were objected to by Goerz as infringing his patent. The orthostigmat "type 2" is represented by fig. 50, and was introduced in 1897. It has an aperture of f/6.3.

Wray's platystigmats. The "platystigmats" of W. Wray were issued, the 5in. lens in 1895, and a series of seven lenses in 1896. In 1897 the lens was improved. Fig. 50 represents the general construction; but, unlike the

collinears and orthostigmats, this lens is not symmetrical. The back combination is useful as a single lens, but it is not advised to use the front combination alone.

Bausch and Lomb's plastigmats. The "plastigmats," introduced in 1902 by Messrs. Bausch and Lomb, are symmetrical doublets of aperture f/6.8, each combination being a cemented quadruple.

Watson's holostigmats. The "holostigmats," introduced in 1900 by Messrs. Watson and Sons, were computed by Mr. A. E. Conrady. This lens is a doublet, each combination being a cemented triple, and consisting of a crossed lens with a concave meniscus on its outer side and a double concave lens on its inner side. Its aperture is f/6.1 to f/6.5, according to whether the doublet is symmetrical or not.

Zeiss's protar lenses. The "protar" lenses of Messrs. Zeiss include several series, f/18, f/9, f/8, and f/6.3. The word "protar" was only recently (1901) applied to these lenses, which were introduced in 1890, 1891, 1893, and 1895 respectively. The first three are the series of unsymmetrical anastigmats that have survived out of the first nine types of anastigmats introduced by Messrs. Zeiss. The last is the celebrated series of convertible anastigmats, computed by Dr. Paul Rudolph, introduced

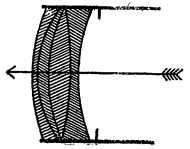


FIG. 51.

as single lenses, f/12.5, as Series VII.; as symmetrical doublets, f/6.3, as Series VIIa.; and subsequently in the

convertible or interchangeable form. Each combination is completely corrected in itself, being a quadruple cemented lens, as shown in fig. 51. The combination may be regarded as two pairs of lenses, each consisting of a collecting and dispersing lens. The dispersing (or negative) lens of the one pair has a higher refractivity, and that of the other pair a lower refractivity, than the collecting (or positive) lens with which it is immediately in contact.

The increase in the number of elements in a cemented combination intended for use ether alone or mounted as doublets has been carried still further. C. P. Goerz, for example, issued in 1899 an extra rapid series of double anastigmats, f/5.5, each combination consisting of five lenses cemented together. One combination alone forms an excellent lens, f/11, and the series is arranged on the convertible principle.

More rapid anastigmats. Although such constructions as those above referred to can be applied in the making of objectives of larger apertures than about f/6 or f/7, yet, as in the case of the ordinary rapid doublets that preceded the anastigmats, such an increase of aperture is not on the whole advantageous. In order, therefore, to meet the demand for lenses of the portrait type, and secure with apertures of f/4, more or less, the advantages of a flat field and comparative freedom from astigmatism, there have recently been many lenses introduced with air spaces in the combinations, the adjacent surfaces of the lenses being separated and generally of dissimilar curvature, as in the back combinations of the lenses designed by Petzval.

Every surface of glass in contact with another medium of different refractivity causes a loss of light by reflection ;

and some, if not the most, of the light so reflected in photographed objectives is generally diffused over the surface of the plate, producing a certain, though it should be a negligible, amount of fog. The various kinds of glass differ so little in their refractivity that when cemented together this loss of focussed light and gain in diffused light is not appreciable, but the difference between glass and air is very notable. The ordinary doublet with cemented combinations gives four glass-air surfaces, the Petzval portrait lens gives six, the lenses immediately following here give eight, and even this number may be increased in certain telephotographic arrangements. Less objection is taken now to the increase in glass-air surfaces than was the case up to a few years ago. The practical point in the use of such lenses is that they be kept carefully clean, for while the loss of light caused in a clean lens may be justifiable for the sake of a considerable advantage, the loss caused by a dirty lens is likely to prove disastrous.

Just as the types of construction generally regarded as most suitable for moderate apertures may in some cases be adopted for objectives with large apertures, so the types primarily devised for large apertures may be and sometimes are extended to objectives of moderate and even small apertures.

Zeiss's planars. The "planars" of Messrs. Zeiss were introduced in 1897. Their apertures vary from f/3.6 in the smallest to f/6 in the largest of the series, which latter has a focal length of thirty-three inches. The general form of the lens is shown in fig. 52. The two lenses cemented together in each combination have conjointly a negative focal length. It is specially adapted

for copying and enlarging, and the smaller members of the series, from three quarters of an inch focal length and upwards, are particularly suitable for photomicrographic

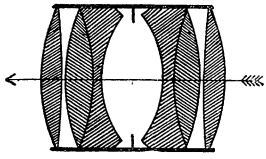


FIG. 52.

work of low power. It is an excellent portrait lens. One of the combinations cannot be used alone as a view lens except with a very small stop.

Zeiss's unars. The "unars" were introduced by Messrs. Zeiss in 1900. They have four separated lenses, as shown in fig. 53, and are not symmetrical. The apertures, varying from f/4.5 to f/5.6, are rather smaller than the

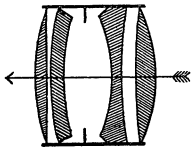


FIG. 53.

apertures of the planars for the same focal lengths, and the lenses are cheaper. The focal lengths of the series range from four and a half inches to eighteen inches. The combinations are not corrected for use alone.

Zeiss's tessars. The "tessars," introduced in 1902 by Messrs. Zeiss, are also not symmetrical. The front combination consists of two lenses separated, and the back is a cemented double.

Goerz's extra-rapid double anastigmat. An extra-rapid double anastigmat, Series 1B., was described by

Goerz and Von Hoegh in 1898, and introduced in 1902. It is a symmetrical lens, with a maximum aperture of f/4·5 to f/5.5, and each combination consists of an exterior double convex lens separated by an air space from a double concave interior lens.

Ross's homocentric lenses. The "homocentric" lenses of Messrs. Ross, introduced in 1903, are symmetrical doublets, each combination consisting of two single meniscus lenses with an air space between them. They are made in series with maximum apertures of f/5.6, f/6.3, and f/8.

Dallmeyer's stigmatic lenses. The "stigmatic" lenses of Messrs. J. H. Dallmeyer are of a different type from those referred to above. They were devised by Mr. H. L. Aldis, and patented in 1895. The f/4 lens was issued in 1896, the f/6 lens in 1897, and the f/7.5 series in 1898. The correction for spherical aberration is made, without prejudicing the correction for astigmatism, by means of a meniscus air space instead of by the usual method of employing a converging element of lower

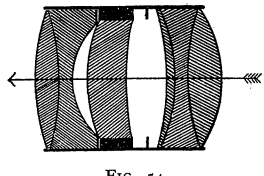


FIG. 54.

refractivity than the diverging element with which it is associated. The portrait lens, f/4, fig. 54, consists of a triple cemented front combination, the glasses of which have all a high refracting power, and a back combination which has a negative focal length. The posterior element of

the back combination can be screwed back to introduce spherical aberration as in the previous portrait lens of Dallmeyer. The f/6 lens, fig. 55, has both of its combinations converging, and either may be used as a single lens, one having a focal length of about twice and the

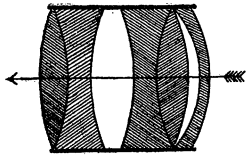


FIG. 55.

other one and a half times that of the entire lens. The combinations cannot be used alone to the same comparative advantage as if the lens were symmetrical. The f/6 stigmatic as first issued had the air space in the back combination, but in 1899 the construction was varied, the triple combination with the air space being put in front, with the advantage that it is only necessary to remove one combination to use the other, without having to shift the front combination to the back for use alone, as in the original model. The f/7.5 stigmatic is a cheaper lens and has a double cemented back combination, with a double instead of a triple front combination with the meniscus air space. It includes a smaller angle of view than the f/6 stigmatic, and is comparable in this with the "rapid rectilinears."

Cooke lenses. The "Cooke" lenses are named after the well known opticians, Messrs. Cooke and Sons, of York, with whom Mr. H. Dennis Taylor, who devised them, is associated. They are made by Messrs. Taylor, Taylor, and Hobson, of Leicester. Mr. Dennis Taylor's patents are dated 1893 and 1895. The "Cooke" lens

is a triplet, an example of which is shown in fig. 56. The two exterior lenses are simple positive lenses of low dispersive but high refractive power, while the central lens is generally also a simple lens, a negative flint of low

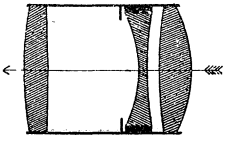


FIG. 56.

refractive index. This negative lens has to correct the chromatic aberration of the other two, to correct their spherical aberration, and finally to flatten the image and eliminate astigmatism. To effect these last two corrections its focal length has to be equal to, or very nearly equal to, the focal length of the two exterior lenses, and it is in its practical application of this principle that the "Cooke" triplets differ radically from the triplets that preceded them.

The first of these lenses, f/6.5, focal lengths of 5in. and 6in., were issued in 1895; in 1896 the series was much extended, and in 1898 a portrait series, f/4.5, was issued. In this last the negative lens is more nearly central, and the mount is so arranged that to get the finest definition the back lens must be unscrewed three turns, and by screwing it up from this position positive spherical aberration is introduced evenly over the plate, a result obtained in the Dallmeyer portrait lens by unscrewing the back element.

The "Cooke extension lens," issued in 1899, provides an alternative back lens, which when screwed in instead of the ordinary one gives about a fifty per cent. increase

to the focal length of the objective. The normal back lens, being of a boro-silicate or dense barium crown, may be replaced by a light or a heavy flint glass lens, which, keeping the colour correction constant, will be of greater focal length, the variation in focal length being substantially proportional to the dispersive power.

The "Cooke focussing lens," introduced in 1901, depends on the fact that a very small increase in the separation between the front lens and the negative shortens the focal length of the whole considerably. Less than half a turn may suffice to bring an object only three yards distant into focus. Therefore, the margin of the cell that carries the front lens is graduated by a scale of distances suitable specially for hand camera work.

The "triple anastigmat," issued by Messrs. Voigtländer and Son in 1898, of apertures f/6.8 and f/7.7, and a series issued in 1899, with an aperture of f/4.5, and this last, or a modification of it, called in 1902 the "heliar" lens, are analogous in construction and apparently in principle to the Cooke lenses.

FIG. 57.

The Aldis lens. The "Aldis" lens, issued in 1902 by Messrs. Aldis Bros., is shown in fig. 57. The front combination has a slight negative focal power. The aperture is f/6, and the distance from the lens to its focal plane (so-called "back focus") is notably shorter than the equivalent focal length. This firm, in 1903, issued another

series with an aperture of f/7·7, of the same general type. In the slower series the posterior single lens is much thinner, and the front component of the anterior combination is thicker, than shown in the illustration.

Very wide-angle lenses. Lenses including an exceedingly wide angle of view are occasionally useful. Emil Busch, of Rathenow, in 1865, made a lens including an angle of about 105°. It was an achromatic symmetrical doublet, reminding one in general appearance of the "globe" lens, but covering a very much wider angle. With an aperture of f/32, good definition was obtained over a very flat field. This lens is practically obsolete, but lately (1901) Messrs. Goerz have introduced their "hypergon double anastigmat," which has an aperture of f/22, and includes an angle of 135°. The whole-plate lens has a focal length of less than two and a half inches. It is a doublet of two single lenses of very deep curves. As with such a very wide angle, the margins of the plate are very poorly illuminated, it is necessary to reduce the illumination of the centre of the field somewhat. This is accomplished by an opaque star that is suspended in front of the lens during a part of the exposure.

CHAPTER IX.

TELEPHOTOGRAPHIC LENSES.

THE direct production of enlarged images in the camera without the necessity for an equivalent distance between the lens and the sensitive plate has occupied much attention during the last ten or twelve years. The method is to introduce a negative or dispersing lens between the objective or image-forming lens and the plate, and the effect of it is to increase the focal length as shown in fig. 58, so necessitating a movement of the screen from the lens, and

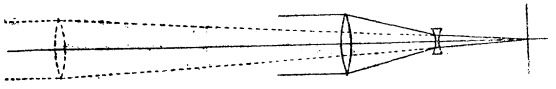


FIG. 58.

to give a magnification of the image that is far greater than proportional to the increased focal length. The size of the image is the same as would be obtained by a single lens in the position shown by the dotted lines. Thus it is possible to get large images with cameras of ordinary extension, and to vary the size of the image by merely altering the positions of the focussing screen and the negative lens, for the nearer this is brought to the objective the greater is the magnification.

The pioneer in the construction of instruments of this class is Mr. T. R. Dallmeyer. He made and showed some preliminary experimental lenses towards the end of 1891, and in March, 1892, he introduced a high power telephotographic lens consisting of a portrait combination with a

symmetrical doublet of negative focal length added to it as shown in fig. 59. This arrangement has the advantage that the negative lens may be corrected for a near object, and then the negative spherical aberration introduced when it is used for a distant object can be neutralised by unscrewing a little the back flint of the portrait lens.

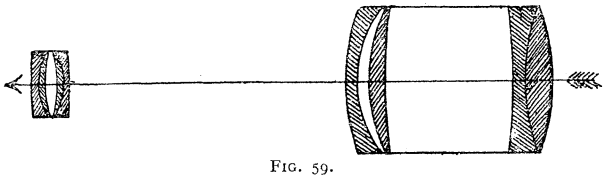


FIG. 59.

If a moderate amplification only is required, then a weaker negative lens is employed in conjunction with a rapid doublet, such as an f/6 stigmatic or any similar lens, preferably with an aperture of not less than f/8. The negative lens being of greater focal length, it has the advantage that it may be made of larger diameter, and that there is no need for the correction for spherical aberration because the error introduced when photographing objects at different distances from that it is corrected for is practically negligible. The negative lens is preferably of about half the focal length of the objective that it is designed to work with.

The " Adon " lens of Messrs. Dallmeyer was described in 1900, and issued in 1902. It is made in only one size, and is intended to be placed in front of an objective of five or six inches focal length, as in a hand camera. When so placed with the camera objective focussed for a distant object, the " adon " gives an image enlarged about two diameters without reducing the effective aperture of the objective. It doubles the equivalent focal length, so that

an aperture marked f/8 becomes f/11, f/11 becomes f/16, and so on.

The "adon" consists of a positive lens of comparatively large diameter and short focal length, with a negative system behind it, the two being separated by a distance equal to the difference in their focal lengths. Parallel rays incident upon the positive lens emerge parallel from the negative lens, therefore the magnified image falls upon the same plane as the image produced by the camera lens alone, when this is focussed for infinity. It is obvious that the "adon" forms a complete telephotographic lens in itself, and it may be so used, the separation of its components being adjustable for the purpose.

Many other opticians make telephotographic lenses, the negative combinations generally being single cemented combinations, Dallmeyer's being, as shown above, symmetrical doublets to avoid distortion.

Messrs. Zeiss provide a series of telephotographic positive lenses of aperture f/3, a quadruple cemented combination, and a series of negative lenses of aperture f/2, a triple cemented combination. Arrangements are provided for various combinations of these, or the negatives may be used with ordinary doublets. The f/3 positive lens gives a great advantage in rapidity.

CHAPTER X.

THE FOCAL LENGTH, APERTURE, AND NODAL POINTS OF LENSES.

To use a photographic objective to advantage requires skill, and, speaking generally, the better or the larger the lens is the more need is there for skill and care. In ignorant and untrained hands, an inferior lens will often give a better result than a more perfect objective, and the amount of carelessness that will do no appreciable harm when using a slow landscape lens and a small plate, would be fatal to the results on a larger plate or with a rapid lens. It is especially for this reason that beginners are advised to practise at first with small cameras and comparatively slow lenses.

To use a lens intelligently it is necessary to know its focal length (or focal distance), its aperture, and the position of its nodal points. There are many other matters that it may be desirable to know in certain cases, but those mentioned are of prime importance.

The focal length of a lens, and this unless otherwise qualified always refers to the focal length for parallel rays, can be determined roughly, but near enough in most cases to identify the lens from the maker's catalogue, by focussing a distant object and measuring the distance between the ground-glass and the back surface of the lens if the lens is a single combination, or between the ground-glass and the diaphragm if it is a doublet. This method, however

carefully performed, cannot give an exact result except in very rare cases, as will be seen below.

By taking advantage of the fact that the focal lengths of non-distorting lenses are proportional to the linear dimensions of the images that they give, it is easy to formulate a method that is practically exact and convenient, especially when several lenses have to be tested. For this purpose it is required to have a lens of known focal length, or a thin spectacle lens will serve as the standard, because, being thin, it is easy to measure the distance between it and the screen upon which it produces a sharp image of distant objects. The spectacle lens used must not be a meniscus, and to be most exact it should be a plano-convex, with the convex side towards the screen, when the distance between the convex side of the lens and the focussing screen is the focal length of the lens. To use such a standard lens, the distance between the sharply-focussed images of two objects that are far enough away to be in focus at the same time that the horizon is sharply represented is determined, and the distance between the images of the same objects is measured, using each of the lenses to be tested in its turn. The proportions that exist between these distances are also the proportions that exist between the focal lengths of the lenses.

An exact, though practically more awkward, method is to mark the positions of two sharply focussed images on the ground-glass, and then to substitute a piece of tinfoil or card with a small hole in it for the lens (or perhaps the smallest diaphragm of the lens itself will answer if the combinations are removed), and to get the two images produced by the simple hole to correspond exactly with those produced by the lens. The distance between

the small hole and the ground-glass is the focal length sought.

Though these methods are not strictly exact when applied to lenses that give curvilinear distortion, they may for photographic purposes be assumed to be exact, because it is the size of the image rather than the focal length that is important to the photographer.

One great difficulty in carrying out such methods, is that the image produced by the spectacle lens or by the pinhole is not well defined, and it is therefore impossible to measure it with exactness.

If any convenient object, such as a white card or a rule, is sharply focussed under such conditions that its image is exactly the same size as the original, the distance between the ground-glass and the printed sheet will be about four times the focal length of the lens employed. This method gives a result near enough for most practical purposes, but the figure so found is rarely more than an approximation to the real focal length. A theoretically correct figure is obtained by focussing as above, and then noting the distance that the ground-glass has to be moved forward to get a sharp image of the horizon, or some object so far away as to be equivalent to it. The practical difficulty in carrying out either of these methods is that it is impossible to make two adjustments (the size of the image and the definition of it) at the same time with the same accuracy as either may be made alone.

Of all methods, one that is the most convenient when no special apparatus, other than a camera, is available, that is theoretically exact (assuming that the lens does not distort), and that gives practical results that depend for their accuracy only on the skill of the experimentalist,

is a modification of the last mentioned method. Instead, however, of getting the image and object of equal size, they are made approximately equal, devoting the entire attention to the focussing, which should be as critically exact as possible. The full lines in fig. 60 represent the object and image of equal size, A is the principal focal

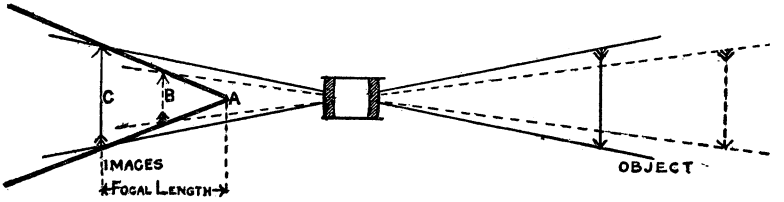


FIG. 60.

point or the position of the sharp image of a distant object, and the distance A to C is the focal length. If the object were removed to an infinite distance, its image would be infinitely small, as the image of a star is (except for the imperfections of the lens), and it would be at A. At such an intermediate position as indicated by the broken lines, the image is formed at B. And at whatever distance the object may be placed, so long as it is kept on the axis of the system, its image will fall between the two thick lines extending from the point A, and the distance apart of these lines will give the length of the image. Therefore the distance of the image from A will bear the same proportion to the distance A C, which is the focal length, as the linear measurement of the image bears to the linear measurement of the image at C, or, what is the same thing, to the linear measurement of the object, because when the image falls at C it is the same size as the object.

To carry out this method practically—(1) Make two small crosses on the focussing screen with a hard, sharp pencil, vertically central, one about an inch or an inch and a half from each end of the screen; (2) focus as exactly as possible a distant object, so that the focussing screen may be in the same plane as if a celestial object were focussed; (3) mark the position of that part of the camera that is moved for focussing on the baseboard in some convenient manner; (4) focus critically a divided scale or rule (the paper scales that engineers use are the most convenient), so that the image falls over the two points marked on the screen, making the image as nearly as may be the same size as the object; (5) count on the ground-glass the number of divisions of the scale included between the two points, this gives the length of the object, s; (6) turn back the focussing screen, lay the scale used on it and measure the actual distance apart of the two points marked on it, this gives the length of the image, i; (7) measure the distance between the present position of that part of the camera that is moved for focussing and its previous position that was marked on the baseboard, this gives the distance, d. This distance bears the same proportion to the focal length that the linear measurement of the image bears to that of the object. f being the focal length sought—

$$f = \frac{s\ d}{i}$$

The more nearly the image of the scale approaches the size of the original the more exact is the determination of focal length likely to be. By working in this way the difficulties of having to measure the image on the ground-glass by applying a scale or compasses to the outer surface of the glass, and of getting in exact focus an

image of an exact and predetermined size, are entirely obviated.

When two lenses are used together, as in doublets, the focal length of the combination can be calculated from the focal lengths of its constituents and the distance between their optical centres. The actual distance between the lenses is of no use in the calculation, and it becomes important to note this, because sometimes the "separation" of the lenses is spoken of in this connection without further explanation. In a certain wide-angle doublet the author finds the distance between the lenses to be a quarter of an inch, while the optical centres of the components are more than two and a half inches apart. To calculate with the lesser figure would give a worse than useless result. The formula for this calculation is—

$$f = \frac{a \times b}{a + b - s}$$

in which a and b are the focal lengths of the two lenses respectively, s the distance between their optical centres, and f the focal length of the combination. Putting the formula into words, the product of multiplying the focal lengths of the two lenses together is to be divided by the sum of the focal lengths added together minus the distance between their optical centres.

It follows from the above that the focal length of one of the lenses can be calculated if the focal length of the other, the focal length of the whole objective, and the separation are known. Using the symbols in the same senses as above—

$$a = \frac{f(b - s)}{b - f}$$

But perhaps the problem in this connection that most often presents itself in practical photography is to

find the focal length of one constituent of a symmetrical doublet. It is a common statement by makers that either lens of such a combination may be used alone as a single view lens, its focal length being "about double that of the complete lens." This is the roughest approximation, often an inch or more in error in the smallest lenses. The following figures give in the first column the equivalent focal lengths in inches of the complete lens, and in the second column that of the back constituents. The first and third are wide-angle lenses, the second and fourth rapid lenses.

4.4	.....	7.8
5.8	.....	10.4
7.8	.....	14.2
12.9	.....	22.7

It is a nearer approximation to say that such lenses as are generally used for small plates have the focal length of one constituent equal to an inch or an inch and a half less than twice the focal length of the entire lens. But if the focal length of the lens, and the distance between the optical centres of its components are known, and assuming that the components are of equal focal length, as they ought to be, the focal length of one component can be calculated from the following formula, in which a is the focal length sought, f the focal length of the entire lens, and s the separation of the constituents—

$$a = f + \sqrt{f(f - s)}$$

Or, in words, by subtracting the separation of the constituents from the focal length, multiplying this figure by the focal length, taking the square root of the figure so obtained, and adding this to the focal length, we find the focal length of one constituent of a symmetrical doublet lens.

DETERMINATION OF APERTURE.

The "aperture" of a lens under any given conditions is the diameter of the beam of parallel rays of light that can pass through it. The maximum aperture is the diameter of the beam allowed to pass by the largest diaphragm. The aperture is the diameter of the diaphragm when this is in front of the lens, but is larger than it when there is a lens of positive focal length in front of the diaphragm, because of the condensing action of the lens. A method that serves for measuring the aperture in all cases is to attach the lens to a camera and focus on a distant object. Then to turn back the focussing screen, and put instead of it a card that has a pinhole pricked at its centre. A candle flame is next placed behind the pinhole, which, by the arrangement, is at the principal focal point of the lens, and gives, therefore, a cylindrical beam of parallel rays issuing from the lens. The diameter of this beam is the aperture, and it may be measured by holding a piece of translucent paper or piece of ground-glass to receive it, and measuring the disc of light with a pair of dividers. A more elaborate method that may sometimes be useful is to push a piece of bromide paper into the lens cap, put the cap on the lens, and after a few seconds exposure develop the bromide paper. The diameter of the circular patch is the aperture.

It is very rarely now that the aperture is expressed by a simple measurement. The chief use of the knowledge of the aperture is to regulate the exposure, and as the intensity of the image is the same for all lenses in which the ratio between the focal length and aperture is equal,*

* This is a general statement and not absolutely true, because it presupposes that no light is absorbed by the glass or lost in any other way. As a matter of fact all glass absorbs some of the light that impinges upon it; glass is not absolutely transparent, so that a thick piece will absorb more than a thinner piece of the same kind. At every glass surface some light is lost by reflection, and some also is lost by diffusion because of the imperfect polish. But these losses are very variable, and in the case of fairly made instruments kept *clean* are comparatively small, so that they may be safely neglected.

whatever these may be, it is this ratio that is the most important and convenient expression of the aperture. Thus, if a lens has a focal length of six inches and an aperture of one inch, and another has a focal length of twelve inches and an aperture of two inches, both lenses would be described as having apertures of f/6, and the difference in the actual apertures would be indicated by the difference in focal length.

Telephotographic lenses having variable focal lengths according to their adjustments, and the same actual aperture having, therefore, different values, are more conveniently dealt with in a different manner. The focal lengths of the positive and the negative elements should be separately ascertained. Probably the most simple method is to regard only the magnification of the image, and the details can be ascertained for certain adjustments of the camera and lens once for all with regard to very distant objects. To do this measure the distance between any two suitable points in the image as produced by the positive lens alone. If then the distance between these points is doubled when the negative lens is in place, the focal length is doubled, and a previous aperture of f/8 becomes f/16, presuming that it is not smaller because of the negative lens itself not allowing the full pencil of light to pass. And so the focal length is directly proportional to the linear magnification, and the aperture is inversely proportional to the same.

If it should happen to be more convenient to measure the distance between the negative lens and the focussing screen, this distance may be divided by the focal length of the negative lens, and the result with one added will give the magnification. From

the magnification the focal length and aperture are obtained as above.

Or the focal length may be obtained directly by measuring the distance from the diaphragm of the positive lens to the focussing screen, and multiplying this by the figure that represents the proportion that the focal length of the positive lens bears to the negative. If the positive lens is twice the focal length of the negative the multiplier is two, if four times it is four, and so on. From the focal length the aperture can be obtained as already stated.

Of these alternative methods, the first is not only generally the most convenient, but is also an exact method, the others are approximate only.

Optical centre, nodal points, etc. In the use of lenses other than by mere rule of thumb, it is necessary sometimes to measure distances from the lens. With a thick simple lens, and much more with such combinations as are practically used in photography, the question arises as to what part of the lens to measure from. In determining the focal length of an objective by the method previously recommended, this difficulty was obviated by making no measurements from the lens itself, and it is generally possible to eliminate the difficulty in practical work as will be shown later, therefore a very short reference to the matter will suffice.

The idea that was prevalent for a considerable time was that it was possible to determine a certain position, a plane, at which it might be supposed for practical purposes that the whole of the power of the lens was concentrated, a plane at which an infinitely thin lens (of course a practical impossibility) of suitable power would produce the same effects as the objective. The conception of such

an infinitely thin lens gave rise to the expressions equivalent lens and equivalent focal length. The centre of this infinitely thin lens, that is the point where the principal axis cut it, was called the "optical centre" of the combination. This idea is simple, and still not without its uses, though it has been shown to need modification. Rays passing through this point are not deflected, but pursue paths parallel to their original paths, as shown in fig. 62.

The position of the "optical centre" of a single lens can be determined by setting out a section of it and drawing a line from the centre of curvature of each surface to its corresponding curve in such a manner that the two lines are parallel. A third line is then drawn through the points where the curves are cut by the radial lines, and the "optical centre" is that point where this third line cuts the principal axis. In fig. 61 this method is

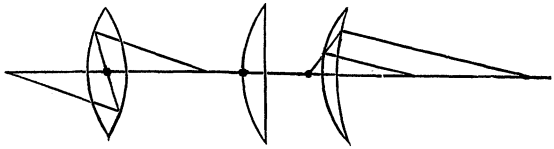


FIG. 61.

shown with a double convex lens and a meniscus. The "optical centre" of a plano-convex is on the curved surface; in the case of a meniscus it is outside the lens altogether. In using a single landscape lens, therefore, the distance between the back of the lens and the focussing screen is equal to or greater than the equivalent focal length of the lens; and as with a doublet this distance is considerably less than the equivalent focal length, a given limit of camera extension may leave a margin with

the latter lens, but be an inch or two too small for the former, though the focal lengths of both lenses are the same.

It used to be stated that the "optical centre" is the point of the lens from which must be measured the distances of object and sensitive plate in copying to exact

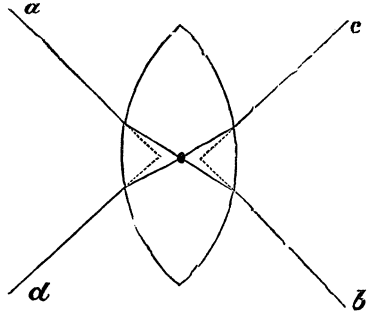


FIG. 62.

scales, but this statement is not generally true in the case of compound lenses. In fig. 62 the "optical centre" is indicated by a dot, and *a b*, *c d*, are rays passing through it. By continuing within the lens the direction of the rays outside the lens, as is done by the dotted lines, two points are obtained which are the "nodal points," or simply the "nodes." They are called, respectively, the point or node of admission and of emission, according to the direction in which the light passes through the lens, and it is obvious that they owe their existence to the thickness of the lens.

Similar remarks apply to the plano-convex lens, represented in fig. 63, one of the nodal points being coincident in this case with the "optical centre."

It is from the nodal points that all measurements

must be taken in calculating distances when enlarging or reducing to scale. Although the distance between them is not great in the illustrative figures given above, and the confusion of them, therefore, would lead to comparatively small errors, it may be very different with the compound systems of lens in practical use. The two

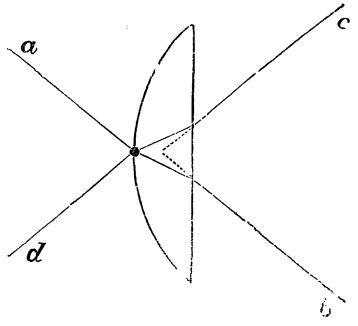


FIG. 63.

nodal points may coincide, or they may be widely separated, or the node of admission may be behind instead of, as usual, in front of the node of emission. Both nodal points may be outside the lens altogether, as in the case of a simple deep meniscus lens; and when negative lenses are used, as in telephotographic systems, the nodal points are very far removed from the lens. In these cases the distance between the lens and the plate is correspondingly shorter than the focal length of the lens system employed. This is the case, not only in telephotographic systems, but to a less though notable extent in some ordinary objectives, such, for example, as the Dallmeyer triplet and the Aldis lens.

CHAPTER XI.

THE USE OF LENSES.

Rapidity or intensity. The rapidity of a lens depends entirely upon the intensity of the light transmitted by the lens to the surface that receives the light and the extent of surface over which this light is spread. The following are the chief items, which, as they increase, diminish the intensity of the light, and therefore the rapidity of the lens. The thickness of glass, the colour of the glass, the number of surfaces of glass (as each surface in contact with the air causes loss of light by regular reflection as well as by reason of the irregularities of its surface), and the distance that the sensitive surface is from the lens. Increase in the aperture of the lens gives an increase of rapidity.

It is only the last two of these controlling circumstances that can be readily estimated, and as these two items are by very far the most important, it is usual to have regard to these alone in stating the rapidity of a lens. It should be distinctly understood that rapidity is not influenced by focal length directly, and that focal length has nothing to do with rapidity except that under certain circumstances it decides the distance of the sensitive surface from the lens. Speaking practically, we may say that in copying and in portraiture, the sensitive surface is never placed at the principal focus of the lens, and in these cases, therefore, the focal length has nothing to do with the rapidity.

Other things being equal, rapidity is inversely proportional to the square of the distance of the sensitive plate from the lens; and this statement may be varied by saying that the rapidity is inversely proportional to the area of the image or to the square of its linear dimensions.

In comparing the rapidities of various lenses without reference to any special work, it is convenient to assume that the surface that receives the image is so placed that the principal focus of the lens is situated upon it. Hence we have the statement that the rapidities of lenses vary inversely as the squares of their focal lengths—a statement true enough in the abstract, but true practically only when the sensitive surface is situated as stated above.

The brilliancy of the image produced by a lens is directly proportional to the area of the lens, or of the diaphragm when that is smaller than the lens. As there is no simple way of measuring the areas included by circles, and as such areas are proportional to the squares of their diameters, the square of the diameter is a more useful comparative expression than the area.

It is convenient to combine these two chief items, that is, the distance of the sensitive surface from the lens (assuming this to be the focal length of the lens) and the aperture of the lens, to get a single figure to express the proportional exposure required. Other things being equal, the exposure must be directly proportional to the square of the focal length, and inversely proportional to the square of the diameter of the aperture; and therefore by dividing the first figure by the second we get the single figure desired. It is more convenient, however, to avoid the two squares, and the use of such high figures as these

would result in, by dividing the focal length by the aperture and squaring the result.

Diaphragms. As already stated, it has become usual to express the diameter of the diaphragm, not in actual measurement, but as a fractional part of the focal length. Thus an aperture of f/4 is an aperture that has a diameter equal to one quarter of the focal length of the particular lens that it is associated with. This custom is convenient and reasonable, as it indicates the rapidity of action of the lens. Under otherwise uniform conditions the exposures required are proportional to the squares of the denominators of these fractions.

The unit aperture is f/1. Various empirical units that have been adopted from time to time, such as f/4, f/10, and $f/\sqrt{10}$, have been found inconvenient, and are now practically obsolete. The smaller apertures are made so that each is half the area of the next larger size. The diaphragms are marked thus—$\frac{f}{4}$, $\frac{f}{5\cdot6}$, $\frac{f}{8}$, $\frac{f}{11\cdot3}$, $\frac{f}{16}$, $\frac{f}{22\cdot6}$, $\frac{f}{32}$, $\frac{f}{45\cdot2}$, $\frac{f}{64}$, etc. Some lenses have a maximum aperture that does not correspond with either of these, such as f/3.5, f/4.5, and f/12.5. It is usual in such cases to state the largest aperture, whatever it may be, and to make the smaller apertures correspond with the series given above.

Depth of definition is sometimes called, though incorrectly, "depth of focus." In all photography, except copying from flat surfaces, it is necessary to delineate objects that are at different distances from the lens, and objects which therefore cannot be all in focus simultaneously. In portraiture the ear and the hair must be represented as well as the nose, and in landscape work the foreground and the distance are generally taken at

the same time on the same plate. To gain these ends something must be sacrificed.

In discussing this matter it is necessary to leave altogether the optical definition of focal points, and to determine the maximum amount of out-of-focus effect that shall be accepted. The usual standard allows that what should be a point may be a spot the one-hundredth of an inch in diameter, and therefore that what ought to be a line (that is, length without breadth) may be a gradual shading or vignetting one-hundredth of an inch in width. This standard, however, is only arbitrary, but it is useful, because tables have been calculated showing the actual amount of depth of definition under varying circumstances without exceeding this amount of diffusion of focus. Such a table is given in the chapter on hand cameras. Depth of definition varies inversely as the diameter of the aperture, so that a given proportional increase in depth of definition gained by reducing the aperture requires an increase in exposure corresponding to the square of the gain in depth. For example, by halving the aperture diameter the depth of focus is doubled, but the exposure must be four times as great as before. Depth of definition also varies inversely as the square of the focal length for the same rapidity, or inversely as the focal length for the same aperture.

These rules are all based upon the assumption that an equal amount of out-of-focus effect is allowable in all cases. This assumption is justifiable in dealing with the smaller sizes of pictures that are made for direct viewing, because it is usual to hold such photographs at about the same distance from the eye irrespective of their size. But for larger pictures, or for negatives that are to be enlarged, these rules are not always applicable.

DEPTH OF DEFINITION.

It is obvious that if a 4 × 3 print has the full out-of-focus effect allowable, an enlargement of it to 8 × 6 will have twice as much as the maximum permissible blurring. In such cases it may be useful to regard the permissible out-of-focus effect as proportioned to the scale of the picture, so that negatives of all sizes taken of the same subject from the same position shall, if reduced or enlarged to the same size, show an equal blurring. Assuming these conditions, then depth of definition is dependent only upon the absolute aperture, or the diameter of the diaphragm, and is independent of the focal length of the lens.

It has been often stated that depth of definition depends only upon the focal length and aperture of the lens, but this is quite untrue, unless indeed regard is paid only to the very centre of the field. The defining power of all lenses falls off at a distance from the centre of the field, of some more than others. At a certain position one lens may give no depth because its best defining power is not greater than the minimum standard adopted, while another of the same aperture and focal length may, at the same position, give perfect definition, and therefore the same depth as at the middle of the field.

Ease of focussing, other things being equal, depends upon the depth of definition, hence the great advantage in using lenses of short focal length in the matter of focussing, and the reason why beginners should always practise at first with small plates, and the lenses suitable for them.

The effects of focal length. This naturally leads to the consideration of the effects of the focal lengths of lenses upon the picture produced. We hear much of the

advantages of long-focus lenses for ordinary use, and of the utility of short-focus lenses in confined situations, of the "false perspective" given by short-focus lenses, and so on. These results are, one and all, due, not to the focal length of the lens, but to the point of view selected, and that is the position of the lens with regard to the object. Every lens in the same position will give the same picture to the extent that the lens is able to define (disregarding for the moment the curvilinear distortion produced by certain view lenses), and the focal length of the lens will influence nothing but the proportional size of the representation of the object, and the extent of the object represented. But when the photographer has only one lens and determines to make the picture cover the plate used, he wanders to and fro with his camera until this condition is fulfilled, and then makes the focal length of the lens the excuse for many shortcomings. The point of view ought to be selected without any reference to the lens, then, if the picture desired more than covers the plate, it is impossible to secure the subject without a lens of shorter focal length which will give the picture on a smaller scale. But if the desired view as reproduced is anything smaller than the plate, it may obviously be secured. Uniformity of size in pictures is impossible without an assortment of lenses, unless the operator is content always to accept the amount of subject that his apparatus happens to give; but by varying the size of the pictures as occasion requires, one lens may be sufficient.

If the point of view, the amount of subject to be included, and the size of the picture are determined, there is only one focal length of lens that will give the required

picture. As defects in these matters are commonly referred to the lens, though they are only associated with it and not dependent upon it, it will be convenient here to refer briefly to the nature of the most important drawbacks to certain undesirable procedures in determining the point of view and the angle of view.

The point of view. The perspective of a picture as produced by any ordinary non-distorting photographic objective is correct when proper care is taken to keep the sensitive plate perpendicular, and will appear to be correct when viewed from a point having the same relation to the picture that the lens had during the exposure; but the picture will not appear exactly true to nature when looked at from any other point. The same limitation extends to pictures of every sort that represent solid objects. The skilful hanging of pictures makes it at least possible for the spectator to see them as they ought to be seen.

It is customary to look at a picture as nearly centrally as possible, unless there is some special part to which attention is particularly drawn, in which case that part will probably be placed opposite the eye. Therefore, the lens should be opposite the centre of the plate, so far as the possibility of moving it in a horizontal direction is concerned, unless there is a point of interest so strongly marked that it causes the attention to be concentrated elsewhere, when the lens may with advantage perhaps be brought opposite, or nearly opposite, the centre of interest.

A picture under examination is not conveniently brought nearer to the eye than a distance equal to its greater dimension, and is more often viewed from a greater

distance. Therefore, the shortest focal length of lens used should be equal to the greater dimension of the plate, except only in those cases where a subject must be taken that it is impossible to secure without using a lens of shorter focal length. There is very little need to fear using a lens of too great a focal length, unless one goes to such an extreme as is sometimes possible with telephotographic lenses.

By changing the point of view, new features are often brought into sight, as in the very simple case of a building

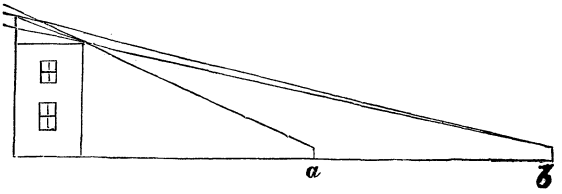


FIG. 64.

with a sloping roof. The operator at *a*, in fig. 64, will get no indication of the roof in his picture, but by retiring to *b* he will get this desirable addition. His picture at *b* will be on a smaller scale unless he uses a lens of about twice the focal length of that used at *a*.

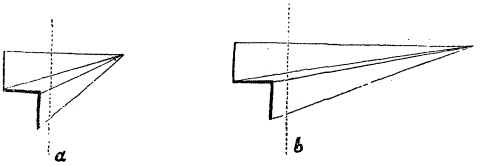


FIG. 65.

The distance that the camera is from a model in portraiture is an exceedingly important item in securing a pleasing likeness. In fig. 65 there are two vertical lines

joined by a horizontal line, the simplest expression of the contour of a sitting figure. The near point of view (*a*) causes the horizontal line, or lap of the model, to cover a very much larger space in the picture than when the point of view is shifted to a more suitable distance (*b*). The same proportions can be got by lowering the near point of view, but this would entirely alter the appearance of the face, showing the underside of the nose, etc.

Anything round, such as a ball, a column, a face, or a limb, shows a greater extent of surface from a distant than from a near point of view, as shown in fig. 66. Such objects have, therefore, an appearance increasing in fulness

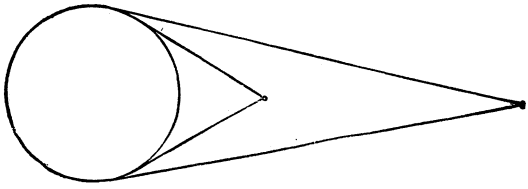


FIG. 66.

and richness as we retire from them until other matters interfere, such as the loss of visible detail from the smallness of the image produced, the loss of vigour because of mist in the air, etc.

Distortion due to photographing on flat surfaces. There is a distortion always present when an image is produced by a lens or a pinhole upon a flat surface, because the surface is flat. Considering the picture as bounded by a circle, this distortion is an abnormal increase in size in the direction of radii of the circle, and the distortion increases rapidly as the distance from the centre becomes greater. This distortion is more marked, therefore, when a wide angle is included. A colonnade or an avenue of

trees of equal girth will be represented as if those whose images are produced on the edge of the plate were stouter than those near the middle. Fig. 67 shows this effect, and at once makes clear the reason of it. If a statue is reproduced at the edge of the plate, it will appear stouter in proportion to its height than it really is. If the eye is brought to exactly the right position in viewing a picture so produced, these discrepancies disappear, and, indeed,

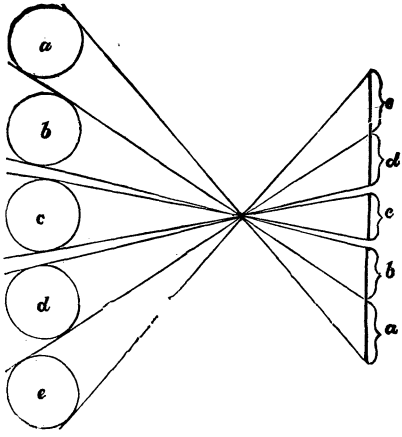


FIG. 67.

are necessary to represent the object properly; therefore, this distortion is only an evil when it is so exaggerated that it is practically impossible to see the picture from the proper point, or when the effect is detectable as a fault to the trained eye. This effect may for practical purposes be avoided by not including too wide an angle in the picture.

Curvilinear distortion. When a single lens is employed in practical photography, it is necessary to use a diaphragm

either in front of or behind the lens to get the necessary definition over the required surface. But by the use of this diaphragm the edges of the picture are produced by the edges of the lens, the centre of the picture by the centre of the lens, and so on. It has already been shown that rays passing through the centre of the lens pursue a path, after emergence, either in a line with, or parallel to, the incident ray, but that a ray passing through any other part of the lens suffers deflection, the outer part of the

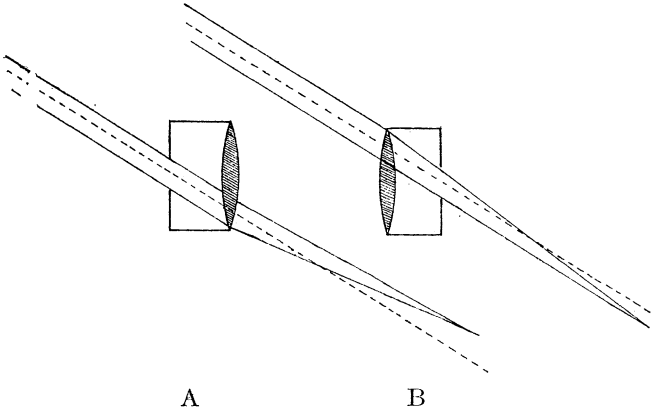
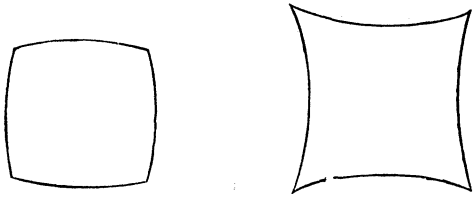


FIG. 68.

lens behaving in a similar manner to a prism, and that this deflection increases as the part of the lens utilised approaches its edge. The image, therefore, is displaced towards the lens axis (or the centre of the plate) when the diaphragm is in front, and from the axis when the diaphragm is behind the lens, as shown in fig. 68, and this displacement becomes gradually greater as the edges of the plate are approached. In the first case, the corners of the image

of a square are drawn inwards to a greater proportional extent than the middles of the sides, and barrel-shaped distortion results, fig. 69*a*. In the second case, the corners of the square are drawn outwards, and the distortion is pincushion shaped, fig. 69*b*. There is no distortion of lines



a FIG. 69. *b*

in the image that pass through the centre of the screen opposite the lens, that is, lines that cross the principal axis of the lens, because the distorting effect takes place lengthwise, and lengthens or shortens, but cannot bend them.

This curvilinear distortion is obviated by having a lens on each side of the diaphragm, because the distortion produced by the diaphragm with regard to each lens is opposite in character, and can easily be made equal in amount. This is the principle of the rectilinear or non-distorting doublets now so largely employed.

It is important to notice that the curvilinear effect is not the essence of the phenomenon, but merely the most obvious and striking result of it. The whole picture is drawn towards or from the centre to an extent which increases according to the distance from the centre. The bending of straight lines that do not cross the principal axis of the lens is merely due to the fact that such lines are not throughout their length equidistant from the centre

of the field of the lens. A circle would in either case remain a circle, but it would be made smaller in the first case and larger in the second.

The choice of a diaphragm. The smaller the diaphragm the more are the faults of the lens reduced, and when good definition is required a small aperture would always be used, except that the duration of the exposure is thereby increased. The smaller the diaphragm the greater the depth of definition, as explained in the previous chapter. As the defining power of lenses varies so much towards the edges of the field, and as it is rarely possible to measure the distances of the various objects that have to be portrayed simultaneously on the plate, it is impossible to make the choice of the diaphragm a matter of calculation. The practice, therefore, is to focus with a moderate diaphragm, and then to reduce the aperture until sufficiently good definition is obtained of all the various parts of the subject, paying particular attention to the edges of the plate if good definition is important there.

Sometimes a large aperture is employed for the purpose of being able to get the principal object in good definition, while the background and other things, perhaps, are represented in a more diffused manner. Such discriminative focussing is increasingly possible with larger lenses, and is often impossible with lenses of small focal length, although they have a large aperture, because of their considerable depth of definition.

CHAPTER XII.

TESTING AND COMPARING LENSES.

THE quality and value of a lens cannot be determined by an inspection of the picture produced by it. A cunning operator can make an inferior lens appear the better by selecting a suitable trial picture, as, for example, in one case known to the author where a street view was chosen. The houses on both sides were near the camera, and the centre of the view was distant from it, so that, with the same apertures and focal lengths, the better picture was, of course, obtained by means of the lens that suffered most from curvature of field. For that particular view this fault was a virtue, and the results were accordingly deceptive.

Unless the difference between lenses is very marked it takes a long time and very shrewd analysis of their ordinary routine productions to form any usefully correct judgment of the comparative merits of the instruments. Anyone can distinguish a knob of glass from a lens, but to decide between two lenses made by reputed makers requires far more knowledge and experience than most photographers can lay claim to. The eye must be trained to see and the hand to work, before either the observation or the manipulation in lens testing is accurate enough to merit the name of scientific. The following hints, however, may be useful.

Interference of the mount. In almost every lens, including even the single lens, the mount is more or less in the way. It acts as a diaphragm towards the edges of the plate, and is thus the chief cause of the rapid falling off

of the light there when large apertures are employed. This defect may be discovered by fixing the lens on a camera and racking out the focussing screen to its proper position for the lens, or focussing some distant object. The screen is then thrown back, the eye is brought to the place formerly occupied by one corner of it, and the stops are put in the lens one at a time, beginning with the largest, until one is found that appears its true shape, because its opening is not at all hidden by the mount. This stop is the largest that should be used for general landscape work with the full-size plate, and the larger the aperture that it represents the more satisfactory is the instrument in this matter.

Centring. It can be discovered whether the combinations in a doublet are truly mounted with regard to each other, that is, if the centring is correct, by holding the lens at arm's length and looking through it at a fairly distant gas or candle flame. The reflected images of the flame should be one behind the other in a direct line. It is not possible to see them all when they are superimposed, but by turning the lens a little to and fro it will easily be seen whether they gradually come together as they ought. There are six reflected images produced by a doublet that has both its combinations cemented, and in a portrait lens of the ordinary or Petzval ccnstruction, in which one of the combinations has its components separated, there are fourteen images produced by reflection that are easily seen, and one other that is a little difficult to find. The number of images is greater than with the symmetrical doublet, because the reflecting surfaces are six instead of four.

Another method of testing the centring is to rotate

the lens on its axis and notice whether a previously focussed point moves during the operation. It is obvious that if the lens is "true," its rotation will not affect the image in any way. Defective centring injures the definition even in the centre of the field.

The glass itself, of which lenses are made, may vary in its physical properties. The colour may be compared by placing the lenses, removed from their mounts, on a sheet of white paper, and looking at them in good daylight. It should be borne in mind that thicker lenses will have more colour, though they are made from the same specimen of glass as thinner and apparently more colourless combinations.

Some specimens of crown glass and the denser qualities of flint, and some of the newer kinds of glass now employed, are liable to form an iridescent film of tarnish upon their surface, and the scattering effect this has upon the light is fatal to good work. If such a film appears after the carefully cleaned lens has been kept in a suitable place, that is, not exposed to deleterious fumes, etc., for a month, the glass is not good. An otherwise first-class lens may show this defect, and there is no cure for it because the defect is inherent in the glass. No first-class optician would refuse to exchange an instrument of his manufacture that suffered in this way.

Small bubbles are difficult to avoid in larger pieces of glass, and in some glasses of special composition even small pieces are rarely free from them. Although they are not desirable, the photographer need not trouble about them if their combined size bears a very small proportion to the smallest stop, especially if they are near the edges of the lens.

Flare Spot. The presence of a flare spot, that is, a spot of light produced by the lens opposite its centre, which fogs the plate at that part, must at once condemn any instrument. This fault, perhaps, may be easily cured by the optician. It should be expected to show chiefly in outside work, especially when a bright sky forms a part of the picture, and when a small stop is used. A lens may show a flare spot with its smaller diaphragms only, and then the smallest stop that can safely be used may be determined.

Ghosts. The doublet lenses of even the best makers sometimes produce a ghost or false image on the ground-glass. To test for this, focus a gas or candle flame that is eight or ten times the focal length of the lens distant from the camera, cover the head with a dark cloth, and bring the image of the flame into the centre of the focussing screen. Now carefully turn the camera so that the image moves slowly towards one side, and look for the ghost moving in the other direction, exactly opposite to the chief image. The ghost may not be in focus when the chief image is, but, if present, it can generally be focussed without difficulty, and then it will be seen to be an erect image of the flame. Although some of the best lenses show this fault, it is obvious that it may prove troublesome, especially in outdoor work, as if, for example, a bright cloud comes on one side of the plate, dark foliage in the foreground on the opposite side must suffer a certain amount of fogging. The author has seen a portrait spoiled by an inverted image of the shirt front appearing over the model's head. Such false images cannot be avoided, but it is desirable that they should not obtrude themselves in ordinary work. They should be well out of focus when

the primary image is focussed, and as nearly as possible spread over the whole plate as a feeble diffused light.

Colour correction. The coincidence of the visual and actinic foci should be examined with the full aperture of the lens. Arrange five or seven well-defined black and white subjects, such as white cards with black devices upon them (playing cards for example), so that they form a series of steps, all facing square to the camera, but each an inch in advance of the next to it. Then focus carefully on the middle one, expose, and develop. If any other card than the middle one is better defined on the plate than it, the lens is not properly corrected. To eliminate any want of correct register in the camera, focus on a temporary screen held in the same back (keeping the back open) that the sensitive plate is afterwards put in. This at its best is a rough test, but probably sufficient for general purposes. A lens that shows no fault when examined in this way may give a very out-of-focus image when used with a yellow screen, unless focussed with the screen in position.

General defining power. If lenses are satisfactory in these respects, and it is desired to form a final judgment as to their comparative merits, their focal lengths and apertures must be exactly determined (the methods of doing this have already been given), and, if necessary, new diaphragms must be made so that the relation of aperture to focal length shall be identical in every case. The focal lengths of the lenses ought to be as nearly equal as possible, as if, for example, they had all the same reputed focal lengths as catalogued by the makers. A test object is then photographed with each lens in succession, taking care that every lens occupies exactly the same

position with regard to the object, and it is well for the object to be as far away from the lens as possible. The sizes of the images on the various negatives will vary as the focal lengths vary, but the same part of the image will be comparable throughout the series.

The test object used for this purpose is conveniently a flat wall or screen as large as possible, say eight or nine feet in each direction, with clean-cut black figures upon it. A very satisfactory test for astigmatism consists of a series of concentric circles, the spaces between them being not much greater than the thickness of the lines. If astigmatism is present there will be sections of indistinctness in the photograph of such a device. Lines running in opposite directions, and a patch of checkwork of lines crossing each other, leaving spaces about equal in width to the thickness of the lines, are also useful figures; astigmatism will give the lines in one direction more clearly than the others, and will alter the shape of the square openings. Something of this sort should be placed at each corner, and there should also be black patches, lines, figures, or letters of varying degrees of fineness. Such a test screen appears to have been first used by Zeiss when he introduced his anastigmats. If this is not possible it will generally be easy to arrange something of the same kind by temporarily attaching various sheets and figures to a flat wall.

When the apparatus is to be arranged for permanent use, it will be convenient to combine with it some simple devices at regularly increasing distances before and behind to test for the coincidence of the actinic and visual images, and a scale or two with accurately uniform distances marked on them to test for curvilinear distortion. The

distances in the image should be equal all across the plate, otherwise curvilinear distortion is present. A scale across the centre of such a test screen is a far better test for curvilinear distortion than any other, such as a line that gives an image near to the edge of the plate, because the scale shows how much of the field is free from distortion, and the amount of the error at any part of the field.

Having arranged such a test object to include as many items as possible, fine-grained clear-working plates, such as transparency plates, should be exposed for equal times, avoiding over-exposure, and then be developed together in the same dish if possible, but in any case with a portion of the same developer and for exactly the same time. After fixing and washing and drying, the various plates are examined critically with a good magnifier.

Tests made with a large aperture such as f/11 will show the comparative values of lenses for rapid work, while if a small aperture of f/32 or less is used, the results will give the relative maximum covering powers of the lenses.

CHAPTER XIII.

SPECTACLE LENSES AND PINHOLES.

SHARPNESS of definition is not always desirable in a photograph, indeed, sometimes it may be very objectionable, and it may cause the loss of an effect without which the photograph would be valueless. The possibility of introducing spherical aberration in Dallmeyer's portrait lens provided a means of getting rid of the excessive sharpness in the focal plane, and in the early days of photography the back combination of a portrait lens was sometimes removed because the front combination used alone gave less sharpness. At the same time the increased focal length of the one combination as compared with that of the complete lens often proved advantageous. In recent years softness of definition has been more cultivated, and the rapidity of gelatine plates as compared with the older collodion plates has made the rapidity of lenses much less important, so that uncorrected lenses and pinholes have a practical value.

Spectacle lenses. It has already been shown that a simple lens made of a single piece of glass is not able to bring to a focus light that emanates from a point, because of spherical and chromatic aberrations. The images produced by such lenses are therefore diffused or soft unless they are associated with a very small diaphragm, say 150th of the focal length. For practical purposes it is convenient to use spectacle lenses, which, before they are shaped to fit the frames, are roughly round and rather

more than one and a half inches in diameter. Larger single lenses are now made specially for photographic work by some opticians under the name of "monocles." When diaphragms are used, they should be put in front of the lenses as in landscape objectives mounted in the ordinary way.

With all such uncorrected lenses the sharpest photographic image will not coincide with the sharpest visual image, but will be nearer the lens by a distance equal to about one-fiftieth of the focal length. But it must be remembered that the rays that are photographically effective give foci in different planes according to their refrangibility, and therefore that no position of the sensitive plate can be truly said to correspond with the focus of the photographic rays because there is no such focus. There will be a certain range of position for the plate that will make very little difference in the sharpness of the image. In using such lenses it is well to get an approximate figure for each that represents the "focus difference," or the distance through which the screen must be moved in order to get a photographic image of a distant object as nearly as possible equal in quality to the visual image.

When the object is nearer the lens than a distance equal to about one hundred times its focal length, the difference (estimated for a distant object) will have to be increased. The following figures are from a much more extended table by Dr. Steinheil, and give in the first column the number of focal lengths that the object is from the lens, and in the second the figure by which the "focus difference" must be multiplied.

I.	II.	I.	II.	I.	II.
100	1.020	10	1.23	2.8	2.35
80	1.025	8	1.30	2.6	2.56
60	1.034	6	1.43	2.4	2.84
40	1.051	4	1.75	2.2	3.23
20	1.102	3	2.20	2.0	3.81

Pinholes give a visual and photographic image practically alike, but the visual image is so feeble that it is rarely of use, even for seeing how much of the subject is included on the plate, much less for determining the definition of it. The chief characteristic of the image given by a pinhole is the evenness of definition for objects at all distances; the depth of definition being, practically speaking, perfect.

The sharpness of definition does not continue to increase as the hole is made smaller, because at the same time the phenomena of diffraction become more marked, that is, the hole tends to produce effects as if it were itself a source of light, instead of the light simply passing in straight lines through it. The result is that a point in the object is reproduced in the image as a series of small concentric rings, alternately light and dark.

As nearly as one can infer from the results of those who have investigated the matter, the diameter of the pinhole that will give the sharpest definition may be found by dividing by 200 the square root of the distance of the hole from the plate. But at the best this is only an approximate result, as it is affected by variations in the attendant circumstances, such as the distance of the object. A hole of twice the diameter so calculated will give results but little inferior in sharpness, and the necessary exposure will be reduced to about one-fourth.

The calculation of the exposures with pinholes is much facilitated if they are arranged so that each has half the area of the next larger. The author has proposed the following series, and an apparatus with these holes is now on the market. The figures represent inches, and the distances are calculated by the method given above. The smallest hole specified will give the best definition. Thus at a distance of ten inches the best result may be expected with a hole $\frac{1}{64}$in. in diameter, but if the hole is $\frac{1}{45}$in., or even $\frac{1}{32}$in., the results will be but little inferior.

Pinhole diameters	$\frac{1}{16}$	$\frac{1}{22}$	$\frac{1}{32}$	$\frac{1}{45}$	$\frac{1}{64}$
Distance from plate for sharpest image	160	80	40	20	10
Minimum distance as stated above	40	20	10	5	$2\frac{1}{2}$
Suggested distance to facilitate calculation of exposure ..	64	32	16	8	4

Assuming that the exposure with a pinhole is governed by the aperture when compared with lenses as commonly employed, then the exposure for any of the above holes can be calculated by estimating the exposure that would be required by a lens with an aperture of f/16, f/22, f/32, f/45, or f/64, as the case may be, and multiplying it by the square of the number of inches that the plate is distant from the pinhole. If, for example, we are using the $\frac{1}{32}$in. hole at a distance of ten inches from the plate, the exposure is estimated for f/32, say, half a second, and this is multiplied by the square of ten, giving fifty seconds for the exposure required.

If the distances and holes are used as suggested in the lowest line of the above table, the case is still more simple, as then the exposure is just as many minutes as the plate is inches distant from the hole for a subject that would require one second with an aperture of f/16.

In the example taken above, in which the exposure at f/16 is equal to one-eighth of a second, then the inches of distance must be divided by eight to give the minutes of exposure. This last method involves a small error, because there are sixty, and not sixty-four, seconds in a minute, but this is practically negligible.

But the exposure required is influenced by other circumstances. The retarding effect of glass which absorbs much of the ultra-violet light is absent, and as the exposure necessary with a single thin lens is stated to be very markedly less than with an ordinary photographic objective of the same aperture, because of the diminution of the thickness of the glass that the light has to pass through, we must expect to find a still greater difference when the glass is done away with altogether. On the other hand, the light that passes through a pinhole when spread over a considerable surface is generally very feeble, and very feeble lights do not produce as much photographic effect as strong lights, although the time is adjusted so that by calculation the effects might be expected to be equal. This is more marked with slow than with more rapid plates. Probably, taking all things into consideration, the exposure as calculated by the above rules will be found to be rather more than what it is advisable to give.

PART III.—PROCESSES.

CHAPTER I.

GELATINO-BROMIDE NEGATIVES. THE SENSITIVENESS OF THE PLATE.

It is necessary to have some idea of the rapidity of a plate before it can be used, but it is impossible definitely to express rapidity, unless the exact character and intensity of the light are known to which its rapidity refers. Up to the present there is no suggested standard of light that has not very important limitations. But if we take the best available, whether a standard candle, an amyl-acetate lamp, a pentane flame, or an electric light produced under known conditons, and then estimate the comparative rapidities of various plates, those rapidities will only apply to the light used, and will be no more than approximate, and perhaps entirely misleading, for other lights. It does not at all follow that because one plate is faster than another to candle light it will be faster to daylight. And this may be pushed even a step further, and it may be said that equal sensitiveness on a bright day will not of necessity lead to equal sensitiveness on a dull day. If the sensitiveness of one plate were chiefly towards the green and blue constituents of daylight, it would suffer less from aerial fog than if the sensitiveness were specially towards the violet and ultra-violet.

It must remain impossible to estimate sensitiveness exactly until there is a suitable and convenient standard

light that can be reproduced at will, and also a method that will enable the estimation to be made with regard to rays of several different refrangibilities, each independently of the other. The sensitiveness would then be expressed as a spectrum curve, showing the intensity of action on the plate of the various sections of the spectrum given by the standard light, and from such a curve it would be possible to calculate the sensitiveness of the plate to any other light of known character. No method short of this can properly be claimed to be exact.

But in ordinary photographic practice, it is not possible to estimate the available light with scientific exactness. Daylight often changes from hour to hour, and sometimes from minute to minute, and it requires special arrangements to get artificial lights of even approximate constancy. Therefore, an exact determination of the sensitiveness of a plate would be of no special use in photography as applied to ordinary purposes. If there were not a large permissible latitude in exposure, the practice of photography would have to be radically changed.

The sensitiveness of a plate, moreover, is not inherent, but depends upon its treatment. It is commonly admitted that some plates are more sensitive when developed in one way than in another way, and it is only natural that it should be so. It has been proposed to use a standard developer, but to do this would be absurd, because if a plate happened to be slow to the developer adopted as a standard but rapid when used with another developer, we should be led into the false position of describing a fast plate as a slow one. For practical purposes, therefore, it may be said that an approximate determination of sensitiveness is sufficient; and it may be added that

even if it were not sufficient, we should still have to be content with it for the present.

When gelatino-bromide plates were first made, their rapidity was generally indicated by such expressions as thirty times or sixty times that of a wet plate, or they were labelled ordinary, instantaneous, drop shutter, extra rapid, etc. These names still survive, and mean very little. The "extra rapid" of one maker may be slower than the "ordinary" of another, but such descriptions are fairly useful as indicating the different plates of any one maker.

Sensitometry. Warnerke's sensitometer provided a better means of indicating rapidity. In using this instrument a phosphorescent plate is excited by burning an inch of magnesium ribbon in front of it, and the plate is put in its place in a frame that contains the sensitive plate behind a graduated screen that has an opaque number marked on each of its squares. One minute after burning the magnesium, the shutter that separates the phosphorescent tablet from the sensitive plate is withdrawn for thirty seconds and then replaced. The exposed plate is then removed and developed, and the highest number that can be seen upon it indicates its rapidity. A great drawback to this apparatus is that the graduated screens differ considerably one from another. Other disadvantages are that the light emitted by the phosphorescent tablet cannot be depended on to be always of uniform intensity, and that its light is not fairly representative of either daylight or any ordinary artificial light. Its spectrum consists chiefly of a strong band between F and G, and a band of less intensity between C and F with a maximum at D. Therefore, the red, yellow, and green

sensitiveness is not properly valued. The numbers on this sensitometer extend from 1 to 25, and are so arranged that each third number indicates about a doubled rapidity. For example, a plate that shows 25 is approximately twice as fast as one that shows 22, and this again is about twice as rapid as one that shows 19.

The irregularities of such a graduating screen as Warnerke's can obviously be eliminated by the use of holes of the necessary sizes in an opaque screen, and an apparatus on this principle was made by Arthur Taylor in 1869. He had a box divided into compartments, so that it practically formed a collection of short wide tubes, all of which were open below to the sensitive surface and closed at their upper ends with diaphragms, each of which was perforated with the necessary number of uniform holes. The intensity of the light acting on the sensitive surface at the bottom of each short tube is proportional to the number of holes in its diaphragm. Mr. Spurge has devoted a great deal of attention to this form of instrument, and what is known as "Spurge's sensitometer" is a similar arrangement, but with only one hole in the cover of each of the short tubes, the area of the holes being such that each third in the series allows double the amount of light to pass through it. It is obvious that this apparatus is not a sensitometer, but only a graduating device; to use it for sensitometric purposes a uniformly luminous surface is required. We believe that Mr. Spurge himself uses a white opaque surface illuminated by gaslight. Before comparative sensitometric tests can be made with such an apparatus, it would be necessary to agree upon the character, intensity, and positions of the lights, and the nature and position of the illuminated surface, and then

the tests would only apply to lights of the same character as that employed.

The Hurter and Driffield method of determining plate speeds has the advantage of taking into consideration not only, nor even chiefly, the very faint deposits produced where the light of feeblest intensity has affected the plate, but the behaviour of the plate with regard to those intensities of light that are most useful in ordinary negative making. The method consists of giving to different parts of the plate exposures equivalent to 2.5, 5, 10, 20, 40, 80, 160, and 320 candle metre seconds (a candle metre second is the light given by a standard candle at a distance of one metre burning for one second), keeping a part unexposed. The plate is developed, fixed, washed, and dried, and the opacities of the various parts are measured by an instrument graduated to give at once the logarithms of the opacities, which Messrs. Hurter and Driffield call the "densities." The density of the unexposed part is taken as "fog," and deducted from each of the other readings. The net densities are then plotted as a curve on a ruled sheet, and the speed is indicated from that part of the curve that is approximately a straight line, neglecting the extremes which indicate under and over-exposure. The method is described in full in the *Journal of the Society of Chemical Industry* for May, 1890. The H. and D. numbers are directly proportional to the speed of the plate, and this is unfortunate because the same proportional increase of speed is represented by an increase in the number that is greater as the plates are faster. The numbers used with the previously described sensitometers are more convenient.

It was claimed for this method that it was exact,

but although it differs from other methods it suffers from very much the same limitations. As a general guide to the sensitiveness of plates, the results so obtained must be accepted with as much caution as any other statements of sensitiveness. One maker's numbers are not comparable with another maker's, because of the different treatment of the plate in making the test. And the method of the user may perhaps differ, too. The same want of discrimination between sensitiveness to various colours affects this as previous methods, and the difference between the light adopted and daylight, or other artificial lights, is in no way compensated for. The advantage of the method is that it neglects a possible long range of feeble tones that might give a plate a semblance of useful sensitiveness, though of no advantage in practical work. All estimations of sensitiveness are only rough guides, except as regards the exact conditions under which they are made, and then exact only when they are carried out with scrupulous attention to details.

In 1901 the author devised a "plate tester," which does not pretend to give more than a general idea as to the practical sensitiveness of plates, but that gives in addition an item that no other method has included, namely, the sensitiveness to different colours, besides other matters that are not immediately connected with sensitiveness. From the colour sensitiveness it is possible to form a very good idea as to the comparative sensitiveness of very different plates under widely different circumstances. This apparatus and its use are described in the chapter on measurements.

Mr. Watkins and Mr. Wynne have for some years published at frequent intervals series of plate speed num-

bers, obtained by daylight tests in the camera, for use with their exposure meters. The units, P1 Watkins and f/8 Wynne, are practically the same, and represent a plate that, with full midday summer sunshine in England, will require an exposure of two seconds for an average landscape—that is, a landscape with a well-lighted foreground—or one second for an open landscape with no foreground, using a lens aperture of f/8. This unit is more definite than it may at first sight appear to be, because it corresponds to a light that will darken the sensitive paper in either of the meters to the full tint in two seconds when the paper faces the open sky but is shaded from direct sunshine.

Mr. Watkins states that the H. and D. number multiplied by one and a half gives his P. number, and this may be useful sometimes as a rough guide, but obviously it is nothing more.

It is very desirable, if not necessary, that the user of plates should estimate the sensitiveness of each batch for himself, and there is much to be said in favour of making that estimation by a method similar to that which he will follow in the use of them. For ordinary daylight work out of doors, for example, an exposure is made on some convenient object, such as a building, noting at the same time with an actinometer the value of the light that falls upon the object. If this exposure happens to be correct, then the lens aperture, the duration of the exposure, and the time taken for the silver paper to darken to its standard tint, taken together indicate the sensitiveness of the plate. It is convenient to use always the same diaphragm for such estimations, then the sensitiveness is inversely proportional to the duration of the exposure

and directly proportional to the actinometer time. That is, divide the actinometer time by the period of exposure, and the result indicates the proportional sensitiveness. The actinometer used will be one attached to an exposure meter, and the exposure will be made as nearly correct as possible, judging by experience. For special work of whatever kind, as, for example, by artificial light, this method can generally be easily modified to suit the circumstances.

CHAPTER II.

GELATINO-BROMIDE NEGATIVES. EXPOSURE.

THE first step towards the making of a negative is the exposure of the plate. The use of lenses and the variations in exposure needed under different circumstances in connection with the lens, and methods of estimating the rapidity of the plate, have already been described, but there remain two items to be settled before the necessary exposure can be known, namely, the general character of the subject to be photographed and the intensity of the light that illuminates it.

Actinometry. To get the value of the light, one of the various "exposure meters" now made commercially should be employed, though it is only the actinometer portion of the meter that is essential. The sensitive paper provided for the meter must always be used, as it is coated with a preparation of silver bromide, and is a better guide to the light action on the plate than other silver papers, besides being more uniform. It is a convenience to have attached to the meter a cord ten inches long with a weight at its end, or the chain, as provided for the Watkins meters, to assist in counting seconds. The oscillation of the chain or cord can be felt while the sensitive paper is being watched, and each double oscillation indicates one second.

The actinometer should be held facing the light that falls upon the subject. If part of the subject is illuminated by direct sunshine, a shaded position should

be selected, and where there is a large range of brilliancy not the very deepest shade. The sensitive paper should face directly towards the light, and generally there is no difficulty in determining the most suitable position for the testing. It is then quite a simple matter by the scales provided on any exposure meter to calculate the exposure required under the given conditions for most ordinary subjects. But if the use of the calculating devices is found troublesome, they may be dispensed with, and one or the other of the following mental methods of calculation may be adopted.

A convenient unit of light is that represented by one sixteenth of the full tint or the fourth of the quarter tint of either a Watkins or a Wynne meter, that is the light effect indicated by the Watkins "indoor meter." Ordinary rapid plates will often be found to be well exposed with one such light unit and a lens aperture of f/16. Very rapid plates may be fully exposed with a half or a quarter of the unit, while slower plates will require two, four, or more units with the same aperture. The value of the plate can be discovered from the published plate-speed lists, or found experimentally. To find the exposure, the light is tested as usual and the time in seconds that gives the full tint divided by sixteen, or the quarter tint by four, or the direct reading of the "indoor meter" is taken, and this is the time-equivalent of the light unit, that is the time necessary to expose for to get the unit effect. This time is divided or multiplied according to whether the plate requires a fraction of a unit or several units at f/16, and the time so found is the exposure for that aperture. The time is halved for each larger aperture or doubled for each smaller. To take an example. If the subject is

focussed with an aperture of f/32, and if the plate is moderate in speed and requires two units of light at f/16, and the actinometer darkens to its full tint in four seconds. the time of exposure for the light unit is $\frac{1}{16}$ of 4 = $\frac{1}{4}$ second ; two units are equal to half a second, which is the exposure at f/16. At f/22 the exposure will be one second, and at f/32 two seconds. This is, in a general sense, on the principle of calculation adopted with the Watkins meters.

Instead of finding the number of units for a fixed aperture, the aperture corresponding to the unit of light may be noted. In the above example the period of exposure for the unit is a quarter of a second, and the plate at f/16 requires two units. Therefore, at f/11 one unit will be the correct exposure, and the plate may be remembered as an f/11 plate instead of a two unit plate (at f/16). In this case the time equivalent of the unit is the exposure required with the aperture that describes the plate. This is the principle in the calculation by means of the Wynne meters. In both the Watkins and the Wynne meters the unit of light is the full tint, and although this is not disadvantageous when using the calculating devices provided, and may even be preferable in that case, it would generally be less convenient for calculating the exposure without their use.

The advantage of finding the required exposure by any such method as those described is that there is no need to trouble about the weather, the time of year, or the time of day. The unit suggested above may be on a bright day out of doors the eighth of a second, indoors on a dull day it may be sixty seconds or more, but the effect that it will produce on the same plate will always be practically the same.

The exposure so calculated will be suitable, whatever the light, for landscapes with ordinary foregrounds, buildings, foliage, portraits, whether indoors or out, interiors, and similar subjects. For some subjects the exposure must be reduced. For sea or sky give one-tenth. For snow scenes, glaciers, landscapes with practically no foreground objects, sea views with shipping not too near, white flat objects such as engravings (it is only the white parts of black and white pictures that should be exposed for) give one-fourth. For open landscapes with no dark shadows or objects in the foreground, white solid objects such as statuary, flat objects in graduated tints such as photographic prints, give one-half. For dark coloured objects such as dark oak carving and oil paintings, give one and a half times to twice. Exposure must be increased a little for any object nearer to the lens than from twenty to thirty times its focal length. A portrait for example may have one and a half or twice the exposure when the model is unusually near, and under the same circumstances details of dark carving and oil paintings may be exposed for the full twice instead of one and a half times the normal. Generally speaking, if an exposure is obviously incorrect, it is of little use to make a less change than doubling or halving it.

The latitude of the plate is an essential property of it for practical work. In all cases, taking the best exposure, that is the least that will give a fully detailed and suitably vigorous image on development, the exposure may be reduced or increased to a certain extent without notable injury to the print that the resulting negative will give. A good plate that has not lost its useful properties in the getting of great sensitiveness may give a satisfactory

negative when the exposure is halved or when it is doubled or even multiplied by four, these extreme figures representing a range of exposure of from one to eight. It is not possible to vary the exposure without getting a difference in the negative, but if by exposing for printing a little longer or a little shorter time the prints from the negatives variously exposed are scarcely if at all distinguishable to the eye, the range of exposure for the negatives may be considered as the range within which the photographer may work. All suggestions as to the exposures aim at giving the shortest that would be called "full," and where there is any doubt as to which of two exposures is to be preferred, it is better to give the longer rather than the shorter. There is no such thing as a correct exposure in an absolute sense.

Other methods of estimating exposure. Instead of finding the value of the light that falls upon the object, it is possible to estimate desirable exposures by taking into account the subject, the time of day, the time of year, and the weather. This method is not comparable with the other for accuracy or convenience, and would be altogether impossible if there was not a considerable range of serviceable exposures. The following details are added, as they will be useful if ever an actinometer is not at hand.

With an ordinary rapid plate and an aperture of f/16, the following table will give at least some idea of the necessary exposures, on a fine clear day within three hours of noon in the months of May, June, and July—

Sea and sky	$\frac{1}{50}$ second.
Open landscape	$\frac{1}{40}$ to $\frac{1}{20}$ second.
Landscape and foreground: buildings	$\frac{1}{8}$ second.

Landscape with dark foreground; details of buildings; portraits out of doors	$\frac{1}{4}$ second.
Under trees, up to	10 seconds.
Interiors	10 secs. to 5 mins.

These exposures may be multiplied by four or five for the middle of a fine day in November, December, or January. If the light is not good the exposure may be doubled on that account, and if dull multiplied by four or five. For later or earlier in the day there must be a further increase.

Other methods have been suggested for estimating the required exposure, but it is useless to enumerate them, as they are more uncertain even than that just described. No method is to be recommended that does not involve the testing of the light than illuminates the object, for it is impossible to estimate the value of the light by mere observation, because the chief part of the photographically useful light is not visible, and, moreover, the eye will not serve to estimate even the visible part of a light with an approach to accuracy, unless there are two lights to be compared simultaneously in view. The eye spontaneously tries to adjust itself to light intensity, and of itself, therefore, it reduces the difference between the impressions that would otherwise be received from lights of different value.

Exposures for moving objects. To find the permissible exposure for moving objects which are being photographed, so that the image of the moving objects shall not be too blurred, there have been many tables published as to rates, distances, and the direction of the movement of the object, but they cannot be remembered, and are rarely at hand when they might be useful. Even if at hand

they are often useless, because it is difficult to estimate the distance of an object unless one has had much practice under very similar conditions.

The photographer who makes a special study of the representation of any particular class of moving objects, will, of course, soon discover the best conditions under which to work. But he who has only occasionally to include moving objects in his views, and these, from time to time, of very various kinds, will probably find that the most convenient key to the exposure necessary is the fact that a movement at the rate of four miles an hour is equal to a movement of seven inches in the tenth of a second, and seven inches is, for all such practical purposes, the diameter of the human head. An individual walking at the usual rate that would be called fast, moves forward a distance equal to the diameter of his head in the tenth of a second. The space occupied by the image of his head on the ground-glass will indicate the amount of blurring under these conditions, whatever distance he may be from the camera. If his path makes an angle of forty-five degrees with the lens axis, instead of a right angle, his apparent rate of movement will be practically halved. His legs will move, during a part of each step, at about twice the rate of his body; and other circumstances, such as these, can generally be estimated with sufficient accuracy by comparing them with this standard rate of movement.

A yacht sailing at sixteen miles an hour will move a distance equal to the diameter of a man's head in the fortieth of a second; as the rate is four times the standard one, a fourth of the time must be taken for the same distance. If the image of a man's head is a mere speck

on the ground-glass, an exposure of the fortieth of a second will give a sharp photograph of a yacht moving at such a rate; in any case the image of the head will indicate the amount of blurring for the stated exposure and rate of movement.

Many other examples of the application of this standard might be given, but probably the way to use it is sufficiently obvious. In working by this method, there is nothing more to remember than one figure and two facts; namely, that fast walking (four miles an hour) means a movement equal to the diameter of a head in the one-tenth of a second. The variations of these conditions to meet practical circumstances involves no more difficult mental calculations than multiplying or dividing by two.

CHAPTER III.

GELATINO-BROMIDE NEGATIVES. THE PRINCIPLES OF DEVELOPMENT.

THE exposure, if properly timed, will have made no difference in the appearance of the plate, and, indeed, no difference that can be recognised in any way except one. By the application of a developer the silver bromide that has been affected by light is robbed of its bromine, while the silver bromide that has not been affected, or has been insufficiently affected, remains unchanged. The silver salt is a light yellow, and the metallic silver produced is grey or black, therefore the progress of the development is obvious. How the silver bromide is changed by the light to make it thus less stable is considered in a subsequent chapter.

Developers. All substances that can take bromine away from silver bromide, leaving the metal, will not act as developers, because some will not distinguish between the exposed and the unexposed silver bromide. The greater number of the active agents that form good developers will not act alone, and some need different conditions from others. The greater number of developers in use act only in the presence of alkalies, but some will work in neutral solutions and others in acid solutions. Generally speaking, the addition of an alkali urges on development, but ferrous citrate or citro-oxalate to which ammonia has been added will not develop, although it will reduce the silver bromide to the metal. It is necessary,

therefore, not only to have a good developing agent, but to apply it to the plate under those conditions that will ensure its satisfactory working.

The development of gelatine plates is almost always done with " alkaline " developers, or developers in alkaline solutions.* A prepared developer of this kind generally contains the developer proper, the alkali, the sulphite, and the restrainer.

The developing agents themselves have been described from a chemical point of view in the first part of the volume; their practical use will be treated of in subsequent chapters. They vary considerably in their action: with some, plates will require much more exposure than with others. Alkaline developers suitably prepared generally need less exposure than ferrous oxalate, but if the alkali is omitted they will generally require very much more. Some, such as metol, give all the detail that can be developed very soon after development begins, while others, such as pyrogallol as generally used, develop the brighter parts of the object first, the remainder following while the " lights " gain in density. In the last case, with slight under exposure, the " lights " may become too dense before all the developable detail is brought out—a difficulty that is avoided by the use of the other class of developers. At the same time a so-called rapid developer (that is, quick to begin not necessarily to complete development) will behave like one of the other class if the prepared solution has been used before, or has much restrainer added to it. In this characteristic the various developing agents pass by insensible degrees from one extreme to the other.

*The word developer is sometimes applied to the active agent, and sometimes to the whole solution as prepared for use.

For exposures inclining to be short rather than full or more than full, the rapid developers are preferable for the reason given, but for full or over-exposure those that bring out the detail gradually are better, because they give more possibility of control as to how much detail shall be developed.

The preservative is the sulphite, and it is used to keep the solution from getting coloured during use, because coloured solutions are liable to stain the gelatine. Sodium sulphite is to be preferred. Potassium metabisulphite and "acetone sulphite" are acid, and therefore better for keeping a stock of solution of pyrogallol, but being acid they neutralise some of the alkali added, and thus leave quite uncertain the amount of alkali remaining effective. They have no advantage whatever during development, and as they are more effective in keeping the stock solution, they are generally prescribed in very insufficient quantities for actual development.

The accelerator is generally an alkali. The practical use of other accelerators is discussed subsequently.

As to the choice of alkali. Ammonia has some advantages. Its volatility and the mobility of its solution appear to give it exceptional energy. But it has two disadvantages. It is a solvent, though a very feeble one, of silver bromide, and gelatine is very liable to be stained by such solutions of silver compounds. And it is a matter of fact that when bromide plates begin to deteriorate an ammonia developer will often produce silver stains upon them, while they work perfectly with other alkalies. The other disadvantage is its volatility. A developer containing it, when exposed in a dish, is always losing ammonia and becoming weaker, and the loss is liable to vary according

to circumstances which are beyond control. In short, ammonia puts the quality and condition of the plate to a more severe test than sodium or potassium carbonate, and as there is always an element of uncertainty in its use, the author considers that the balance of advantage rests with the fixed alkalies. Ammonia is rarely used at the present time. It has been stated that carbonate of potassium tends to give detail and carbonate of sodium density, but this depends very much on how each is used. On the whole sodium carbonate appears to be preferable to the potassium salt, and a mixture seems to offer no special advantage.

The retarder is generally potassium bromide. Other retarders are subsequently considered. It is important to observe that ammonium bromide must not be used with soda or potash or their carbonates, for such a mixture would give ammonia and sodium or potassium bromide. The function of the retarder is to hold in check the developing action that it may not be too vigorous and fog the plate ; for a too energetic developer is very likely to reduce the silver salt that has not been exposed. The retarder, also, makes it possible to correct very largely for too much exposure, for an over-exposed plate that would develop so rapidly that the lights would not have the opportunity of becoming dense enough before the whole plate fogged over, may by the restrainer be caused to develop at a normal rate, getting proper density in the lights and enabling one to stop development at a suitable time, utilising only a part of the exposure very much as if the part utilised were the whole. Some boast that they use no restrainer, and appear to think that there is some virtue in the abstinence. It is certain that there must be a

restrainer present, and whether the gelatine itself is sufficient, or whether its action is slightly supplemented, is an unimportant detail. The fact that no bromide is added to the developer is not evidence that none is present, for if the working without bromide is considered a merit the plate-maker can easily secure this supposed advantage by putting a little bromide into the film, as is sometimes done.

The effect of development on the developer. The changes that take place during development alter the proportion of the constituents of the developing solution. The action of the developer is to take away the bromine from the silver bromide that has been affected by the exposure. The action may be expressed thus—

$$2AgBr + 2Na_2CO_3 + H_2O = 2Ag + 2NaBr + 2NaHCO_3 + O$$

the atom of oxygen being taken up by the developing agent which is oxidised by it. It is the tendency of the developing agent to be oxidised that starts the action, for the changes represented by the equation just given will not take place without the presence of something that will take up the oxygen. During development, therefore, alkaline bromide, which is a restrainer, is produced, the alkali, that is the accelerator, is diminished in quantity, for of course the sodium changed into bromide becomes a retarder instead of an accelerator, and the bicarbonate is practically useless as an alkali. The developing agent gets oxidised and so loses its power, and the products of its oxidation often have a powerful retarding action. The oxidation of the developer is effected also by the oxygen of the air in contact with the surface of the liquid. Thus every circumstance tends to reduce the power of

the developer as development proceeds, and the rocking of the dish, or agitation of the solution by other means, is necessary in order to mix the exhausted developer in contact with those parts of the plate where it has done much work, and at the surface where it is deteriorated by the air, with the fresh portions of the solution to counteract as far as possible the weakening of its power. For this reason, too, the quantity of developer should not be too small, or else loss of vigour in the negative will be the result.

The methods of development are several. The prepared developer may be applied to the plate, the dish gently rocked to ensure an even action, the development watched until it appears to be approaching completeness, when the plate is examined by looking through it, in front of the lantern, and at the back to see how nearly through the film the image is. If the image shows, in the dense parts, with equal clearness at the back and front of the plate, it will lose very little of its apparent density by fixing. But if there is so much unchanged silver salt that the image hardly shows at the back of the plate, the apparent density on looking through the plate will be largely reduced by fixing. Whatever method the student may finally adopt, it is well that he should begin by working on the lines just laid down that he may get thoroughly acquainted with the process of development. Many continue to prefer this method to any other.

The factorial method of development was introduced by Mr. Alfred Watkins in 1894 for the purpose of determining when sufficient density is obtained without having to rely on a simple inspection of the negative during development. Mr. Watkins found that the time from the

pouring on of the developer till the image begins to appear bears a constant proportion to the total time of development for the production of negatives of a constant density. The "multiplying factor" is the figure by which the "time of appearance" must be multiplied to give the total time of development. If one's negatives are too thin, the multiplying factor is increased, and they will be uniformly denser. This method of work has the advantage that the plate has not to be removed from the developer nor even looked at until development is complete. The following details are quoted from Mr. Watkins's "Manual of Exposure and Development." The following multiplying factors are suggested for getting average results, but they may be increased or reduced according to individual requirements—

MULTIPLYING FACTORS.

	Pyro, grains per oz.	Potassium Bromide, per oz.	Factor.
Pyro-soda or pyro-potash without bromide	1	0	18
	2	0	12
	3	0	10
	4	0	8
	5	0	6½
Pyro-soda or pyro-potash with bromide	1	¼	9
	2	½	5
	3	¾	4½
	4	1	4
	8	2	3¼
Hydroquinone (usual amount of bromide)			5
Metol			30
Eikonogen			9
Rodinal			40
Amidol (two grains per ounce)			18
Adurol			5
Pyrocatechin			10
Ortol			10
Glycin			7
Imogen sulphite			6
Edinol			20
Diogen			12

DEVELOPMENT BY TIME.

To facilitate the timing of development, Mr. Watkins has devised a dark room clock with a ten minutes dial and a calculating device, which is called an "eikronometer."

The simple time method of development. Under certain circumstances it is possible to develop for a fixed predetermined time with successful results. This applies to those numerous cases in which over-exposure is absent, as in the very great majority of hand camera work, and when using plates or films that do not give a very steep or sudden gradation. It is possible then to develop all that is developable and to secure a proportion of successful negatives that will compare well with those obtained by any other method of work. But even with full exposures, that is, when over-development is possible, an average time of development may be found that will give a large proportion of satisfactory plates, especially if the subjects are of a somewhat similar character, as is often the case in a series taken by any one photographer. It is necessary, in taking advantage of this method, to pay attention to the temperature, as the warmer the solution the more rapidly does it act.

The Kodak Company, in 1903, introduced a developing machine that is especially convenient for roll films, and will work with perfect safety in an ordinary light. In the closed machine the film is wound face outwards against a coiled celluloid apron, the developer is introduced, and the film is rotated slowly for a fixed time. It is washed and fixed similarly, and is then removed from the machine. For a certain developer and with their films, the company specify development for five minutes, at a temperature from 60° F. to 65° F., four minutes at 70° F., and

eight minutes at 45° F. This is a very advantageous method of manipulating roll films, as there is no risk of damage to the film, and the whole roll is done at once.

CHAPTER IV.

GELATINO-BROMIDE NEGATIVES. DEVELOPMENT WITH PYROGALLOL.

DEVELOPMENT with pyrogallol (pyrogallic acid) [$C_6H_3(OH)_3$] in solution with an alkali has the advantage of giving the operator considerable power to vary his developer to suit the peculiarity of his subject. Many photographers consider, and not without reason, that for general work there is no developer that can be more advantageously employed than this. To realise the full benefit of it, each constituent should be kept separately. This also has the advantage that if one of the chemicals deteriorates it does not involve the loss of another.

The pyrogallol is conveniently kept in the solid condition, as its decomposition is then entirely prevented, and it is almost as easy to measure the solid substance as a solution of it. But if it is preferred to have it in solution, it may be dissolved in a convenient quantity of water, say, to form a ten per cent. solution, and a little potassium metabisulphite, or nitric acid, or citric acid, may be added to it to give the solution a distinctly acid reaction to litmus paper. The quantity of acid required will be too small appreciably to affect any formula. It is well not to dissolve more pyrogallol than will serve for a few days' use.

The precautions necessary in dealing with sodium sulphite have been pointed out in the first part of this book. It is convenient to prepare a fifty per cent. solution

of the crystallised salt, so that it is only necessary to take twice as many grain measures or cubic centimetres as there are grains or grams required. If an ounce of the salt is taken it must be so dissolved that the final bulk of solution is 1 oz. 6½ drs. fluid measure, or the total bulk produced by dissolving 500 grams should be 1,000 c.c.

In cold climates or in winter in this country, this solution will be found so strong that the salt will be likely to crystallise out as it stands in the bottles. In this case the solution may be doubled in bulk, and of course twice as much must be taken for development. It is advisable to keep the sodium sulphite solution in small bottles that are filled and closed with indiarubber stoppers. Then there will be no trouble from its deterioration.

Bromide of potassium is conveniently employed as a ten per cent. solution. To prepare it dissolve 1 oz. of the solid, making the total bulk of the solution equal to 9 ozs. 1 dr. fluid measure, or prepare with 100 grams a solution measuring 1,000 c.c.

An alkali is also required. It is customary to use either ammonia, or sodium carbonate, or potassium carbonate, or a mixture of the last two. The two carbonates are conveniently taken in the crystalline form and dissolved to ten per cent. solutions, taking the quantities as given for potassium bromide. The ammonia may be diluted to ten times its bulk, assuming that the strongest ammonia (s.g. .880) is at hand.

In studio portraiture as often practised, development is merely a routine operation like the fixing and varnishing of the plate; indeed, it is actually possible to apply always a uniform developer for a uniform time, and to secure what is wanted by suitable arrangements

in the lighting, exposure, etc. But in landscape work it is different. The range of light intensities varies in every view, and in every view it varies from hour to hour, and from day to day. The view cannot be regulated to suit the developer, therefore it is often desirable to adjust the development to suit the view, and it is in this that the art of development lies.

The statement that a certain formula of development is that best suited to a certain make of plate is therefore chiefly a guide to the nature of the plate. The process of development must be suited to the given subject taken on the plate employed. A maker's formula generally shows the maximum amount of alkali and the minimum amounts of restrainer, or, in other words, the most trying developer that it is advisable to employ or that the maker will guarantee his plate to bear; but these limitations will stand for little with the experienced operator.

The sodium sulphite is used to ensure a clean working developer and a negative free from the coloured products that result when pyrogallol in a simple alkaline solution is exposed to the air. It should be proportioned to the bulk of the developer rather than to the pyrogallol contained in it. It will be well to increase it a little if the amount of alkali is raised in any notable degree, or if development is to be prolonged. When sodium carbonate is used, the amount of sulphite may be from fifteen to twenty-five grains per ounce (or thirty to fifty grams per 1,000 c.c.) With ammonia less will suffice, namely, from six to eight grains per ounce (or ten to fifteen grams per 1,000 c.c.) There are some photographers who prefer to work without any sulphite. They consider that they get a certain quality in the negative which is lost when

sulphite is present. This idea is doubtless due to a want of experience in the use of sulphite. When this salt is absent there is always staining matter present in the negative due to the products of oxidation of the pyrogallol, and the image consists partly of these dark-coloured substances and partly of metallic silver. Hence, an inferior or poorly-coated plate may give a better negative when developed without sulphite because of this reinforcement of the silver image. But for certainty of result stains must be prevented, and the negative should have nothing in the gelatine film but the image in pure silver. The photographer then knows what he has, and if after-treatment of the negative is desirable he can proceed with confidence.

It has been already stated that a given formula is not suitable under all circumstances. But it is well to have a standard formula, suitable for what may be called average subjects, and it is convenient to regard the necessary modifications as variations of it. The formula that the author prefers for general purposes is—

Pyrogallol	.. 2 grains or	4 grams.
Sodium sulphite ..	.. 20 ,,	40 ,,
Potassium bromide	.. 1 ,,	2 ,,
Sodium carbonate	.. 6 ,,	12 ,,
Water to	.. 1 ounce or	1,000 c.c

The sulphite and carbonate are both crystallised, and a second proportion of carbonate may be added as development proceeds. If over-exposure is feared, it may be better to take less alkali to start with.

If the solutions above recommended are employed this developer will be made up as follows, multiplying every figure by the number of ounces of solution

required, or proportionately adjusting the grams and cubic centimetres—

Pyrogallol, solid	2	grains or	4	grams.
Sodium sulphite, 50% sol.	40	minims or	80	c.c.
Potassium bromide, 10 % ,,	10	,,	20	,,
Sodium carbonate, 10 % ,,	60	,,	120	,,
Water to	1	ounce or	1,000	,,

adding more alkali if required.

This developer will work slowly. It may be five minutes before the image begins to appear, and twenty minutes before development is complete. If a more rapid action is desired, the alkali may be considerably increased. As is subsequently shown, intensification is reliable while reduction is exceedingly uncertain; it is therefore better to develop a negative too thin than too dense.

If ammonia is preferred, this may replace the sodium carbonate, using about half the bulk of the ten per cent. diluted solution, reducing the sulphite also to about one-half.

In every case soak the plate in water first for a minute or two, taking care that no bubbles adhere to the film. Then pour off the water and apply the developer, and do not add any more alkali so long as development proceeds satisfactorily. The high lights come out first, and as these grow in intensity the other detail appears. Experience alone will guide as to when to stop development, but it will generally be advisable to go on until the whole surface of the plate shows signs of darkening, and sometimes longer still. Methods of timing development have been described in the previous chapter.

In this method of development the density of the negative grows with the detail, and it sometimes needs a little skill to prevent the high lights from getting too dense

before the dark detail is out. This is the worst accident that can happen in development, as subsequent reduction cannot be relied upon to save it. It is possible that the negative may be improved by the accident, but an improvement got unwittingly, though good for the picture, is no credit to the operator; accidental improvements form no part of scientific development.

If the high lights get too dense when development has not been unduly prolonged, give more exposure, reduce the pyrogallol and the bromide, increase the alkali, and make these changes in the order given until the desired effect is secured.

Plates that are known to be over-exposed may be soaked for a few minutes in the developer prepared with no alkali, and containing, if necessary, a considerable increase in the bromide, adding alkali afterwards in small quantities at a time.

Plates that are under-exposed only to that extent that hardness is to be feared may be developed with those modifications given for avoiding hardness; but if the under-exposure is considerable, as sometimes occurs in the use of rapid shutters, it will be found at times impossible to get the desirable vigour by development only; the action stops when all the silver salt made developable by the exposure has been developed. In such cases it appears to matter very little how the development is conducted so long as it is made as complete as possible, and intensification must be relied on for giving printing value.

Development may be carried out by getting the detail first and the density afterwards, by applying a developer that is weak in pyrogallol and restrainer to begin with

and until the plate is covered with detail, and then using a strong and well-restrained developer. But this principle is only advisable under exceptional circumstances. In a plate exposed upon a subject that presents a considerable range of brightness there must be what is commonly called over-exposure or under-exposure, or both, according to whether the exposure is suited to the darkest parts or the lightest parts of the subject, or those parts that present a medium luminosity. By putting a developer on the plate that is energetic enough to bring out the darkest detail at the same time as the high lights, the effect of the over-exposure is obtained in its full force, and consequently the high lights lose their gradation and their beauty. When the range of brightness is only small, or the exposure has been too short, this principle of development may be useful.

A developer, or "redeveloper," proposed by Mr. B. J. Edwards for the purpose of giving density after a thin image has been obtained, is as follows—

Pyrogallol	8	grains.
Sodium metabisulphite	8	,,
Potassium bromide	16	,,
Sodium carbonate (cryst.)	72	,,
Water to	1	ounce.

This may be regarded as an example of the furthest limit in concentration and restraining to which it is well to go.

A defective plate may require special precautions, but these are generally obvious. If the image shows vigorously through at the back of a gelatino-bromide plate before fixing, the coating is too thin or poor, and the plate not fit for use. As soon as any detail is developed right through the film its density ceases to increase, and the detail that was a little less luminous grows to an equal

density, and so the high lights lose their gradation and become flat. In any case development should be stopped as soon as any detail is right through on any part of the film. If all the detail is out, intensification may make a good negative of it; it not, it is useless to spend any more time on it.

CHAPTER V.

GELATINO-BROMIDE NEGATIVES. OTHER ALKALINE DEVELOPERS.

In discussing the comparative merits of these developers and pyrogallol from a practical point of view, it is usual to say that they stain less than the other. But this appears to be largely due to a misconception, because pyrogallol does not stain gelatine if it is properly used with sulphite, while without sulphite some of the others will cause worse stains even than pyrogallol. Probably each developer has its own characteristics, and, by taking advantage of these, the photographer will find that he is better able to adapt his methods to his requirements.

Hydrogen peroxide (H_2O_2), that is, two hydroxyl groups joined together, or sodium peroxide (Na_2O_2), which is strictly analogous to hydrogen peroxide, will develop if in strongly alkaline solution, caustic soda, or potash, but only slowly, and not usefully.

Hydrazine (N_2H_4), that is, two amido groups joined together, has a feeble developing power in the presence of a caustic alkali, but tends to produce a breaking up of the film, and is not practically useful.

Hydroxylamine (NH_2OH), that is, an amido group and a hydroxyl group joined together, was suggested as a developer by Messrs. Carl Egli and Arnold Spiller in 1884, the hydrochloride ($NH_2OH.HCl$) being used for convenience sake. They claim that this developer allows a wide latitude in exposure, and that the solution used

is unaffected by the air and therefore does not deteriorate during development. Gelatino-bromide plates yield with this developer a fine black image quite free from stains, but the exposure must be rather more prolonged than for other developers.

A simple solution of hydroxylamine hydrochloride appears to be useless as a developer, and the addition of ammonia or sodium carbonate makes very little difference, but with caustic potash or soda a solution can be prepared that will eventually, perhaps, get as much detail as an ordinary pyrogallol developer. The chemical changes that take place in the production of the image are probably those shown in the following equation—

$$2NH_3O.HCl + 6NaOH + 4AgBr = 4Ag + 4NaBr + 2NaCl + 7H_2O + N_2O$$

The nitrous oxide gas produced being liberated in the film tends to injure it by causing "reticulation," that is, a rough appearance due to innumerable little cracks. The caustic alkali is also troublesome from its softening the gelatine. A formula for this developer is—

Hydroxylamine hydrochloride	2 grains or	4 grams.
Caustic soda	3 ,,	6 ,,
Potassium bromide	½ ,,	1 ,,
Water to	1 ounce or	1,000 c.c.

adding citric acid one grain (or two grams) or less, if the water used is hard, to prevent the precipitation of lime carbonate (from the lime present in the water) upon the face of the negative. If the citric acid is necessary, the bromide of potassium may be omitted except in cases of over-exposure. Hydroxylamine is stated to have a considerable tendency to cause frilling (and therefore must be used in dilute solutions), and to be unsuitable for

developing plates that have received anything less than a full exposure. It has been stated that neither pure hydroxylamine nor hydrazine, even in the presence of alkalies will develop, but probably sufficient time was not allowed when negative results were obtained.

Paraamidophenol. This compound is not much used except in the prepared solution called "rodinal." Many formulæ have been proposed with widely-differing proportions of the constituents. The following approximates closely to that recommended by Andresen—

Paraamidophenol hydrochloride	2½ grains	or	5 grams.
Sodium sulphite (cryst.) ..	16 ,,		32 ,,
Potassium carbonate (cryst.) ..	14 ,,		28 ,,
Water to	1 ounce	or	1,000 c.c.

Rodinal is a very convenient form in which to use paraamidophenol. It is a concentrated solution prepared as previously described, and keeps well, especially in bottles closed with indiarubber stoppers. The following formula will be found to work satisfactorily, giving good density with fair rapidity—

Rodinal	1 part by measure.
Potassium bromide 10% solution	1 ,, ,,
Water to	10 ,, ,,

For fully timed exposures less rodinal may be used. The potassium bromide may also be reduced, but some is desirable, and it has far less effect with paraamidophenol than with many other developers.

Unal, when dissolved in water as directed, gives a solution that is the same as diluted rodinal.

Glycin acts more slowly than most developers, and gives more density with clear shadows. Therefore, it is to be recommended for black and white work, but not for ordinary half-tone subjects. In making the de-

veloper it is advised to dissolve the glycin first, and then to add the other salts.

The following formula will serve—

Glycin	6 grains or	12 grams.
Potassium carbonate (cryst.)	30 ,,	60 ,,
Sodium sulphite (cryst.) ..	30 ,,	60 ,,
Water to	1 ounce	1,000 c.c

Hydroquinone was first suggested as a developer in 1880 by Sir William Abney. It may be used without a restrainer, as it is not so vigorous a developer as pyrogallol, and for the same reason it tends to give hard negatives, and is advantageously associated with caustic alkalies instead of carbonates. The formula first proposed was twelve grains of hydroquinone with four drops of strong ammonia to one ounce of water. This was subsequently modified to from six to twelve grains of hydroquinone with one dram of a saturated solution of ammonium carbonate to one ounce of water. Since this a considerably less amount of hydroquinone has been found effective.

A formula that has been much appreciated is due to Messrs. Thomas and Co., and is as follows—

Hydroquinone	4 grains or	8 grams.
Sodium sulphite (cryst.) ..	22 ,,	44 ,,
Citric acid	1.5 ,,	3 ,,
Potassium bromide	1 ,,	2 ,,
Caustic soda	4 ,,	8 ,,
Water to	1 ounce or	1,000 c.c.

The caustic soda is kept separate from the other constituents. It may be dissolved in half of the water, which is kept apart for that purpose, mixing equal bulks of the two solutions for use. It is generally preferred to dilute this developer with at least an equal bulk of water.

The use of alkaline carbonates with hydroquinone leads to very uncertain results. The author has kept an

exposed plate under such a developer for half an hour, increasing the alkali very considerably, without a trace of developing action being visible, although, after washing, the plate developed easily with pyrogallol.

Hydroquinone is preferable to pyrogallol when density and hardness are desiderata, as in negatives of black and white subjects. Care must be taken in using it, however, as it has a tendency to cause frilling. And it is necessary to observe that it is particularly sensitive to low temperatures, so that it may work very slowly, if at all, when the solution is cooled to a temperature that would have very little effect on other developers.

Adurol is a monochlor- or monobrom-hydroquinone, and the introduction of the halogen atom has a very beneficial effect. As compared with hydroquinone, adurol does not need so much alkali, it does not work so slowly, low temperatures are not so detrimental, nor has the negative so much tendency to hardness.

The formula that has been recommended is as follows—

A.	Adurol	25 grams.
	Sodium sulphite (cryst.)	200 ,,
	Water to	1,500 c.c.
B.	Sodium carbonate (cryst.)	350 grams.
	Potassium bromide	2·5 ,,
	Water to	1,000 c.c.

For portraits take A 30 parts and B 20 parts. For landscapes A 30 parts, B 20 parts, water 20 parts.

Or a more concentrated developer may be prepared—

Adurol	25 grams.
Sodium sulphite (cryst.)	200 ,,
Potassium carbonate	100 ,,
Potassium bromide	2.5 ,,
Water to	300 c.c.

For portraits dilute to five times its bulk, and for

landscapes to seven and a half times. The image may be expected to appear in about twenty seconds, and development to be complete in four or five minutes.

Pyrocatechin may be used according to the following formula—

Pyrocatechin	5 grains	or	10 grams.
Sodium sulphite (cryst.)	12½ ,,		25 ,,
Sodium carbonate (cryst.)	25 ,,		50 ,,
Water to	1 ounce	or	1,000 c.c

Metol is probably the most used of all the newer developers. The author recommends the following formula. It may be preferable to dissolve the metol in the water before adding the sulphite—

Metol	4 grains	or	8 grams.
Sodium sulphite (cryst.)..	24 ,,		48 ,,
Sodium carbonate (cryst.)	24 ,,		48 ,,
Potassium bromide ..	½ ,,		1 ,,
Water to	1 ounce	or	1,000 c.c.

It is convenient to make the solution of double this strength for a stock solution. It will then keep in good condition for a long time. This formula is particularly adapted for rapidly developing hand-camera plates. For the more cautious development of larger plates the stock solution may be diluted with two or three times its bulk of water. To gain more control over development, metol may be used after the manner recommended for pyrogallol, by dissolving the metol and sulphite alone, and adding the alkali and bromide as required.

Metol is often called a "rapid" developer, as the image appears within a few seconds of the application of the solution to the plate, and it starts practically all over the plate at the same time, the density growing slowly. The idea that it gives thin negatives is incorrect, and arose from the fact that photographers were in the habit

of considering development complete very soon after the darkest detail was brought out. Metol is specially to be recommended when thin negatives full of detail are wanted or when it is desired to overcome a tendency to hardness, as the detail soon comes fully out, and the development can be stopped when the required density is obtained. But by continuing development metol will give probably as much density as any developer. A well-restrained or previously used solution will develop detail as the density grows, behaving similarly to an ordinary pyrogallol developer.

Several persons have found metol to cause painful sores upon the hands. It is advisable, therefore, not to let solutions of it come into contact with any wound, however small. Those who are sensitive to metol may use the formula given for eikonogen, as it is hardly to be distinguished in its working from the above metol formula, or adopt one of the many other developers now available.

Edinol (at first called paramol) is intermediate between the "phenol" (pyrogallol, hydroquinone, etc.) and the "rapid" (metol, amidol, etc.) developers, but it more nearly approaches the latter. Bromides have but little retarding action upon it. The following is the formula for a one solution developer—

Edinol	5 grains or	10 grams.
Sodium sulphite (cryst.)..	10 ,,	20 ,,
Sodium carbonate (cryst.)	25 ,,	50 ,,
Water to	1 ounce or	1,000 c.c.

A concentrated solution may be made of five times this strength, and diluted for use, and it may be diluted from five to ten times, that is, down to half the strength given above. It is advised to dissolve the sulphite first, then the edinol, and finally the sodium carbonate. Other

formulæ that have been recommended vary from the above only in having twice as much sulphite, and in keeping the sodium carbonate in one part of the solution and the edinol and sulphite in the other, to be mixed as required. For soft results more alkali may be added.

Eikonogen was introduced by Andresen in 1889, and was the first of the numerous developers that have been utilised during the last few years, and generally referred to as the newer developers. A good sample of it will keep for years without deterioration, though there have been complaints of it blackening and so becoming useless. The following formula will be found to give excellent results—

Eikonogen	12½ grains	or 25 grams.
Sodium sulphite (cryst.) ..	25 ,,	50 ,,
Sodium carbonate (cryst.)..	25 ,,	50 ,,
Potassium bromide, ..	¼ ,,	½ ,,
Water to	1 ounce	or 1,000 c.c.

This solution is conveniently prepared of double this strength by boiling the water for a few minutes to drive out the dissolved air, then adding the sulphite, carbonate, and bromide, and lastly the eikonogen. The solution will keep in good condition for many months. For fully-timed negatives the double strength solution may be diluted with three or four times its bulk of water with advantage.

For ordinary landscape negatives the alkali may be omitted from the above formula and the plates immersed in the solution containing the eikonogen, sulphite, and bromide alone. If then the exposure has been more than necessary, the image will probably develop satisfactorily without the addition of alkali. Eikonogen may thus be used after the manner recommended for pyrogallol, but

it must be remembered that the bromide has a much greater retarding effect with eikonogen. This developer cannot well be taken in the solid condition for each development, because of its sparing solubility; and to preserve it in solution sodium sulphite must be used, avoiding acids, as they decompose it.

Hydramine is a compound of hydroquinone and paraphenylenediamine. A simple aqueous solution of it will develop slowly. When used with soda, potash, trisodium phosphate, or acetone and sulphite, it gives flat negatives. The following formula is recommended—

Hydramine	2½ grains or	5 grams.
Sodium sulphite (cryst.)	16 ,,	32 ,,
Caustic lithia	1½ ,,	3 ,,
Water to	1 ounce or	1,000 c.c.

More lithia than this is stated to be useless, while less tends to flatness. This developer is very sensitive to potassium bromide.

Ortol is a mixture of methylorthoamidophenol sulphate with hydroquinone. It is regarded as intermediate in its characteristics between metol and pyro soda, and is very much appreciated by some photographers. The following formula will give some idea of the suitable proportions for this developer—

Ortol	4 grains or	8 grams.
Sodium sulphite (cryst.)..	48 ,,	96 ,,
Sodium carbonate (cryst.)	32 ,,	64 ,,
Potassium bromide ..	¼ ,,	½ ,,
Water to	1 ounce or	1,000 c.c.

A common method is to dissolve the ortol with about a quarter its weight of potassium metabisulphite in half the water, and the remainder of the ingredients in the other half, mixing equal bulks for use.

Diogen is supplied in the form of a light impalpable

powder. The makers prescribe that a quarter of a litre of water be taken, and in it dissolved sodium sulphite 100 grams, diogen 25 grams, potassium carbonate 125 grams, with subsequent filtering. For use 14 c.c. of this is diluted with 60 c.c. of water and two drops of a ten per cent. solution of potassium bromide are added. For doubtful exposures the water may be doubled.

CHAPTER VI.

GELATINO-BROMIDE NEGATIVES. NEUTRAL AND ACID DEVELOPERS.

THE greater number, and perhaps all, of the developers mentioned in the preceding chapter will develop an exposed plate without the addition of any alkali, even if care is taken that the sulphite has no alkali or alkaline carbonate in it. In many cases, however, development under such conditions is practically useless because of its slowness, extending over a whole day, for example, and often requiring a prolonged exposure.

Sometimes this method may be useful in cases of considerable over-exposure, adding a very little alkali if the image does not begin to appear for about half an hour. Pyrogallol, eikonogen, and probably metol, may be applied in this manner. It is stated that a simple aqueous solution of hydramine will develop but very slowly, and that the addition of sulphite alone does not increase its energy.

Amidol is, so far, the most important of the developers that acts normally without the addition of any alkali. Sodium sulphite must be present, and acts as an accelerator. Potassium bromide may be added freely, as increasing it has but little effect. The solution may be slightly acid without stopping development, and if desirable the action may be urged on by adding a little alkali. The image appears very quickly, as with a fresh metol solution, and slowly gains density.

Amidol solutions will not keep. It is therefore wise to dissolve it only as it is wanted, or not to make up more solution than is sufficient for one day's use. Amidol dissolves quickly in a cold solution of sodium sulphite by merely shaking it or stirring it up, though of course not so readily as pyrogallol in its ordinary feathery crystals. The following formula may be used—

Amidol	2 grains or	4 grams.
Sodium sulphite (cryst.)..	20 ,,	40 ,,
Potassium bromide ..	0.2 ,,	0.4 ,,
Water to	1 ounce or	1,000 c.c.

More sulphite will accelerate the action.

By adding a little alkali, less sulphite may be used, and the following formula will be found as serviceable as that above—

Amidol	3 grains or	6 grams.
Sodium sulphite (cryst.)..	15 ,,	30 ,,
Sodium carbonate (cryst.)	0.5 ,,	1 ,,
Potassium bromide ..	0.5 ,,	1 ,,
Water to	1 ounce or	1,000 c.c.

Diamidoresorcin is somewhat similar to amidol. It develops more slowly and potassium bromide is stated to retard its action energetically. The following formula will indicate the manner of its use—

Diamidoresorcin hydrochloride ..	2½ to 5 grains or	5 to 10 grams.
Sodium sulphite (cryst.)..	30 ,,	60 ,,
Water to	1 ounce or	1,000 c.c.

To urge on development add more sulphite up to about three times as much as stated, or a little weak alkali solution; to retard it, add a little acid or bromide.

Triamidophenol hydrochloride gives a yellow solution with sodium sulphite, and is used in a similar way to the two preceding developers.

Quinomet (first called Metoquinone), a crystalline

compound of metol and hydroquinone, will develop without the addition of an alkali, though not so quickly as amidol.

Quinomet	9 grams.
Sodium sulphite (cryst.)	120 ,,
Water to	1,000 c.c.

gives a colourless single solution developer. By adding ten grams of sodium carbonate the rapidity of development is increased from two to three times.

Diphenal is supplied as a ready-made developer in the form of a brownish solution. The developing agent is diamido-oxydiphenyl, which is hardly soluble in cold water, or solutions of alkaline carbonates or sulphites. It is therefore not advantageous for the photographer to prepare his own developers from the separate ingredients. The commercial solution may be diluted with from fifteen to twenty times its bulk of water, varying this to from eight to ten for known over-exposure, and from twenty to twenty-five for under-exposure. For much under-exposure it is recommended to add a little caustic soda.

CHAPTER VII.

GELATINO-BROMIDE NEGATIVES. VARIOUS ALTERNATIVES IN DEVELOPMENT.

THE preceding chapters have given the simplest and most usual formulæ and methods. These may be varied in many ways, but, as generally the same variations are applicable to all (or at least the greater number) of the developers given, it is convenient to consider these variations in a general sense.

Retarders. Some photographers appear to consider that a peculiar advantage results from the total omission of a retarder from the developer. All such claims must be received with caution, because, as already remarked, commercial plates often contain a small quantity of a soluble bromide in the film. With some plates the omission of bromide from the developer will allow of a considerable reduction of the exposure; the plate becomes practically more sensitive. But immediately development begins, alkaline bromide is produced by the bromine removed from the silver salt.

IODIDES, such as potassium iodide, are stated to quicken the appearance of the image, but to render it necessary to develop for a longer total time. By doubling the exposure and adding to the developer about half a grain of potassium iodide and an eighth of a grain of potassium bromide to each ounce, the development is slow, and the negative shows much contrast.

CITRATES OF THE ALKALIES were suggested for use

as restrainers by Mr. Watmough Webster more than twenty years ago. They have a different effect from potassium bromide, especially if added after development has begun. In sufficient quantity they prevent the development of more detail but not the increase of density, and hence are very valuable in cases of over-exposure. As to quantity, an alkaline citrate may be added to the extent of from two to six or even twelve or more grains to the ounce. Six grains to the ounce will probably be found sufficient as a powerful retarder of detail development in cases of ordinary over-exposure. The citrates work well with pyrogallol and eikonogen, and probably with the greater number, if not all, the usual developers. Ammonium citrate was preferred either to potassium or to sodium citrate at first, but this was with pyro ammonia developers. The ammonium salt is still recommended even with sodium carbonate as the alkali, but this practically converts the soda developer into an ammonia developer. It would be safer to use potassium or sodium citrate in a potash or soda developer.

THE OXIDATION PRODUCTS OF DEVELOPERS in general have been stated to exert considerable influence in retarding development, but this has been contradicted by Dr. Luppo-Cramer, who states that the retarding effect of old developers is due simply to the bromide that they contain.

In cases of considerable over-exposure it is possible partially to undo the light effect, that is, partially to destroy the developable image. This matter is considered more in detail in the subsequent chapter on solarisation.

Accelerators. Several alternative accelerators have been proposed. Caustic soda or potash may be used instead of the carbonates, and offers a distinct advantage with

a developer such as hydroquinone, which tends to work sluggishly and to give hard results with the milder alkaline carbonates. Caustic soda is used in the preparation of rodinal, and with phenolic developers will sometimes prove advantageous if the amount is limited to the quantity that will produce a phenolate of the alkali. In any case the caustic alkalies must be sparingly used because of their action on gelatine, and especially with hydroquinone, which itself has a considerable tendency to cause frilling.

TRIBASIC SODIUM PHOSPHATE may be practically regarded as a mixture of caustic soda and sodium phosphate, and its convenience appears to be only that it is a little more permanent when exposed to the air than caustic soda, and, being crystallised, is easier to manipulate. Its use was suggested in 1895 by Messrs. Lumière and Seyewetz, who recommended the following formulæ, keeping the phosphate and half the sulphite in a separate solution for adding when required—

		Sodium Sulphite.	Tribasic Sodium Phosphate (cryst.)	Water.
Pyrogallol ..	..	10	30	26 to 40	1,200
Hydroquinone	..	10	40	80 , 140	1,200
Eikonogen ..	..	6	24	144 ,, 216	1,200
Metol ..	..	9	45	90 ,, 120	1,200
Glycol ..	..	18	48	150 ,, 240	1,200
Paraamidophenol ..		7	200	160	1,200

By calculation this salt should be equivalent to about one-tenth of its weight of caustic soda.

ACETONE, in the presence of sodium sulphite, which is necessary to render it active, has the advantage over the tribasic phosphate of not giving caustic alkali when added to the solution that is to constitute the developer, but of providing, as it were, a source of alkali that can be drawn upon as development proceeds to exactly the

required amount. The developer, therefore, does not suffer from the ordinary disadvantages that result from the solution being alkaline, it is not oxidised so readily by the air, nor is it so likely to stain the gelatine film.

Acetone, while without action on the normal sulphites, combines with the acid sulphites of the alkalies forming definite compounds. In order to understand the action of the acetone, imagine an exposed plate covered with a solution containing a developing agent and sodium sulphite. Now, the addition of alkali will start development at once, and if the exposure has been considerable, or if a long time be allowed, development will take place even without adding the alkali. The change that takes place in such a case may be represented thus—

Silver Bromide.	Sodium Sulphite.	Water.	
Ag Br	Na SO_3Na	H	Developing
Ag Br	Na SO_3Na	H O	agent.

becoming as development proceeds—

Silver.	Sodium Bromide.	Sodium Bisulphite.	
Ag	Br Na	SO_3NaH	Developing
Ag	Br Na	SO_3NaH	O+ agent.

But the sodium bisulphite being an acid substance very much retards development, and under ordinary conditions prevents it from taking place. Acetone, however, can combine with the bisulphite, rendering it inert, very much as an alkali would by neutralising its acidity. The acetone, therefore, determines the change by practically effecting the neutralisation, though no alkali is ever present.

The tendency of the developer to oxidise being reduced by the fact that it is not alkaline, the amount of sulphite may be somewhat reduced. Taking a ten per cent. solution of crystallised sodium sulphite, four or five

grains of pyrogallol may be added to each ounce, and then acetone in small quantities at a time if over-exposure is feared, otherwise in any quantity not exceeding a maximum of ten per cent. (fifty minims to each ounce). An increase of acetone beyond ten per cent. is useless, except, as in developing lantern slides, when the colour of the image is required to be modified. Sixty per cent. of acetone gives an image approaching a red colour. It is obvious that acetone is not so useful with those developers that are difficultly soluble except in the presence of an alkali.

FORMIC ALDEHYDE acts in a manner similar to acetone, and at the same time hardens the gelatine film. About ten minims of formaline to the ounce of a hydroquinone developer may be tried. But formic aldehyde has too much tendency to produce stains and fog to be advantageous.

"FORMO-SULPHITE" is a mixture of—

Trioxymethylene	3 grams.
Sodium sulphite (anhyd.)	100 ,,
Potassium bromide	A little.

It is a dry powder easily soluble in water, though the trioxymethylene alone is insoluble. When the formo-sulphite is dissolved, it is only necessary to add a developing agent to produce a complete developer, the trioxymethylene playing a similar part to acetone or an aldehyde. The following formulæ are recommended—

Water	100 c.c.
Formosulphite	9 grams.
Pyrogallol	1 gram.
Water	100 c.c.
Formosulphite	9 grams.
Metol	1 gram.
Water	100 c.c.
Formosulphite	8 grams.
Metol	½ gram.
Hydroquinone	1 ,,

ALTERNATIVE ACCELERATORS.

"PINAKOL SALT N" is a twenty per cent. solution of sodium amido-acetate, and serves as a substitute for alkalies in development. The makers give formulæ made by adding ten per cent. by volume of the commercial solution to a pyrogallol developer, twenty per cent. in the case of pyrocatechol, thirty per cent. in the case of glycin, and from seven to about twenty-five per cent. with paraamidophenol, in each case, instead of alkali.

"PINAKOL P" is a one solution developer containing pyrogallol, sodium sulphite, and sodium amido-acetate.

Preservatives. As a preservative during development no reagent has been shown to be superior to sodium sulphite. Potassium or sodium metabisulphite is better for keeping a solution of pyrogallol, because it is acid, but is not advantageous in one-solution developers because when neutralised it is no better than sodium sulphite, and the quantity of alkali that it neutralises is often uncertain. Acetone sulphite does not appear to the author to offer any advantage over sodium sulphite.

CHAPTER VIII.

GELATINO-BROMIDE NEGATIVES. DEVELOPMENT WITH FERROUS OXALATE.

FERROUS oxalate is the yellow powder obtained by warming a mixture of solutions of ferrous sulphate and oxalic acid. It is practically insoluble in water, but dissolves to a certain extent in solutions of alkaline oxalates, that is, the oxalates of potassium, sodium, and ammonium. Of these the oxalate of potassium is preferred, because it yields a stronger solution than either of the others. The oxalate of potassium used must be the neutral oxalate, and this salt as purchased may be sufficiently distinguished from the other oxalates of potassium by its not turning litmus paper red, but inclining rather in the opposite direction. For use, a saturated solution of potassium oxalate is required, and this is conveniently prepared by shaking the powdered salt with three times its weight of water. This solution will be alkaline, and may be made *just* acid by adding a strong solution of oxalic acid drop by drop as required, or a little of the finely-powdered acid itself, though this is not often necessary. The solution is then filtered, and will keep indefinitely.

The most powerful developer is made by adding solid ferrous oxalate to the boiling solution prepared as above until no more is dissolved, and allowing the solution to cool in well-corked bottles. Or, instead, the yellow oxalate of iron may be shaken with the cold potassium oxalate solution at intervals during two or three days. But the

most convenient form of this developer, though weaker than either of the above, is made without the prepared ferrous oxalate at all, by simply adding a solution of ferrous sulphate to the potassium oxalate solution. The maximum amount of the saturated ferrous sulphate solution is one-third the bulk of the potassium oxalate. If this amount is exceeded there is not a sufficient excess of potassium oxalate to hold in solution the ferrous oxalate that is formed, and a yellow deposit of ferrous oxalate is likely to disfigure the negative. It is much to be preferred always to use at least four times as much potassium oxalate solution as of the ferrous sulphate solution. When these two salts are mixed, the following reaction takes place—

$$FeSO_4 + K_2C_2O_4 = FeC_2O_4 + K_2SO_4$$

The potassium sulphate is useless, but inert, and the ferrous oxalate produced is kept in solution by the large excess of potassium oxalate present.

In the actual development of landscape negatives, it is better to add the ferrous sulphate solution in smaller portions, beginning, say, with a quarter of the whole amount that it is allowable to add; but there is no need for this precaution if the exposure is known to be suitable for the prepared developer, as is generally the case in portraiture, copying, etc.

For outdoor work, a little potassium bromide is generally necessary as a restrainer, but it must be sparingly added except when exposure has been needlessly prolonged. It may also be used in studio work, though some operators consider that a finer quality of negative is obtained if it can be dispensed with.

A maximum of about ten drops of a solution of

hyposulphite of soda containing two grains in each ounce may be added to each ounce of the developer in cases of under-exposure. The action of the sodium hyposulphite is unknown, but it may be that by its solvent action upon bromide of silver it brings this into a more intimate contact with the developer. Other explanations have been suggested, but they do not appear to meet the case.

It has been stated that the sodium hyposulphite does not secure any detail that could not be got without its aid, and that therefore it only compensates for under-exposure in an indirect way. That its action is to quicken development, and hurry out the dark detail before the high lights have had opportunity to get too dense. Granting this to be so, it is a cure for the hardness generally characteristic of under-exposed negatives rather than for under-exposure itself, but others state that they find it most potent in bringing out detail that could not be developed without its aid.

The action of the ferrous oxalate upon the silver bromide is expressed by the following equation—

$$3AgBr + 3FeC_2O_4 = FeBr_3 + Fe_2(C_2O_4)_3 + 3Ag$$

and as the ferric salts produced have a directly opposite action to the ferrous salts, the developer does not merely lose strength as it is used, but the amount of restrainers increase at the time when it would be preferable if they were to diminish.

It is possible to strengthen the developer as the work proceeds by adding the ferrous sulphate in portions as mentioned above, or an old developer may be used to start with, and this may afterwards be replaced by the new and energetic developer.

DEVELOPMENT WITH FERROUS OXALATE.

As the development results in the production of ferric salts, and as these salts have an action exactly opposite to that which the original ferrous salts have, it is obvious that an exhausted developer still contains a large amount of ferrous compounds that would be useful if they could be separated from the solution. There is no ready way of doing this, but it is possible to reduce the ferric salts to the ferrous state, and so not only stop their harmful action, but render them in considerable measure available for use over again. By exposing the old developing solution to light the ferric oxalate is decomposed into ferrous oxalate and carbonic anhydride, thus—

$$Fe_2(C_2O_4)_3 = 2FeC_2O_4 + CO_2$$

This action is slow because the red colour of the solution hinders the chemically active light from penetrating intc the bulk of the solution.

Metallic zinc may also be used to regenerate the developer. It takes from the iron the bromine that has been added to it during development, thus—

$$2FeBr_3 + 2Fe_2(C_2O_4)_3 + 3Zn = 3ZnBr_2 + 6FeC_2O_4$$

The zinc acts rather slowly, and produces its effect upon those parts of the solution only that are in immediate contact with it; therefore, the zinc should be clean and its surface extensive. The bromide of zinc produced will not remain as such, but will probably cause a white deposit of oxalate of zinc, leaving the bromine in combination with the potassium. Thus the regenerated developer is not brought back to its original condition; it has an additional amount of restrainer. Some operators like old developers because they give brilliancy, though they hesitate to add a restrainer to a new developer;

they like the effect of the bromide when they do not know that it is present.

Ferrous oxalate is not much used for development, although there was very much prejudice in its favour a few years ago. As compared with organic developers, it is more costly, more troublesome to use, and requires more exposure of the plate. It cannot give organic stains, but it is liable to give a slight brownish tint to the gelatine, while alkaline developers if properly used leave the gelatine absolutely colourless. Any advantages that ferrous oxalate offers are so trivial, and are counterbalanced by so many disadvantages that it is not to be recommended as a developer. It has, however, other uses, as in intensification, where it stands alone. Its one merit is that it produces clean results without a sulphite. If, therefore, it is desired to avoid the presence of sulphites in any experimental work, ferrous oxalate is the developer to employ.

CHAPTER IX.

GELATINO-BROMIDE NEGATIVES. FIXING, ETC.

WHEN the developed negative is thoroughly washed it may be taken into ordinary light without fear of deterioration, but if it is not washed, the adhering developer may produce fog by causing reduction all over the plate, and stains are likely to result. It is therefore better to fix the negative before it is taken out of the dark room.

The fixing of the negative is the dissolving away of the silver compound or compounds in the film without injury to the image itself, which consists of very finely divided metallic silver. If it were simply a matter of dissolving bromide of silver, potassium cyanide would be selected, for a comparatively dilute solution of this reagent works rapidly and produces a double cyanide of potassium and silver which is easily washed out.

$$AgBr + 2KCy = KBr + AgCy,KCy.$$

But potassium cyanide is not to be preferred because it dissolves to a perceptible extent the finely divided silver that constitutes the image. The oxygen of the air takes part in the action, giving the double cyanide of silver and potassium and caustic potash, but it is not possible practically to exclude the air.

Potassium bromide will combine with silver bromide, forming a double salt (KBr,AgBr), but this compound could not be washed out of the film with water, as water decomposes it into its constituents. Various other substances have been suggested for fixing, especially sodium

sulphite and ammonium sulphocyanide, but none of the reagents suggested up to the present are likely to supersede sodium hyposulphite, because their capability of dissolving silver salts is in most cases considerably less; some of them attack gelatine, and all of them are more expensive and far less efficient.

Sodium hyposulphite has advantages not possessed by any other known solvent of silver compounds. It attacks metallic silver in the presence of the air, but so slowly that its action upon the image may be quite disregarded in the ordinary process of fixing. It has very little effect upon the gelatine itself, and the soluble compound that it forms with silver salts when properly used is easily soluble in water without decomposition. The sodium hyposulphite first changes the silver bromide into silver hyposulphite, thus—

$$2AgBr + Na_2S_2O_3 = Ag_2S_2O_3 + 2NaBr.$$

and a further quantity of the sodium salt combines with the silver hyposulphite to form a double salt. There are two double hyposulphites of silver and sodium, $Ag_2S_2O_3$, $Na_2S_2O_3$ and $Ag_2S_2O_3$, $2Na_2S_2O_3$. The first is practically insoluble in water, but the second is very soluble.

The double salt itself, when in solution, is readily decomposed, the hyposulphite of silver being changed into sulphide of silver, which is black and insoluble, thus—

$$Ag_2S_2O_3 + H_2O = Ag_2S + H_2SO_4.$$

But in the presence of excess of sodium hyposulphite this decomposition is scarcely possible. For this reason it is necessary to have a large excess of the sodium salt.

The usual formula for the fixing bath is—

Sodium hyposulphite ..	4 ounces	or 200 grams.
Water to	1 pint	1,000 c.c.

and this strength is specified merely because if much stronger the solution may not be able to penetrate the film so rapidly, and if much weaker it acts more slowly because its dissolving power is reduced.

It is preferable to dissolve the sodium hyposulphite at least a day before it is required, as this gives time for a slight turbidity that shows on first dissolving it to settle down. The simple solution will keep a very long time without an appreciable loss of fixing power, but if an old solution is to be used it is well to test it for acidity, and to add a little alkali if necessary.

Alkaline fixing bath. There is considerable advantage in adding a little sodium carbonate and sodium sulphite to the fixing bath, to prevent the possibility of the liberation of sulphur from it, and to keep the oxidised products of the developer in solution, and so avoid staining. The quantities are not very important, but the following will serve as an example—

Sodium hyposulphite ..	4 ounces	or	200 grams.
Sodium carbonate (cryst.)	20 grains		2 ,,
Sodium sulphite (cryst.)	100 ,,		10 ,,
Water to	1 pint		1,000 c.c.

With this exception, nothing should be added to the hyposulphite of soda. Alum and acids decompose it with precipitation of sulphur and liberation of sulphurous anhydride, thus, with hydrochloric acid—

$$Na_2S_2O_3 + 2HCl = 2NaCl + SO_2 + S + H_2O.$$

The sulphurous anhydride may have a cleaning action upon the film, but it is produced in this case at the expense of fixing power, and it is exceedingly doubtful whether it has any cleaning effect at all. Alum, so far as it hardens the film—and it is useless if it does

not—actually retards the fixing and tends to render it incomplete.

After development the negative should only be rinsed to remove the solution that adheres to its surface, and then at once placed in the alkaline fixing bath. It should not be considered fixed and ready for washing until it has remained in the fixing bath for about twice as long as was required before the visible milkiness of the film was removed. Fixing is not complete until an excess of hyposulphite of soda has reached every part of the film.

The amateur who works only occasionally should always take a fresh quantity of hyposulphite of sodium solution for every three or four negatives developed, and when much work is done it is better to have two fixing baths always in operation, and to give each negative fixed in the first a minute or two of soaking in the second. When the first bath shows signs of exhaustion by working slowly, it is rejected; the second bath now becomes the first, and a new second bath is taken into use. To be sparing of hypo, or to use its solution until it can act no longer, is bad policy; because the salt is cheap, and the life of the negative depends upon its being thoroughly fixed.

An acid fixing bath has been much recommended of late, the idea being that the negative may be fixed and "cleared" at the same time, and the hyposulphite solution remain comparatively free from colour. It is, however, an incomplete knowledge of the facts of the case that leads to the use of acid solutions for clearing purposes. After alkaline development especially, an alkaline fixing bath is to be recommended, and by the proper use of sulphite in the developer, clearing will be rendered unnecessary.

Those, however, who desire to use an acid fixing bath

will find it convenient to replace the carbonate and sulphite in the above formula by—

Sodium sulphite ..	..	½ ounce or 20 grams.
Sulphuric acid ..	..	20 minims or 2 c.c.

the acid after dilution to be added to a solution of the sulphite, and the mixed solution added to a solution of the hyposulphite, the whole being then made up to the total bulk named. But it must be insisted on that an acid fixing bath of any kind is a grave source of danger. The negative may appear satisfactory for some time, perhaps even improved by the use of it, but no one can tell what hidden possibilities of change remain in the film.

If the negative has been developed, rinsed, and fixed as recommended, it will only need a thorough washing before it is put to dry. The washing may with advantage be extended to from one to two hours, or even more, according to the thickness of the film.

If the film shows a tendency to frill, that is, to separate from the glass at the edges of the plate, and if the frilling appears likely to extend to the image, the negative may be put into a saturated solution of alum for a few minutes after washing it as long as appears safe, the washing being continued after the treatment with alum. Formic aldehyde has been recommended for hardening gelatine. The negative may be immersed in a dilute solution of it (formaline diluted with ten times its bulk, or more, of water), or the vapour given off from a stronger solution may be caused to act on the film. But the film should not be hardened unless it is really necessary to do so, as it will then require a more protracted washing. Hardening gelatine renders it less easily permeable by water.

CHAPTER X.

GELATINO-BROMIDE NEGATIVES. CLEARING, HYPO-ELIMINATORS, ETC.

If a negative needs "clearing" it has been faultily made. If developed in a properly compounded developer, rinsed (not washed, for dilution of the developer remaining in the film tends to produce stains), and fixed in an alkaline fixing bath as recommended in the last chapter, and then thoroughly washed in water, it will be free from stains or any colour due to the developer.

A too prolonged development, the use of an inferior sample of sulphite, and other accidents, may lead to the production of stained negatives, so that the removal of stains must be considered by practical photographers. Stains are of various kinds. A metallic shimmer, especially liable to show on old plates and particularly round the edges of them, is superficial and may be rubbed off, sometimes dry, but it is generally better to soak the plate thoroughly and rub it gently with a small wet pad of cotton wool. Sometimes a coloured stain is due to a deposit on the surface of the film; if so, it may generally be detached in the same way.

The stains that most frequently have to be dealt with or guarded against are those due to oxidation products of the developer, and are of a brown or reddish brown colour, and within the film. Nothing of this sort ought to be allowed to remain in the negative either as a part of the image or otherwise, because the staining matter

is liable to change, its amount cannot be controlled, and because its quantity and optical effect will never be properly proportional throughout the negative. It is itself uncertain in every way, and it will render any after operation, such as intensification, uncertain in its effect. In dealing with methods of getting rid of staining matter, it is convenient to include prints as well as negatives, and to note that the clearing reagent often acts, or is supposed to act, also as a "hypo-eliminator."

Alum was used by Sir W. J. Newton as early as 1855 and even earlier to remove hyposulphites and other impurities from developed prints. Since then its introduction has been ascribed to several people.

Hydrochloric acid was used by Mr. W. Cobb in 1879, that is, in the very early days of gelatine plates and before the use of sulphites, when alkaline pyrogallol developers blackened terribly during use. Mr. Cobb used strong hydrochloric acid diluted with eight times its bulk of water. Since then much greater dilutions have been proposed.

Soaking all night in an alum solution, or a fixing bath, or dilute peroxide of hydrogen, was recommended in 1880. Probably plain water would have been equally or more effective.

Sulphites as stain preventers were introduced by Mr. H. B. Berkeley in 1880.

Acid and alum was suggested by Mr. H. B. Berkeley in 1880, as a saturated solution of alum with one dram of hydrochloric acid added to each four ounces, the plate to be immersed for "several minutes." Less acid has since been proposed, such as half an ounce to the pint. Mr. J. Cowell, in 1881, proposed citric acid, and then citric acid

two ounces, alum one ounce, to water ten ounces, adding about two-thirds as much water for use.

Copper sulphate in conjunction with acid or acid and alum was proposed by Mr. T. Furnell in 1882, with two hours immersion, "several hours" doing no harm.

Ferrous sulphate with alum and acid was proposed by Mr. B. J. Edwards in 1883.

Alum	1 ounce.
Citric acid	1 ,,
Ferrous sulphate	3 ounces.
Water to	20 ,,

Innumerable modifications of the above solutions have since been proposed, using chrome alum, acid sulphites, etc.

Ammonium thiocyanate and nitric acid, three grains of each dissolved separately in one ounce of water and mixed immediately before use, was recommended in 1892 for removing silver stains.

Thiourea (or thiocarbamide) two parts, citric acid one part, to water one hundred parts, was recommended in 1893 by Mr. A. Bogisch for removing pyrogallol stains. A year later Dr. J. M. Eder advised one part of each in one hundred parts of water.

The author's investigations, published in 1890, experimentally demonstrated that all clearing solutions hitherto proposed were founded on wrong principles. This enquiry referred to pyrogallol, hydroquinone, eikonogen, and ferrous oxalate; but subsequent work has shown that the results obtained are of general applicability to the more recently introduced organic developers. These investigations showed that alum actually retards the washing away of stains, because, presumably, it makes the film less easily penetrable by water. That acids, although they do lighten the colour of the staining matter, render it insoluble, and

so fix it in the film instead of removing it from the film. That the staining matter as lightened by acids is darkened again by alkalies, and is liable also, in any condition, to changes of colour, the reasons for which are obscure. That staining matter is soluble in water, and may therefore, in the absence of acids, be washed away with the exception of a very small remainder in the case of pyrogallol, and rather more with hydroquinone. That this small part cannot be washed away and is not apparently affected by any clearing solution known, except the one that contains ferrous sulphate, and that this darkens the stain. The correctness of these conclusions has been confirmed again and again.

Caustic soda in the form of a very weak solution, just enough to render the water alkaline, the author recommends as the best clearing solution. The staining matter is by its use kept in a soluble condition, so that it may be really washed away, and it is also kept in its most highly coloured form, so that its removal is clearly perceptible. It is the solubility of the organic oxidation products in alkalies and their insolubility in acids that make the alkaline treatment throughout desirable. The developer is alkaline, the fixing bath should be alkaline, then with careful work there will be no stains, but if developer stains do show, it is perseverance in washing with alkaline water that will best remove them. And no exception can be made in favour of the use of thiourea so far as the author's experience is concerned.

Hypo-eliminators. On the whole, there can be no doubt that efficient washing with plain, or slightly alkaline, water (the important point is to avoid acids) is the best method of getting rid of the hyposulphites after fixing;

There have been many attempts made to decompose the thiosulphates that remain after a comparatively short washing so as to save time, but none of them are satisfactory. The chief reason for thoroughly getting rid of hyposulphites is to leave a clean film with nothing in it liable to change, one that may be treated by intensification processes if necessary. Certainly, therefore, if any method of hypo-elimination will leave anything that can give a precipitate with a solution of mercuric chloride, it is not efficient.

Alum is doubtless the first recorded hypo-eliminator, as it was used for this purpose by Sir W. J. Newton before 1855. It certainly does attack sodium hyposulphite, but its action is far from simple, and the products of it are very undesirable.

Sodium hypochlorite was proposed by Mr. F. W. Hart in 1866, after having used the less convenient mixture of chlorine water and barium chloride in 1864. The method was specially intended for paper prints, and consisted of treating them with a very weak solution of hypochlorite until the prints no longer discharged the blue colour of starch paper made blue with iodine. Such paper is bleached by hyposulphites and made blue again by hypochlorites. The print was then washed with very weak ammonia to dissolve out a little silver chloride formed during the reaction. This method is effective, for the hyposulphite is completely oxidised to sulphate. Sulphates are inert, but in the presence of organic matter, such as paper, and moisture, they are liable to be reduced to such injurious compounds as sulphides. It does not appear more easy to wash away the sulphate than the hyposulphite, therefore the final advantage is doubtful. But if any method of

chemical hypo-elimination is good this is the one to be preferred, for it appears to be the only one that completely oxidises the hyposulphite.

Hydrogen peroxide was proposed by Dr. R. Angus Smith, and immediately afterwards, if not at the same time, by Mr. J. Spiller, in 1866. Both these gentlemen were mistaken in supposing, because some sulphate is produced immediately when the peroxide is added to sodium hyposulphite, that therefore the oxidation was complete. Less than one-third of the sulphur present as hyposulphite is converted into sulphate at once, and after even six days more than half the sulphur remains not as sulphate, and the solution readily gives a precipitate with mercuric chloride. The peroxide, when it first acts upon the thiosulphate, produces a mixture of trithionate and sulphate, thus—

$$2Na_2S_2O_3 + 4H_2O_2 = Na_2S_3O_6 + Na_2SO_4 + 4H_2O,$$

and the trithionate, being very unstable, soon begins to change with the production of tetrathionate, and this in its turn slowly decomposes into other undesirable substances. Therefore this reagent is useless.

Iodine was suggested by Dr. Vogel in 1872, a few drops of the tincture being added to water giving a light straw coloured solution, and the print immersed in repeated baths of this until the liquid was no longer decolourised quickly, or until the paper was turned bluish, showing excess of iodine. The author has tested this method repeatedly, using a solution of iodine in an aqueous solution of potassium iodide, and the life of an unwashed print is certainly prolonged by the treatment. But iodine by its action on sodium thiosulphate gives the tetrathionate,

and this latter compound is as faulty as the hyposulphite so far as its action on mercury salts is concerned. Moreover, the tetrathionate itself is not stable. This method, therefore, is inferior to the treatment with hypochlorite, and is useless for negatives, though it may be advantageous for prints wanted in a hurry.

Potassium persulphate was introduced under the name of "anthion" by Messrs. Schering in 1895. A solution is made of five grams to the litre, and the plate, after five minutes washing, is allowed to remain for five minutes in the prepared solution, washed again for five minutes, and the treatment and washing repeated. The action of the persulphate appears to be similar to that of hydrogen peroxide or iodine, for the power of a solution of sodium thiosulphate to give a precipitate with mercuric chloride is very little affected by it even after an excess of it has acted on the thiosulphate for two days. The persulphates dissolve metallic silver, so that prolonged action on a photograph is not permissible.

Other methods have been proposed, of which a saturated solution of alum, acidified or not, and weak hydrochloric acid are the most worthy of mention. For practical purposes, if anything at all is desirable, the negative after a thorough washing may be soaked for a minute or two in very weak hydrochloric acid and then washed again. But as a rule simple washing should be relied upon.

CHAPTER XI.

GELATINO-BROMIDE NEGATIVES. REDUCING.

WHEN the image of a negative has been made too dense, so that it gives a print with too much contrast, it may sometimes be improved by reduction. In the early days of gelatine negatives, before sulphites were used in the developer, the image consisted largely of the coloured products of oxidation of the developer, and the removal of this staining matter effected a considerable reduction of the image. It is usual now to speak of the removal of staining matter as "clearing," and a change that affects the silver image itself as "reduction."

If the negative is simply over-developed, a proportional reduction throughout is desirable, but if it is fogged it may be wished to remove more of the deposit in the thinner than in the denser parts, and so make a brighter negative. The image in a glass-supported gelatine film is on the outer surface of the film, and penetrates more deeply into the film as the part is more opaque. The reducing solution that is brought to bear upon the negative must begin its action at the outer surface of the film, and if it penetrates and acts completely as it goes, dissolving away the image, the shadow detail will be rapidly thinned, and may be altogether removed before the high lights are much affected. Generally, in reduction, therefore, the thin parts of the image are affected to a greater proportional extent than the dense parts. Methods of reduction are, therefore, of two kinds: (1)

Those that act in a simple way and unproportionally, and (2) those that produce an approximately proportional effect upon the image.

The simplest reducers, that is, those that dissolve away the silver from the outer surface of the film downwards, act by changing the silver of the image partially into some compound, such as the chloride or bromide, and dissolving away this compound. There are many ways of changing the silver into its haloid salt, and there is little to choose between them. Ferric chloride, chloride of lime, sodium hypochlorite (called eau de Javelle), or the corresponding potassium salt, either will, by the simple application of its dilute solution, effect the change. With ferric chloride, which may be used of such a strength that the solution is of a light sherry colour, for example, we have—

$$Ag + FeCl_3 = AgCl + FeCl_2$$

The chloride of silver is then to be dissolved away by refixing the plate, and the reduction is complete. The drawback to this method is that the extent of the reduction is determined by the first action, but is not clearly visible until the sodium hyposulphite has dissolved off the compound formed. What is wanted is that the acting and the dissolving ingredients shall be mixed, and thus that the reduction shall go on only as it proceeds visibly.

But this is a problem not so easily solved as might at first sight appear, because the hyposulphite is easily oxidised by any of the reagents mentioned. With ferric chloride, for instance—

$$8FeCl_3 + Na_2S_2O_3 + 5H_2O = 2HNaSO_4 + 8FeCl_2 + 8HCl$$

the ferric chloride is changed to ferrous chloride, and is

therefore robbed of its power to impart chlorine to the silver of the negative.

A method that combines in one solution the oxidiser (that is, the source of chlorine) and the solvent of the silver salt produced was suggested in 1883 by Mr. J. Spiller. He used a solution of cupric chloride mixed with a saturated solution of common salt. The cupric chloride gives chlorine to the silver—

$$CuCl_2 + Ag = CuCl + AgCl$$

and the common salt dissolves away the chlorides produced.

Mr. E. Howard Farmer about the same time published a far neater method, and one that has met with considerable favour. For the oxidiser he employs ferricyanide of potassium, because, while it is perfectly effective, it may be mixed in solution with sodium hyposulphite quite long enough for use before a very appreciable amount of reaction takes place between the two compounds.

The action of potassium ferricyanide upon the silver of the image is quite analogous to the action of ferric chloride given above, and in reality just as simple. Just as the $FeCl_3$ gives up a part of its chlorine and becomes $FeCl_2 + Cl$, so the K_3FeCy_6 gives up a part of its $FeCy_6$ to the silver—

$$4K_3FeCy_6 + 4Ag = 3K_4FeCy_6 + Ag_4FeCy_6$$

and forms, according to this equation, the ferrocyanide of silver. It appears that some ferricyanide of silver is formed under certain conditions, though it is scarcely possible in this case in the presence of sodium hyposulphite If the ferricyanide is produced it is by an analogous reaction—

$$4K_3FeCy_6 + 3Ag = 3K_4FeCy_6 + Ag_3FeCy_6$$

and it matters nothing practically which silver compound is obtained, for either is no sooner produced than it dissolves in the sodium hyposulphite.

Though the precaution is not necessary, it is advisable to use a freshly-prepared solution of potassium ferricyanide for this process, because this salt in solution is very easily decomposed by light or by contact with organic dust, etc. To reduce a negative, first soak it in water for a few minutes, and replace the water with a solution of sodium hyposulphite containing two ounces to the pint. While soaking in this put a crystal or two of the ferricyanide into a conical glass, and run water on and pour it off until the crystals are clean and of a bright ruby red. Add a little water, agitate for a few seconds, pour the solution so prepared into a glass, add the hyposulphite solution from the negative, and re-apply. Add more ferricyanide solution if the yellow colour of the mixed solution disappears, or if the reduction is too slow. After treatment, wash the negative as necessary after the usual fixing.

Sodium amido-acetate (pinakol salt N) is a solvent of silver salts, and is not affected by mixing it with potassium ferricyanide. Dr. B. Homolka, in 1903, recommended the following as a permanent solution for reducing—

Potassium ferricyanide	5 grams.
Dissolved in pinakol salt N	100 c.c.

preserving the solution in a coloured stoppered bottle.

Mr. L. Belitzki, in 1883, suggested a reducer that has the advantage that the whole solution may be kept ready for use, if stored in the dark. He used the green crystals of potassium ferric oxalate that separate from an old ferrous oxalate developer.

Potassium ferric oxalate	5 to 10 parts.
Sodium hyposulphite, a 20 % solution	100 ,,

Even the smaller proportion of the ferric salt will be found to act rather quickly, and the plate should be removed from the solution for washing before the reduction has gone quite as far as desired. Two years later Dr. Eder suggested a modification, as the ferric salt is not always easy to procure.

Ferric chloride ..	1 part in 8 parts of water.
Potassium oxalate ..	2 parts in 8 ,, ,,

Equal bulks to be mixed just before use, or the mixture will keep for a few days in the dark. This solution to be added to hypo solution (twenty per cent.) as required up to a quarter or a half of the hypo solution. This reducer was modified in 1894 by Mr. O. Jarecki to make it more suitable for use after acid fixing baths. He uses the liq. ferri perchlor. of the Pharmacopœia, that contains 37.8 per cent. of the dry salt—

Water	7 fluid ounces.
Liq. ferri perchlor.	2 ,, drams.
Potassium oxalate	3 drams.
Sodium sulphite (cryst.)	2 ,,
Oxalic acid (about)	35 grains.
Sodium hyposulphite	1¾ ounces avoir.

The ingredients are to be dissolved in the order stated, and the oxalic acid added a little at a time until a green colour is reproduced from the red given by the sulphite. Filter for use.

Other reducers. Potassium cyanide, a half to a one per cent. solution, a prolonged immersion in the fixing bath, or in dilute ammonia, will also effect reduction, the oxygen of the air taking part in the charge; but these methods are not generally to be recommended.

A part of the image may be removed or thinned by

mechanically rubbing it away. A piece of wash-leather drawn over the finger end or over a piece of soft wood, such as a match, according to the size of the part to be operated on, or a little pad of cotton wool, just moistened with alcohol and rubbed upon the dry film, will soon remove a part of the image. The rubbing surface only needs moistening, as too much alcohol prevents the erosion, and it is easy to know whether any effect is being produced by the blackening of the rubber.

To produce a proportional effect throughout the negative, that is, to preserve the character of the gradation but to lessen its range, is never a very reliable operation. The effect would be secured by acting on every particle of silver in the image in the same way ; any such complete action will give a proportional effect throughout. Obviously, methods that dissolve away the silver can never be complete, or there would be no image left. To secure as proportional an effect as possible with the above-mentioned reducers, they should be made dilute that they may soak into the film and act all over and through it as nearly as possible simultaneously, and act slowly that the exhausted parts of the solution may be replaced as speedily as possible.

As an example of a complete action, a saturated solution of mercuric chloride may be allowed to act on the plate until the image is thoroughly bleached, the plate being then well washed. The silver of the image is entirely changed into the white silver mercurous chloride, thus—

$$Ag + HgCl_2 = AgHgCl_2$$

and although the amount of matter that composes the image is very considerably increased, the change of colour

from black to white results in a diminution of opacity. This method is not to be recommended because the results cannot be depended upon, for the bleached image is liable to change by exposure to light and atmospheric influences.

Rehalogenisation and redevelopment. A different type of method consists of converting the silver of the image back into its halogen compound, redeveloping, but not to so great an extent as at first, and then dissolving away the surplus silver salt in the fixing bath. For the rehalogenisation, one of the following formulæ may be employed—

Potassium bichromate ..	5 grains	or 10 grams.
Hydrochloric acid	15 minims	30 c.c.
Water to	1 ounce	1,000 ,,

or the solution may be made more dilute, increasing its bulk to half as much again. Alum twenty-five grains or fifty grams may be added if there is a tendency to frill, otherwise it is better omitted.

Liq. ferri perchlor. B.P. ..	10 minims	or 20 c.c.
Potassium bromide	12 grains	24 grams.
Water to	1 ounce	1,000 c.c.

This converts the silver into bromide, and avoids the presence of acids. The following has been recommended—

Potassium bichromate	90 grains.
Potassium bromide	3 drams.
Water to	18 ounces.

After bleaching and well washing, the image is developed with any developer that may be preferred, working in ordinary light, to the desired extent, rinsed, fixed, and well washed. The denser parts of the image should obviously remain white at the back of the film, when the redevelopment is finished. Strictly speaking, this is not development, as there is no discrimination between the silver salt that is "exposed" and not "exposed"; it

is simply the removal of the halogen from the silver. No restrainer, therefore, should be put into the developer. This method tends to reduce the dense parts of the negative to a greater proportional extent than the thinner parts, but the difference is not great.

The persulphates of ammonium and potassium will dissolve silver without appreciably affecting gelatine. The primary action appears to be very simple, thus—

$$2Ag + K_2S_2O_8 = Ag_2SO_4 + K_2SO_4$$

But other changes take place that are not understood, and when applied to a silver image the dense parts lose much more than the thinner parts, and an approximately proportional effect appears to result. Potassium persulphate is so sparingly soluble in water that it is not so suitable as the ammonium salt. Of ammonium persulphate from five to ten grains to the ounce, or ten to twenty grams to 1,000 c.c., may be taken. After reduction the plate should preferably be placed in a solution of sodium sulphite (about five per cent. strength) for a few minutes. This stops the action of the reducer, and also helps to dissolve out the silver sulphate formed. What the resulting image consists of is not known, nor is it understood why the thin parts of the negative should survive while the dense parts are so vigorously attacked. Microscopic examination seems to indicate that the particles of silver in the original image are changed into some more transparent substance, instead of being entirely removed, as they would be if the reagent were a simple solvent of the metal. While this uncertainty as to the character of the change exists, it would not be wise to apply the method to a valuable negative.

REDUCTION OF NEGATIVES.

Reduction after intensification. A weak solution of potassium cyanide (one or two grains to the ounce) will serve after intensification with mercury and ferrous oxalate, or any process that leaves an image consisting of metallic silver and mercury. After any method that leaves a halogen salt of silver or silver cyanide, sodium hyposulphite may be used. A uranium intensified negative may be reduced by means of a very weak alkaline solution (one or two drops of dilute ammonia to the ounce to begin with), or by continued washing with ordinary hard water.

CHAPTER XII.

GELATINO-BROMIDE NEGATIVES. INTENSIFICATION.

IT will be gathered from the last chapter that reduction is an uncertain process even in the hands of the most experienced, and is on the whole to be avoided. Intensification, on the other hand, is perhaps the simplest of photographic operations; by the selection of a suitable method it may be performed so as to produce an exactly predetermined and uniformly proportional result. Reduction always tends to alter the proportional opacity of different parts of the negative, but intensification need not do this because it may be made complete, producing its change upon every individual particle of silver. Complete reduction would be obviously useless, as it would entirely remove the image.

Unless a special result is desired, and the operator is skilled enough to know how to produce it, intensification should be thorough, that is, each solution should produce its maximum effect and work right through the film. It is undesirable to select a method that gives a sufficient increase in opacity to suit the most extreme need and to make this a universal method, stopping its action in each case when it has gone far enough, because all solutions act first on the exposed surface of the film and gradually penetrate into it. If such a principle is adopted, a weak negative may be properly and proportionately strengthened, while a negative requiring only a little intensification will have its dark detail (say) doubled in opacity, because

the solutions have acted thoroughly there, but the middle tones will have only (say) half their thickness and the high lights (say) a quarter of their thickness doubled by the process, because the solutions have not been allowed time to penetrate deeper. This result may be an improvement, and if secured of set purpose is sometimes good; but if the negative needs simple intensification it will be spoilt by this partial process, and if a procedure gives an improvement not sought for it is not due to science in the work or skill in the operator. The function of science in photography is to give certainty. The effect of a partial intensification is always uncertain.

But if a partial intensification is to be condemned (except perhaps in the hands of those who know the peculiarity of its effect and when it is desirable), we must condemn in much stronger language those processes of intensification in which the effect increases to a maximum and then diminishes by simply persevering with the original solution. It is impossible in such cases to be sure that the reducing action has not begun at the top of the film before the intensification effect has had time to extend to the deepest part of the high lights. It is obvious also that the intensified image should be permanent, and made neither darker nor lighter by exposure to daylight.

To prepare a plate for intensification it is advisable to soak the well washed negative for a few minutes in a bath of hydrochloric acid diluted with two or three hundred times its bulk of water, the intensification being proceeded with after rinsing it. Experience shows that this treatment tends to minimise the possibility of stains appearing in the after treatment. Any alkalinity in the film, or any trace of hyposulphite remaining, will tend to produce

stains by the precipitation of mercury compounds other than by the image, and to produce abnormal results with other than mercurial intensifiers. Those intensifiers that contain hyposulphite or are alkaline, obviously do not need this preparation for their application.

Mercurial intensification. If a solution of corrosive sublimate (mercuric chloride) is allowed to act upon the silver image it will be whitened, and at the same time considerably increased in bulk. The change is expressed thus—

$$Ag + HgCl_2 = AgHgCl_2$$

To ensure cleannness in the result it is advisable to add one or two drops of strong hydrochloric acid to each ounce of the cold saturated solution of mercuric chloride (half a dram may be added to 20 ounces, or 3 c.c. to 1,000 c.c.) The negative is allowed to remain in this solution until the image is nearly as white at the back as at the front, and then well washed. The bleaching should become complete during the washing. The mercuric chloride solution may be used as often as wanted until it acts too slowly.

No silver is removed from the image, but each atom of silver is changed into one molecule of silver mercurous chloride. Although there is a great increase of matter the image that results is less opaque because of its whiteness. To produce a practical intensification, therefore, it is necessary to change the colour of the image. There are many reagents that will effect this.

Mercury and ferrous oxalate. Ferrous oxalate has a perfectly simple and definite action upon the bleached image, removing the chlorine from the silver mercurous chloride and leaving the pure metals. The result, therefore,

is quite definite both chemically and optically, and no secondary change is possible by prolonging the action of any of the solutions used. The intensified image has the great advantage that it may be intensified a second time by exactly the same method, for mercuric chloride acts upon metallic mercury exactly as it does upon metallic silver—

$$AgHg + 2HgCl_2 = AgHg_3Cl_4$$

and from this product ferrous oxalate will remove the whole of the chlorine as before. By repeated applications, therefore, the image produced has the following constitution—

ORIGINAL	INTENSIFIED		
	Once.	Twice.	Three times.
Ag	$AgHg$	$AgHg_3$	$AgHg_7$, and so on.

The mercury being inclosed in the gelatine and alloyed or combined with the silver is not volatile as it would be if freely exposed and alone, and it will stand prolonged heating even to the temperature of boiling water without sensible diminution. No negative intensified by this method has been known to show signs of change, and the process has been in considerable use since the author first recommended it in 1888.

In practically applying this method of intensification, the negative must be well washed after fixing and before treatment with the mercuric chloride solution, and well washed after the bleaching process. One great advantage of the method is that there is no loss of image, the faintest trace of deposit is duly intensified, but of course the intensifier cannot distinguish between silver stains and silver image, and therefore the negative must be clean. And it will be clean if it has been prepared by the methods previously described in this volume.

After bleaching and washing well, one hour is generally sufficient time for the washing, the following solution is poured over the plate—

Saturated solution of potassium oxalate	6 parts by measure.
Saturated solution of ferrous sulphate	1 part ,,

the ferrous sulphate being poured into the other. The solution of potassium oxalate will keep indefinitely, and may be prepared in large quantity. The ferrous sulphate solution will not keep for more than a few days, and is best prepared as wanted by putting a few crystals in a narrow tall vessel, such as a two dram measure, and adding water just sufficient to cover them, an hour or so before the solution is required.

The ferrous oxalate slowly blackens the image, and as soon as the last trace of whiteness has disappeared from the back of the film, it may be poured off and the plate well washed. After two or three rinsings the surface of the film may be rubbed gently, under water, with a small pad of cotton wool to detach any deposit. If when dry there is a white deposit on the surface of the film it is due to the use of hard water, but it may be neglected, as it will disappear on varnishing the plate and it can do no harm. It may be entirely avoided by the use of soft water, or giving the plate two or three changes of soft water before and after its treatment with the ferrous oxalate.

Mercury and alkaline developers. It has often been proposed to replace the ferrous oxalate in the above method by alkaline developers. These blacken the image and leave pure metals, if properly compounded, but some of the mercury is always dissolved out. The mercury lost

is often a large proportion, from twenty to forty per cent., and the quantity always variable. The effect, therefore, is uncertain and not proportional. By omitting the sulphite from the developer the mercury may not be lost, but stains result. No such method yet proposed is to be relied on.

Mercury and sulphite. The bleached image may be treated with a solution of sodium sulphite. This reagent dissolves away three-fourths of the mercury and half the silver, leaving the rest of the metals in the metallic state to form the image. The action may be expressed thus—

$$4AgHgCl_2 + 7Na_2SO_3 + xNa_2SO_3 =$$
$$Ag_2 + Hg + Ag_2SO_3, xNa_2SO_3 + 3HgNa_2(SO_3)_2 + 8NaCl$$

the x being equal to about seven.

It will be observed that in this case also the image consists of pure metals. But the weight of metals in the intensified image is less than the weight of the silver in the original image. The increase of density is therefore very slight, sometimes, indeed, there is practically no intensification effect. By repeating this process after the first application of it the image gets thinner and thinner.

The sodium sulphite solution is conveniently of from five to ten per cent. strength and slightly acidulated, and this, like the mercury solution, may be used repeatedly until it ceases to act quickly enough. The sodium sulphite has no injurious effect upon mercuric chloride, and the only result of too little washing between the application of the two solutions is a retardation of the action of the sulphite.

Although this method gives a very slight intensification effect, if any, some have obtained a notable increase

of density by its means. This is because they have not made the action of the sulphite complete, some of the silver salt not being changed into sulphite as shown above, but remaining as chloride and reinforcing the image. But the amount of silver chloride left is uncertain and uncontrollable; it will not be left proportionately upon the image, and its liability to subsequent change renders it an exceedingly undesirable constituent of a photographic image. Whenever, therefore, this method gives a useful increase of density, it must be regarded as unreliable, and the negative as not permanent.

Very much more effect may be obtained by using mercuric bromide instead of mercuric chloride for the bleaching, or a mixture of mercuric chloride and potassium bromide—

Mercuric chloride	.. 10 grains	or 20 grams.
Potassium bromide	.. 10 ,,	20 ,,
Water to	.. 1 ounce	1,000 c.c.

but the increased effect is due to the much more sparing solubility of silver bromide in sodium sulphite; this method therefore is also uncertain, that is, slight variations in the manipulation will cause variations in the result, will give differently proportioned results in various parts of the same negative, and cannot be depended on to give a permanent image.

Mercury and hyposulphite. Sodium hyposulphite has a somewhat similar action on the bleached image to sodium sulphite, but it dissolves away two-thirds of both the metals. This method is not worth consideration.

Mercury and silver cyanide. This is often called Monkhoven's process, though it was in use long before his name became associated with it. The essence of the

method appears to have been suggested to Mr. H. J. Burton about 1869, who shortly afterwards formulated it much as it is used at present.

The solution of silver cyanide may be prepared by taking—

Potassium cyanide	..	10 grains	or 20 grams.
Silver nitrate ..	..	10 ,,	20 ,,
Water to	..	1 ounce	1,000 c.c.

The cyanide may be dissolved in half the water and the silver nitrate in a part of the remainder, and the silver solution added to the other until the precipitate produced as each drop is added begins to remain undissolved. After standing a little the solution is made up to the bulk and filtered. The above quantities are only approximate, as cyanide of potassium is of such various strengths. Really pure potassium cyanide would require more silver than stated, but many samples considerably less.

The prepared solution is poured over the bleached image. A rapid and intense blackening takes place. There is little doubt but that the primary reaction is as follows—

$$HgAgCl_2 + KAgCy_2 = Ag + AgCl + HgCy_2 + KCl$$

But secondary reactions follow so rapidly that the image consists of a mixture of metallic silver, silver chloride, silver cyanide, and mercuric cyanide. Such an image cannot be expected to be permanent, and experience shows that it is not. Many negatives intensified by this method have subsequently changed disastrously.

But if the image were permanent the method would not be advisable, because it does not produce a proportional effect, nor is the effect that it does produce under control. The continued action of the cyanide solution results in

further and uncertain and unproportional changes, gradually thinning the image.

Mercury and ammonia. The ammonia solution that is applied to the bleached image may be of almost any strength (for example, five to ten drops to the ounce upwards), but the stronger it is, or the longer it is allowed to act, up to a certain point never fully reached in practice, the thinner will the image be. Ammonia first intensifies and then reduces the image, so that its effect is always uncertain and never equally proportional in the shadows and the high lights. Indeed the thin detail is often more transparent after the intensification than before.

The resulting image is not stable, and it sometimes changes notably in a few weeks. It appears to consist of ammonium chloride in which some of the hydrogen is replaced by silver and some by mercury, or a mixture of such compounds. Both silver and mercury are always dissolved out by the ammonia. This method, therefore, like the preceding one, is not to be relied upon.

Other mercurial methods. Other substances have been proposed as followers to the mercury salt, but none of them merit much attention. Caustic soda leaves all the mercury as oxide and the silver partly as oxide and partly as chloride; its action is partial and uncertain. Lime water doubtless acts similarly. Sodium carbonate acts partially and dissolves out some of the mercury. Ammonium sulphide, converts both metals into sulphides, and may be useful in special cases. Potassium cyanide leaves one-third of each of the metals in the metallic state, and is therefore analogous to sodium hyposulphite, but it is so energetic a solvent (in the presence of air) of both silver and mercury that it is useless for intensification.

MERCURIC IODIDE INTENSIFICATION.

Mercuric iodide dissolved in excess of potassium iodide with hyposulphite of soda forms a one-solution intensifier, and was introduced many years ago by Mr. B. J. Edwards. This solution applied to the negative after fixing (much washing is not necessary) thickens the image considerably, giving it a brownish colour and eventually a more yellow or reddish brown tint. It appears that so far as the action extends the silver of the image is converted into a mixture of silver and mercurous iodides. The colour of these compounds renders it unnecessary to blacken the image as when mercuric chloride is used. But such an image soon fades to a sickly yellow colour. Recently sodium sulphite has been substituted for the hyposulphite.

Mercuric iodide	.. 2 grains	or 4 grams.
Sodium sulphite (cryst.)	32 ,,	64 ,,
Water to	.. 1 to 2 ounces	1 to 2 litres.

The weaker solution will probably be strong enough. A negative intensified with this will fade as with the older form of the intensifier. To obviate this a developer is sometimes subsequently applied. If the action of the developer is complete, the result is the same as if mercuric chloride and a developer had been used, but obtained with more trouble and less precision. If the action of the developer is not complete, that is, if the iodides are not completely reduced to metals, the final image will not be stable. If alkaline developers are used mercury will be lost. The method should on no account be used for valuable negatives that have to be preserved.

Uranium and similar methods. Leaving the mercury intensifiers, there is another general process which involves the use of ferricyanides in which the silver of the image reduces ferricyanides to ferrocyanides, itself becoming at

the same time either a ferro- or ferricyanide, as shown in the chapter on the reduction of negatives. If the ferricyanide of a metal that forms a soluble ferricyanide and an insoluble ferrocyanide is selected and its solution is caused to act upon the silver image, the silver is changed into its ferro- or ferricyanide, and is associated with the ferrocyanide of the metal chosen. The reaction is somewhat analogous to that of mercuric chloride, and gives the salts of two metals instead of the single metal itself. If uranium ferricyanide is used, the reddish or chocolate-coloured salts of the silver and uranium that result are so opaque to photographically useful light that no further change is necessary. When lead ferricyanide is used, the resulting image is practically white, and needs to be treated with a soluble sulphide or chromate. The first changes the silver and lead into their sulphides, which are black, and the second into their chromates, which are red and yellow respectively.

As it is not convenient to prepare the ferricyanides of such metals as uranium and lead, it is usual to employ a mixture of potassium ferricyanide and the nitrate of the metal. The ferricyanide of the metal is then produced, as, for example, with lead—,

$$2K_3FeCy_6 + 3PbN_2O_6 = Pb_3Fe_2Cy_{12} + 6KNO_3$$

and the potassium nitrate, which is also produced, does not interfere with the reaction.

There are many precautions necessary with these methods. In the first case, as it is essential that the ferrocyanide of the metal employed should be insoluble, the introduction of ferrocyanides into the solution by any means other than by the action of the silver image itself

must be rigorously avoided. Ferricyanides are very easily reduced, the negative therefore must be most thoroughly washed, and it is well to soak it for a short time in very weak acid as recommended for the mercurial intensification. The crystals of potassium ferricyanide are often coated with a layer of ferrocyanide produced by the action of light, of dust, or possibly a gas in the air like sulphuretted hydrogen which has a reducing action. They should therefore be washed by running water over them for a few seconds until they are quite clean and of a bright ruby red colour, before they are dissolved, unless the mixed solution is to be prepared some time beforehand. In the latter case the ferrocyanide of the metal is precipitated in the solution, and filtration immediately before use will remove it. The process of intensification should not be carried out immediately under a window that is strongly illuminated, as sunlight tends to decompose the ferricyanide. It is best to use distilled water, but tap water should be preferred to rain water, and if it is hard it should be acidulated with acetic acid, as hard water reduces the intensity of the uranium image. Indeed, in any case, the uranium solution should be acidified, as a ferricyanide is not so easily reduced in the presence of an acid as it is in a neutral or alkaline solution, and the tendency to stains and fog is therefore lessened. Acetic acid may be added to the extent of about one-fiftieth of the bulk of solution, or even to a rather greater proportion. If hard water were used with the lead process the carbonates and sulphates in it would precipitate carbonate and sulphate of lead upon the negative, and these salts would be blackened by the ammonium sulphide and cause fog. The addition of a little acetic acid to the lead solution will be found beneficial.

The following formula may be used—

Uranium nitrate	4 grains	or 8 grams.
Water to	1 ounce	1,000 c.c.
Acetic acid	as stated above.	

Immerse the plate in this, then pour the solution back into the glass into which has been put a dilute solution of potassium ferricyanide made by running water over a few crystals to wash them, and then shaking them with a little water for a few seconds. Add more ferricyanide as necessary. The washing after this intensifier must not be prolonged if hard water is used, or the image will lose density unless, as is preferable, the washing water is slightly acidified. This method obviously gives an incomplete action, and being incomplete it does not give the same proportion of effect throughout.

The lead method is hardly applicable to gelatine plates, and the effect that it produces is so great that it would not be advisable to use it if it were.

Lead nitrate	20 grains	40 grams.
Potassium ferricyanide . .	30 ,,	60 ,,
Acetic acid	10 minims	20 c.c.
Water to	1 ounce	1,000 c.c.

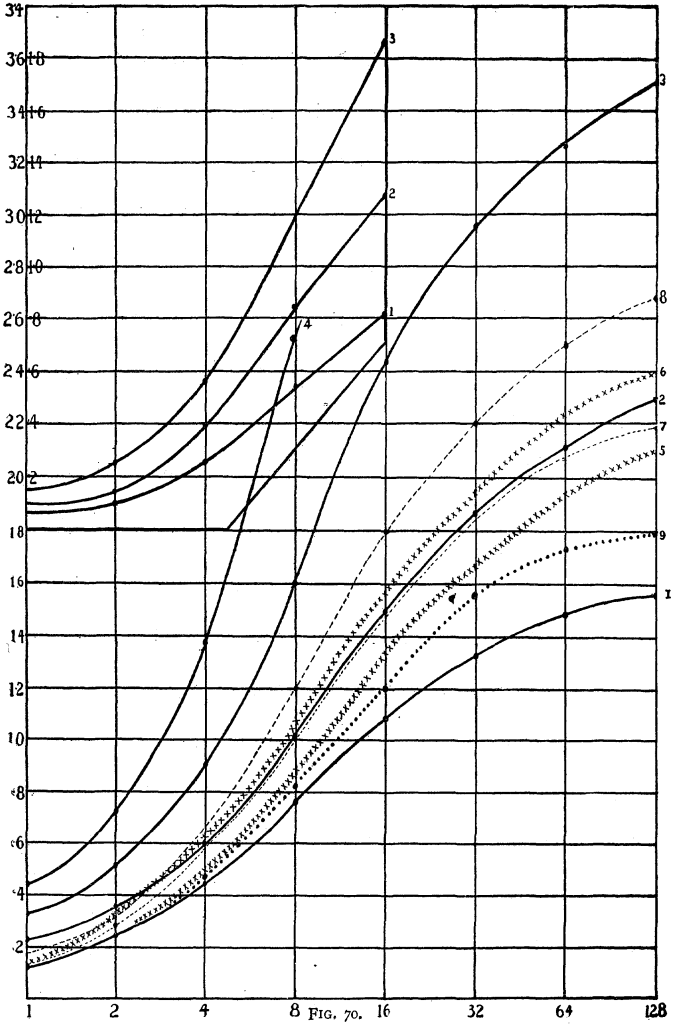
When the image is bleached, follow, after a *very thorough* washing, with ammonium sulphide diluted with ten times its bulk of water. The washing before the ammonium sulphide is applied should be continued until the drainings from the plate give a scarcely perceptible blue colour with ferrous sulphate solution, that is, until the ferricyanide is quite washed out, for the least trace of lead remaining will inevitably cause fog.

Silver intensification. Collodion plates were generally intensified by the deposition of metallic silver on the image from a very dilute solution of a silver salt containing a reducer. It has been sought to apply this method to

gelatine plates but with very indifferent success. There does not appear to be any advantage in these methods, and if the collodion process had not preceded gelatine plates, they would probably never have been introduced. It is a good principle to keep solutions of silver salts, as far as possible, from contact with gelatine films.

The optical effects of intensification. The only function of a negative is to retard the passage of light through it to different extents in different places, and so suitably graduate the light that it shall produce the effect desired upon what is placed beneath the negative.

It is more convenient to give the logarithms of the opacities than the opacities themselves for many reasons which need not be entered into here. In fig. 70 the effects on the opacity of negatives are shown as produced by some of the most usual methods of intensification. The curve 1 represents the original negative. The curve 2 shows the effect of intensification with mercuric chloride and ferrous oxalate, 3 shows the process carried out twice on the same portion, and 4 three times. The last curve only shows the lower exposures. The small series at the top left hand corner show a different experiment, 1 the original, 2 once intensified, 3 twice intensified. In all these cases the increase of density is strictly proportional throughout, and experiment shows that one intensification by this process always multiplies the opacity logarithms by 1.45 whatever the original density, and whether the negative has been previously intensified (by the same process) or not. When using this method, therefore, it is possible by measuring the opacities to tell exactly what the result of intensification will be, or from the intensified negative, exactly what the original negative was.


34
36 18
34 16
32 14
30 12
28 10
26 8
24 6
22 4
20 2
18
16
14
12
10
8
6
4
2
1
2
4
8
16
32
64
128
3
2
1
4
3
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6
2
7
5
9
I

FIG. 70.

Curves 5 and 6 show the effect of the mercury and ammonia method on the same original, 5 with a stronger solution of ammonia than 6. It will be seen at once that the effect is not proportional throughout, there is no increase of opacity in the thinner parts, and that a little difference in the strength of the ammonia makes a considerable difference in the result. The character of the gradation is altered, and by this method it is impossible to tell what result is going to be produced. The result is altogether uncertain.

Curves 7 and 8 show the effect of the mercury and silver cyanide method, the first when the cyanide solution was applied for a longer time than the second. The effect is uncertain and unproportional.

Curve 9 shows the effect of sodium sulphite after the mercury solution; here also the effect is irregular, and moreover it is very slight.

The choice of methods of intensification. By a study of the chemical and the optical effects of the various processes, it is possible to select the method that will best serve any given purpose. A negative of a solid object (landscape, portrait, etc.) that is flat but full of detail and otherwise satisfactory should be intensified with mercury and ferrous oxalate. The character of the gradation will be perfectly preserved, there will be no loss of detail in the shadows, and if any intensification at all is needed it will not give too great an increase of density. The resulting negative will be permanent. If the range of gradation is still not sufficient, the process may be repeated with the same result as if the first intensified negative were the original.

If a negative of a black and white diagram is not

dense enough, and the negative is only wanted to get a print on a lantern slide from, so that it does not matter whether or not it will last in good condition for more than a few months, then the mercury and ammonia or mercury and silver cyanide method will serve well. The transparent parts of the negative, though they may have a little deposit, will not be increased in density, and may even be made more transparent. These methods are particularly suitable for negatives from which "halftone" blocks are to be made, as the reducing action in the thinner parts is exactly what is wanted, and the negatives are not generally preserved.

CHAPTER XIII.

GELATINO-BROMIDE FILM NEGATIVES.

THE earliest negatives, by Herschel and by Talbot, were made upon paper, and it was a very considerable advance when glass began to be employed. The paper negatives, however, had so many advantages that the process was not discarded, and much labour has been devoted to the production of film-supported negatives that shall not have the drawbacks sometimes associated with them.

The advantages of film negatives are the lightness of the material and often the possibility of using it in long lengths on rollers, so that with suitable apparatus the changing of the exposed film for a new one may be effected with the very greatest of facility, the absence of reflection from the back surface of a supporting medium with its resulting halation, and the possibility of printing from either side. An emulsion spread on an opaque white support, such as paper, gives results as if it were much more sensitive than if on a transparent support, because the light that passes through the sensitive film is largely reflected back on to it instead of being lost.

On the other hand, a film negative rarely prints as quickly as if it were glass-supported. It is difficult to get so even and perfect a coating of emulsion upon it; its surface is not always as flat as that of a sheet of glass however the film may be held in the camera, and there is generally extra manipulation needed in making the

negative. It is more difficult to varnish or otherwise sufficiently to protect the surfaces of a film negative.

It must not be understood that all film negatives have the advantages or disadvantages just enumerated. A glass negative may be printed from the reverse way, that is, with the film towards the light instead of towards the sensitive paper, but the amount of blurring would almost obliterate the subject. There are probably no commercial negative tissues that will allow of printing from their reverse sides without a perceptible loss of sharpness.

The enormous experience that makers have now had in the manufacture of films since they were commercially prepared in considerable quantities has led to their perfection to such an extent that they may be safely relied on for serious work. At the present it is not so much a question as to the perfection of the material as to the general suitability of plates or films for the work that has to be undertaken.

In 1875, Mr. Warnerke worked out a process of manufacturing a dry collodion paper-supported film, which could be exposed in roller slides, and was preferably stripped from its support before development. He shortly after supplied such films in blocks, so that each one as it was exposed was removed to leave the film below ready for exposure. From time to time other workers have also tried to produce satisfactory thin, flexible, and transparent supports for negative films. Mr. H. J. Palmer coated gelatine films with gelatine emulsion, but as he prepared the sheets on glass the size was limited and the cost considerable. The "Cristoid" films at present made by the Sandell Films and Plates Company consist of two

gelatine films, each containing silver bromide, the one much more rapid than the other. These films expand considerably when wet—a property that may be advantageous or otherwise according to the purpose for which they are required.

The first negative tissue that can claim any degree of popularity was that prepared by the Eastman Dry Plate and Film Company in 1885. In this process the gelatine emulsion is supported on paper, but not directly, because the unevenness of the surface of paper would cause a similar irregularity in the side of the emulsion film in contact with it, and so give an objectionable granularity in the negative. The paper of the Eastman Company was first coated with gelatine, and then calendered to obtain a polished surface to receive the sensitive emulsion. To secure an even coating, the sensitive emulsion was put on in two layers. The development of this tissue offered no special difficulties, and to get flatness in the finished negative, it was taken from the last wash-water, and squeegeed down upon a sheet of polished ebonite. When dry it was readily stripped from the ebonite.

Though such negatives could be printed from without further preparation it was customary to make them more transparent. The first method suggested was to immerse them in hot castor oil; then cold oil was applied, allowing it several hours to soak in; and finally a thin vaseline was used for the purpose. This process imparts an excellent quality to the negative, but the oil gradually works out, and always offers an effectual trap to dust.

To overcome these difficulties, the Eastman Company in 1887 prepared a stripping film, which differed from the

other chiefly in having a layer of soluble gelatine between the emulsion film and its support. After fixing and washing for a short time, the developed negative was squeegeed down upon a glass plate coated with collodion, and, after a few minutes, hot water was poured over it to melt the layer of soluble gelatine, and so allow the paper to be peeled off. A gelatine skin was squeegeed on, and when dry, the finished negative was stripped from the glass. The negative thus had a coating of collodion on its face. To ensure the collodion leaving the glass in such an operation the surface of the plate must be either rubbed with French chalk, or, preferably, coated with a thin film of indiarubber by means of a solution in benzene of the strength of about half a grain to the ounce. To secure flexibility in the finished negative, the gelatine skin applied to give it the needed strength was prepared with a certain proportion of glycerine, and care had to be taken that the glycerine was not soaked out of it.

Instead of getting rid of the granularity caused by coating paper directly with a sensitive emulsion by preparing the surface of the paper, the support may be coated on both sides with the sensitive compound. Such a film has the advantage that either side may be exposed, but this is a very trivial matter. The use of the second coat is to correct irregularities in the first, and this it does satisfactorily, because, where the front film is thin, more light passes through to the back film, and the thinness is compensated for. Such a tissue was made by the Vergara Company (working on the suggestions of Mr. W. B. Woodbury) in 1886, the foundation being a thin paper made transparent with a benzene varnish. It was found practically impossible, however, to get a satisfactory

coating on both sides simultaneously, and this preparation was replaced in 1887 by a tough material coated on one side only patented by Froedman.

Other films for negatives have been made commercially, among which may be mentioned Pumphrey's, Balagny's, and Thiebault's. The last were on enamelled cardboard, and used exactly as glass plates, except that in developing the density of the image had to be judged of from the surface appearance only. When finished they were removed from the supporting cards. They were very expensive. Balagny's support was "composed of a succession of very adhesive films of collodion, varnish, and gelatine."

As a film support for negatives, celluloid has very largely replaced other materials, though gelatine and paper-supported stripping films are still on the market. Celluloid is a transparent preparation of pyroxyline and camphor, and with various pigments incorporated with it has been in use for many years in the manufacture of small articles. In 1888, Mr. John Carbutt, of Philadelphia, succeeded in obtaining this material in a fit condition for coating with emulsion, and since then many manufacturers have followed his example. In 1889, the Eastman Company succeeded in preparing a celluloid film of sufficient thinness for use in roller slides. The same company, now called "Kodak" or the Eastman Kodak Company, introduced, in 1903, a celluloid-supported film coated with a thin layer of gelatine on the back to counteract the tendency otherwise shown to curl or roll up when wetted. This non-curling film has replaced the older kind.

There are at the present time many varieties of films

for negatives obtainable, and when using any particular kind it is well to observe the precautions described by the makers. Generally speaking, when used in the camera, special care should be taken to see that the appliance for holding them keeps the surface flat. With very small sizes, say less than half-plate, there should not be much difficulty in this matter. In working with celluloid films it must be remembered that the presence of both collodion and gelatine must be taken into account, and that no treatment that will injure either is permissible. Further than this, the treatment of films does not call for more special consideration than is given them in the chapters dealing with the various photographic operations.

CHAPTER XIV.

GELATINO-BROMIDE NEGATIVES. VARNISHING.

A NEGATIVE can be printed from without varnishing it, and with little risk if strict care is taken to dry both the negative and sensitive paper by warming them a minute or two before placing them in contact. But to print from the unprotected film without special precaution is very unadvisable if any printing-out process, including carbon and platinum, is employed, as the smallest amount of silver nitrate that gets transferred to the gelatine film is certain to cause red stains sooner or later,* and the soluble bichromate or ferric oxalate in contact with a damp negative will not be without effect upon the image. Papers which contain no soluble sensitive compounds, such as bromide paper, may be printed from unvarnished negatives with impunity.

Before proceeding to varnish a negative it should be seen that there is no surface contamination, excepting the deposit of calcium oxalate which may result from intensification with mercury and ferrous oxalate when hard water is used. This, as already stated, may be safely neglected. If the gelatine is of a hard kind or has been hardened with alum, it is often a good practice to rub the surface of the negative gently with cotton wool moistened with alcohol before proceeding to varnish it, as by this means the surface is cleaned, the flow of the varnish over

* Such red stains may be removed by the careful application of a very dilute solution of potassium cyanide if they are not too old, but potassium cyanide will also dissolve away the image if it has the opportunity.

the plate is facilitated, and the film receives a polish that contributes to the smoothness of the varnished surface. The rubbing may be continued until the polishing is effected, if only an inappreciable blackening of the rubber takes place, but it should be remembered that this blackening is due to the removal of a part of the image. With soft or unhardened gelatines this procedure may lead to a roughening of the surface and dirty deposits that are annoying.

When ordinary spirit varnishes are used the clean negative should be warmed before a fire or over a ring gas burner or some similar source of heat, with constant movement, until the glass side is rather hotter than the back of the hand can bear, to dry the film thoroughly, When the plate has then cooled to a temperature that is comfortably warm to the back of the hand, it is held by one corner, or if large otherwise suitably supported, and brushed over lightly with a wide camel-hair brush to remove dust, if any, and a pool of varnish is poured into the middle of the plate slowly and steadily until it covers about half its surface. The plate is then tipped a little to cause the varnish to flow into each corner in turn, and the excess of varnish is poured off from the last corner, while the negative is "rocked" or moved to and fro in such a manner that the flow of varnish does not produce streaks. The plate is then moved about in front of the fire or over the gas burner until it is about as hot as it was made at first. To avoid a thick streak of varnish along the two sides of the plate that meet at the pouring off corner, it is advisable to remove the excess as soon as the draining is finished by drawing a cloth tightly over the finger and passing it along these two edges, so as only just to touch the extreme edge of the glass.

ALCOHOL VARNISHES.

A good alcohol varnish that is not too thin, such as is commonly supplied commercially, applied in this manner, affords a reasonable amount of protection, and this is the method that it is recommended to follow in all but very exceptional cases. If a negative so varnished were put into water, probably in ten minutes or so the water would have penetrated the varnish where it is thinnest, that is, opposite the corner at which the excess was poured off.

If for any reason extreme protection is desired the negative may be coated with collodion before it is varnished. First warm it, to dry the gelatine film thoroughly, and as soon as it is cold coat it with an "enamel" collodion. Then warm it to the required temperature and varnish it as above. If the varnish is poured off at the corner opposite to that at which the collodion was poured off, the combined films of collodion and varnish will be of more equal thickness throughout, as the thinnest part of one will be opposite the thickest part of the other.

Formulæ for alcohol varnishes. The two chief gums employed in the manufacture of varnishes for photographic purposes are lac and sandarac. Lac is harder than sandarac, and to be preferred on that account; but it is of a deep red colour, while sandarac is practically colourless. A varnish made of lac, however, can readily be decolorised by means of animal charcoal to such an extent that the film yielded by it shows practically no colour. Lac is found in commerce in a bleached, and a nearly bleached, condition (shellac); but these preparations are to be avoided, because it is very difficult to get rid of the last traces of acid used in the bleaching process. Seed-lac is to be preferred to stick-lac, because it has

less colour, but this amount of decolouration is effected only by means of water.

"White hard varnish" of commerce is stated to be simply a solution of sandarac in alcohol, while "brown hard varnish" is made of a mixture of two parts of shellac to three parts of sandarac. Either of these thinned down with methylated spirit will give a varnish that may be used for negatives, though, obviously, the preparation will not be so reliable as if the history of the varnish were exactly known.

A formula for negative varnish recommended by Mr. W. Bedford is—

Button lac	8 ounces.
Sandarac	2 ,,
Methylated spirit	2 quarts.

Shake at intervals for a week and filter. This is intended to follow collodion, but may be used without.

A varnish that can scarcely be excelled is prepared by putting seed-lac into methylated spirit, and shaking them together at intervals during three or four days. The amount of alcohol may be three or four times as much as suffices to cover the lac, the amount is not important. When the extraction appears complete, the mixture is allowed to settle for a day, and the solution is poured off. To decolourise it, if necessary, animal charcoal is added to it, and the vessel containing it is heated in hot water for, perhaps, an hour. The solution is then filtered, and diluted with methylated spirit until of a suitable strength, as shown by coating a plate with it. The extraction with alcohol should be done without heat, as the waxy constituent of the lac is then not dissolved out.

If a varnish of the nature of those just described gives a film that is considered too brittle, castor oil may be added to it in any quantity up to about one dram to the quart of varnish. Castor oil is preferred to other oils, because it neither hardens nor evaporates by exposure.

Alcohol varnishes are readily removed by soaking the negative in alcohol, gently rubbing with a pad of cotton wool to facilitate the solution of the thicker parts of the film.

Other varnishes. Water varnishes may be made by dissolving lac in a solution of ammonium carbonate, boiling until the odour of ammonia is no longer perceptible. Or a solution of borax, twenty grains to the ounce, may be boiled with shellac (sixty grains to the ounce) until it is dissolved. Such a varnish may be used for films, immersing the film in the solution and suspending it to dry.

Dammar dissolved in benzene or chloroform gives a varnish that may be used cold without giving a matt surface, and therefore may be applied with a brush. Such a varnish is particularly suitable for application to the gelatine surface of film negatives, which obviously cannot well be warmed like a glass-supported film.

Amber may be dissolved to form a varnish by heating it until it begins to soften, then powdering it and agitating it with chloroform or benzene, in the proportion of about one ounce of solid to sixteen ounces of liquid. Such a varnish is applied to the cold plate. Amber varnishes are not to be recommended, as they are very troublesome to remove, and thus, perhaps, prevent a desirable improvement in the negative from being carried out.

Celluloid chips, or films from which the gelatine has

been removed, left in acetone for a few days until dissolved, will give a varnish that may be applied cold. The resulting film is considered by some to be improved if a little amyl acetate is added to the solution. This varnish gives a coating that is very impervious to water.

Matt varnishes. A solution of lac in alcohol used cold will often give a matt surface, presumably because as the alcohol evaporates the remaining liquid contains an increasing quantity of water until at length a part of the lac is precipitated as a fine powder on the surface being varnished. The getting of a matt surface by this means is very uncertain. Better results are obtained by following the same principle but with other solvents. The following formula has been recommended—

Sandarac	45 grains	or	90 grams.
Mastic	10 ,,		20 ,,
Ether	1 ounce		1,000 c.c.

When dissolved add benzene in quantity from a quarter to threequarters of the volume of the ether solution, according to the temperature and the grain required.

CHAPTER XV.

GELATINO-BROMIDE NEGATIVES. SOLARISATION, REVERSAL, AND HALATION.

If a uniform developer is employed, it will be found that an increase of light acting upon a sensitive plate will give an increase in the opacity of the deposit produced, up to a certain point, that a further increase of light is then without apparent effect, and that, as the intensity of light or the time of its action increases, the opacity produced on development will diminish practically to nothing, and then increase a second time, and so on. For want of a better term, this effect, beyond the first or normal increase of density, is called "solarisation."

Reversal. The reversal of the photographic image by reason of over-exposure is a phenomenon that is not always appreciated as it should be. Janssen found in photographing the sun that from one to two hundred thousand times the most convenient exposure gave a positive instead of a negative on development, and that if the exposure were increased to a million times a second reversal took place and a negative was produced. By further exposure, the phenomena could be repeated, but the images grew weaker each time.

But with a very much less excess of exposure the effect of reversal begins to show itself injuriously, and this especially with gelatine plates. A pure bromide of silver emulsion (that is free from iodide of silver) is most liable to suffer in this way. In the early days of gelatine

plates Bennett showed that with those of his make double the exposure that gave full density caused a very marked diminution of density, and that ten times the exposure was equivalent on development to no exposure at all.

The brightest parts of the high lights are the first to begin to reverse, that is, they are thinner in the negative than they ought to be; and this gives flatness and fog where there ought to be brilliancy and transparency—a fault that some operators are inclined to consider as inherent in photography. As alterations in exposure can to a certain extent be compensated for in development, reversal depends to a corresponding extent on development as well as exposure. A powerful developer may give flatness in the lights, when a weak or more restrained developer would have given a pleasing gradation.

To obviate in development the disadvantages of over-exposure, potassium bromide may be added to the developer, up to, according to Dr. Eder, even ten per cent. (forty-five grains to the ounce), and if pyrogallol is used, it is well to add more of this also. It is possible to eliminate the effect of over-exposure by undoing, to a certain extent, the effect of the light action. By soaking a plate that would have given complete reversal by normal development, for ten to fifteen minutes in—

Potassium bichromate	1 gram.
Strong sulphuric acid	3 grams.
Water	100 c.c.

Dr. Eder obtained a normal negative. For extreme cases this solution may be used of twice the strength stated, and treatment with it may extend to as long as forty-five minutes.

REVERSAL.

Practical use of the reversal of the image by prolonged exposure was made long since in getting a negative directly from a negative; and, probably, the best method of applying this principle is according to the following process, devised by Mr. T. Bolas: A gelatino-bromide plate is soaked for a few minutes in a four per cent. solution of potassium dichromate, rinsed with fifty per cent. alcohol, dried, and exposed under the negative to be reproduced for from two to five minutes in sunshine, or from ten to fifteen minutes in good diffused daylight. The plate is then washed in cold water, and developed with an alkaline pyrogallol developer. The action of the chromate is probably two-fold—it hardens the gelatine and so retards development, in proportion as the light has gained access to the plate; and as reversal appears to be facilitated by the presence of oxidisers, it may be that the chromate, which is a very powerful oxidiser. assists directly in the solarisation.

General J. Waterhouse found in 1890 that reversal may be brought about without prolonging exposure by adding to an eikonogen developer an exceedingly small quantity of thiosinamine. He has since found that a compound that consists of four molecules of thiocarbamide with one of ammonium bromide, called tetrathiocarbamide ammonium bromide, is preferable, especially when lithium carbonate is used as the alkali. The developer he recommends contains five grains each of eikonogen, sodium sulphite, and lithium carbonate, to one ounce of water, and is prepared by dissolving the first two when required in a saturated solution of lithium carbonate. A "few drops" of the solution of the above compound are added. The exposures for this process are with advan-

tage less than for the production of ordinary negatives, in one case even a thirtieth was sufficient.

Halation is another result of over-exposure, but indirectly. The word in its broadest sense indicates the spreading of light beyond its proper boundaries in the image, with the production of local fog, as may sometimes be observed round brilliant high lights, such as windows facing the sky in interiors. Halation is certainly present in negatives produced of very many less difficult subjects. Tree branches that stand out in front of the sky are often fogged in the negative, and the fine detail is quite lost so far as printing value is concerned, because the spreading of the light takes place from both sides. Loss of such fine detail, however, may result from other causes, such as movement of the object or of the camera during the exposure, or because of the lost detail not being in sharp focus.

There are two or three reasons why the light should encroach upon the shadow in negatives, but the chief is because of the reflection from the back surface of the glass. When light impinges upon the solid particles of silver salt in a gelatine film, it is impeded by them, and reflected by them in practically all directions. It is partly reflected sideways, and so affects the silver salt beyond the limit to which it is desirable to confine the light action. But the spreading of the light effect by this direct reflection from the particles may be neglected, except, perhaps, when fine lines have to be reproduced, because the number of particles soon absorbs or exhausts the power of the reflected light. But when the sensitive film is thin enough to allow light to pass through it, it appears that a considerable amount is transmitted in all

directions from the back of the film into the glass, so that the film behind a luminous part of the negative may be considered, for all practical purposes, as an actual source of light. The light that radiates from this impinges chiefly upon the back surface of the glass, and here a part is transmitted out of the glass and is lost, but a part is reflected back through the glass again, on to the sensitive film, and produces the annoying local fog now under discussion. In fig. 71, *a* represents a bright part of a negative from which the light is scattered in all directions into the glass support of the negative below. A pencil of light that passes through the glass plate at right angles to its surfaces passes out of the glass and does no damage, but a pencil that impinges upon the lower surface of the

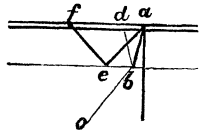

FIG. 71.

glass more or less obliquely, as *a*, *b*, passes partly out of the glass to *c*, and is partially reflected to *d* upon the underside of the sensitive film. As the obliquity of the pencils of light within the glass increases, the proportion that is reflected increases until, when the angle that the pencil makes with the perpendicular is equal to about forty degrees (this figure varies according to the refractive index of the glass), the whole of the light is reflected, as *a*, *e*, *f*. The effect of this is to surround a bright line with a fog that gets denser to a position a little distance away from the bright line itself, and then gradually fades away. The halation in this case produces a halo, and

the distance of the halo from the bright line is greater or less according to the thickness of the glass.

But if, instead of a bright line, there is a bright surface, the interval between the bright part and the halo disappears, and only a general fog remains that dies away gradually at a little distance. It is obvious in this case that the edge of the bright part produces an effect as described above, but the parts just within the edge produce the same result, and so the space between the edge of the bright part and its halo is filled up.

The theoretically correct way of curing this, the chief form of halation, is to use a film so richly charged with silver salt that it absorbs all the photographically active light that falls upon it. By means of the multiple film plates introduced in 1892 by Messrs. Thomas and Co., it was possible to ensure this even in the case of difficult subjects. These plates were coated with a slow emulsion first, and then with an emulsion of ordinary rapidity, and those that were trebly coated had a still less sensitive layer below these. It is obvious that for light-absorbing power a thin layer that is less sensitive is equivalent to a thick layer that is more sensitive. Where the light is strong enough to produce over-exposure in the top layer, a good image may be developed in the layer below, and therefore when using such plates a very considerable increase of exposure was permissible without damage to the negative. These plates did not meet with the appreciation that might have been anticipated, partly perhaps because of the character of the gradation they gave, but this matter appears never to have been investigated. The "cristoid" films now on the market are of this complex type.

The light may be prevented from penetrating the film by colouring it with a red or yellow dye of such a nature that it is easily removed after or during development. Many of the coal tar dyes are of this character, and the effect of a tinted film in curing halation may sometimes be seen in using orthochromatic plates. Or a substratum of stained gelatine may be put on the glass before the emulsion. Excellent plates of this type were made commercially a few years ago by Messrs. Thomas and Co., in which the substratum was coloured with brown hydrated manganese peroxide, which was easily removed after development by a bath containing sulphurous acid.

Plate backings. In those cases where the subject is of such a character that it is impracticable to absorb in the film all the light that falls upon it from the most luminous part, as, for example, a bright sky seen through a window in photographing an interior, and if it is impossible to modify the subject by reducing the brightness of the troublesome part, halation is generally mitigated or prevented by "backing" the glass, so as to reduce the reflected light to a negligible amount. A suitable material for this purpose may be black, brown, red, or yellow when using ordinary plates not sensitive to these colours, but with specially sensitised plates it is preferable to avoid any colour to which the plate has been made sensitive. But this discrimination is not essential when using daylight, because the sensitiveness of all plates is so much greater to the blue and violet than to the yellow and red. On the other hand, if a coloured screen is used to prevent the excess of effect produced by the blue, so that the yellow or red constituent of light

becomes an important factor, the backings of these colours must be avoided. It is desirable that the substance used be of such a character that it may be easily cleaned off before development, and it should not be so moist that it endangers the keeping properties of the film.

Many methods of backing sensitive plates have been proposed. A thin solution of bitumen in benzene (or Bates's black varnish, or Brunswick or Berlin black) may be applied with a brush; it dries almost as quickly as it is put on, and is easily removed by rubbing with cotton-wool moistened with a little benzene or turpentine.

An aqueous mixture is as follows:

Powdered burnt sienna	1 ounce.
Gum	1 ,,
Glycerine	2 drams.
Water	10 ounces.

This dries in a minute or two, and is wiped off before development with a damp sponge.

Black glazed paper or American cloth may be pressed into optical contact with the back of the plate after smearing a little glycerine over it; or a piece of carbon tissue may be applied in the same way. If the tissue is too horny, it should be put in a damp place for a few hours, but the more flexible materials mentioned above are to be preferred. Carbon tissue thoroughly soaked in water is easily put on, and is effective, but the large quantity of water is a drawback if the plate is not for immediate use. Mr. W. E. Debenham has shown that gelatine coloured by mixing about an equal quantity of caramel (or "burnt sugar") with it is superior to any of these.

For a plate backing to be thoroughly effective it must have the same refractive index as the glass and be in optical contact with it, so that light in passing from

the one medium to the other suffers no refraction, for if there is refraction there must be reflection. The backing must form, in fact, an actual continuation of the glass, and vary from it, so far as it affects the light, only in its opacity. It should preferably contain no opaque particles, but allow the light to travel in it until it is absorbed.

Diffused light. But when the halation by reflection from the glass is entirely prevented by mounting the sensitive film upon an opaque support, the fogging around high lights is still perceptible. The chief cause of this is probably to be found in the motes which we see very markedly when a beam of bright light passes through the air. The visibility of these motes is proof that they reflect light. Under ordinary circumstances the path of every pencil of light that passes from the lens to the sensitive surface is in a measure luminous, and scatters light in every direction within the camera. The effect of this scattered light is to produce fog upon the plate round the proper image of the luminous object, and a fog that gradually decreases in density from the image of the light outwards, and may extend an inch or two before it fades away. It is not practically possible to cure this defect, and, indeed, it is not worth while to spend much trouble about it, as it is not often obtrusive even in difficult subjects.

And the lens itself is a source of scattered light, for the very best of lenses are not polished to such perfection as is necessary in a good telescope objective of large size, because such refinement would add to the expense, without giving any appreciable improvement, at least in the vast majority of cases, in its performance in the camera. The imperfections of finish in a photographic lens are easily

seen by holding the instrument between the eye and a candle or gas flame, and moving the lens to one side, so that the flame just disappears. The lens will now appear more or less luminous, showing that the irregularities of its surfaces are sufficiently numerous and great to reflect the light in stray directions in a manner similar to the motes in the sunbeam. The tendency of this imperfection of the lens is to give a uniform fog over the whole plate, rather than the local fog that is more immediately under discussion.

CHAPTER XVI.

THE NATURE OF THE DEVELOPABLE IMAGE.

THE change that the light effects in the sensitive salt of the plate is obscure, and the chief fact known about it is that the developer will rob the silver of its bromine where the light has fallen upon the film, while the developer is unable to effect this change where the light has not preceded it. Hence it may be said that the practical result of the action of light is to loosen the attraction between the silver and the bromine, or to render the silver bromide less stable.

It is generally considered that the main question is whether a chemical or a physical change takes place in the silver salt (silver bromide) when a developable image is produced. A physical change is an alteration in the nature of the substance which does not affect its composition. Silver bromide, when physically changed, remains silver bromide, but the nature of the combination or of the combination of the molecules into aggregates is modified. A chemical change consists of an alteration of the composition of the substance. In this case it would be a matter of decomposition; the silver and bromine, instead of remaining combined, would be wholly or partially separated.

Now a chemical change must be preceded by a physical change; there must be a movement or commotion within the molecule before actual decomposition takes place. The question, therefore, is not whether the change

is chemical *or* physical, but whether it is physical only, or whether it passes beyond the physical stage to an actual decomposition. There certainly is some change, and, therefore, there is a physical change; but while some consider that this is followed by decomposition, others, including the author, consider that the balance of evidence is overwhelmingly against decomposition.

Production of the developable condition. The developable condition of silver bromide may be produced by all the known forms of energy. Heat, light, mechanical force, electrical stress, and the application of chemical substances, are all, under suitable conditions, able to effect the change.

Intense cold does not prevent the production of the developable condition. Professor Dewar found in 1894 that gelatine emulsions at —180° C. to —200° C., although not so sensitive as at the ordinary temperature, were still fairly sensitive, and he remarked that if the effect were due to a chemical change, "it appeared to be the only one that could be traced . . . . . at such low temperatures." These results have been in a general sense confirmed by other observers. The conclusion quoted above doubtless requires modification in the light of subsequent experiments, but it remains substantially true.

Mr. Carey Lea showed, in 1887, that by touching a haloid salt of silver with sodium hypophosphite, it was made amenable to the developer as if light had acted upon it.

Dr. W. J. Russell showed, in 1899, that hydrogen peroxide in minute quantity would convert silver bromide into its developable condition. A piece of inert blotting

paper moistened with the peroxide diluted with 500,000 times its bulk of water and dried for threequarters of an hour, when placed into contact with a gelatino-bromide plate for two hours, produced a distinct developable effect. He also found that certain metals, such as zinc, if clean, boiled linseed oil, turpentine, and substances containing them, such as printers' ink and copal varnish, and many other substances, gave off something that similarly affected silver bromide. He ascribed the action in these cases also to the production of hydrogen peroxide, but there remains much doubt as to whether hydrogen peroxide is the direct agent. These active emanations do not pass through glass or paraffin wax, but they will pass through sheet gelatine, celluloid films, guttapercha tissue, sheet india-rubber, collodion, vegetable parchment, real parchment, and gold-beaters' skin.

The Röntgen rays, which have been found not generally able to promote chemical action, the emanations from pitchblende and other uranium compounds, and from radium, are often detected and utilised by the fact that they produce a developable image. It has been stated that the various forms of radiant energy recently discovered which produce the developable image do not all act in the same way, as certain of them will produce reversal when following certain others, but not all others. If this can be confirmed it distinctly points to physical effects.

Although we are concerned chiefly with the nature of the developable image produced in gelatine plates, it is worth noting that Moser, in 1842, found that a silver surface by exposure to light had its power to condense vapours, such as of mercury and water, upon it enhanced.

General Waterhouse in 1900 confirmed these experiments, and showed that the image so produced could be developed, not merely by the condensation of such vapours (this development being of the kind employed in the Daguerreotype process), but also by other methods, such as those used for the development of wet collodion plates. He found, however, that if the silver plate was made red hot and plunged into dilute sulphuric acid and then washed and dried, it was not sensitive to light, therefore it appears probable that the change on exposure is not in the metal, but in the minute amount of some compound that apparently clean metal has upon its surface.

The developable condition produced by pressure. By drawing a smooth end of a glass rod across a gelatino-bromide plate, a developable line results from the slight pressure. It requires a considerable stretch of the imagination to suppose that this operation produces chemical decomposition, but such pressure does produce a physical change in many cases, as, for example, in yellow mercuric iodide, a substance that is somewhat closely related to silver bromide. In the case of the mercury salt, a striking change of colour results, from yellow to red. Colour is a mere accident of physical condition, but in this case it demonstrates the change beyond dispute. In dealing with a stable substance such as silver bromide, it is more easy to imagine that so slight a cause produces a physical change, which, it is known, can be produced in such a manner, rather than a chemical decomposition, the possibility of which has not been proved.

The action of sensitisers does not seem to present any difficulty in connection with the physical theory. They appear always to be substances that can combine

with bromine. Before they combine they must exist in a condition of preparedness-for-combination; there must be a tendency towards combination, but this alone (under normal conditions) produces no change. Light has a tendency to change the silver bromide into a more easily reducible condition, and eventually to decompose the salt, but alone it is powerless. But light and the sensitiser together are able to effect the change that each has a tendency to do, though neither alone can accomplish it. Whether this change is an actual decomposition or a change into a less stable form of compound is immaterial, so far as the action of sensitisers is concerned.

The quantity of material that forms the developable image. If there is decomposition, the amount of silver salt that is decomposed must be exceedingly minute, small almost beyond imagination. The amount of decomposition might be increased many thousands of times before the products of decomposition would have accumulated in sufficient quantity for direct recognition. The exceeding minuteness of the extent of the decomposition is allowed, as it must be, by all who advocate the decomposition theory, but it is a very weak point in that theory, as will be subsequently shown. If the change is regarded as physical only, this difficulty disappears altogether, and the quantity of silver salt changed into the developable condition is readily recognised and weighable.

Stability of the developable condition. The remarkable stability of the developable image has been adduced as an argument in favour of its consisting of a substance that is chemically, and not merely physically, different from the original silver bromide. But there is no reason

why a physically changed silver bromide should not be as stable, or even more stable, than the sub-bromide. The soluble and the insoluble varieties of sulphur remain soluble and insoluble respectively for long enough. The black and the red sulphides of mercury are chemically identical, and both are stable. The same may be said of the yellow and the red oxides of mercury. And each of these substances, it may be noted, behaves to certain reagents in a different manner from the other, though both, in each case, have the same composition. Many other examples might be quoted. On the other hand, many of the products of chemical change are exceedingly unstable.

The stability of the developable image is not much argument either for or against either theory of the nature of the developable image, but what little weight it has appears rather to favour the physical theory. An *exceedingly minute* amount of metallic silver or silver sub bromide would probably be more readily affected by outside adverse influence than a physically modified silver bromide present in relatively very large quantity. Moreover, the silver or the sub-bromide is in any case, according to the chemical theory, in the immediate presence of the bromine that it has lost, and one cannot accept this theory without supposing that the bromine easily leaves the gelatine and returns to the silver, or else that aerial oxygen readily oxidises the sub-bromide, as these are the only explanations of reversal that have been suggested to fit in with that theory. The stability of the developable image becomes, therefore, from this point of view, a strong argument in favour of the physical theory, because it is necessary that the image shall be unstable according to the chemical theory.

Image transference. In 1881, Eder and Pizzighelli found that the developable image produced in one compound of silver would be retained if this compound was changed into another. A chloride of silver plate was exposed, soaked in potassium bromide solution until only bromide of silver remained, then well washed and developed. Dr. Eder says: "The latent image, which previously was of chloride of silver, was not destroyed, but changed into an analogous bromide of silver picture."*

Further experiments in "image transference," as it is called, were carried out by Mr. Carey Lea in 1887. He found that if a film of citrate, benzoate, tartrate, or pyrophosphate of silver were exposed to light under a negative, the film was developable even after it has been treated with hydrochloric or hydrobromic acid, and the silver salt consequently changed into the chloride or bromide. Indeed, the haloid salt produced is more susceptible of development than the original salt. These experiments are not evidence either for or against the idea that the developable image is due to a chemical change, because a physical condition may be transferable from one compound to another.

The reversal of the image, that is, the loss of the developable condition by increased exposure, is difficult to account for on the decomposition hypothesis. It is generally ascribed to an accumulation of bromine in the gelatine (in combination with it), which recombines with the silver sub-bromide to reproduce the original bromide, or else to the oxygen of the air which oxidises the sub-bromide. In either case the product would not give those

* This shows that potassium bromide does not destroy the developable image, as it has often been stated to do, but simply retards development.

nuclei of metallic silver from which, according to the decomposition hypothesis, the image is supposed to grow. In the case of the bromine going back, having once left the silver for the gelatine, it may be asked why should it go back from the gelatine to the silver, while the force that determined its movement in the first direction continues to act? But, suppose that it does migrate in this strange way, the amount of silver salt affected must be, according to this theory, so exceedingly minute that there must be a comparatively enormous quantity of silver salt ready to be decomposed, and so to furnish a developable image. Development should be possible until the whole of the silver salt has been decomposed and recomposed in turn, and even then it is difficult to see why the cycle of changes should not begin all over again.

If it is aerial oxygen that gives an undevelopable oxy-bromide from the sub-bromide, then it would appear that the image should be developable until all the silver salt has been converted into the oxy-bromide, and this production of oxy-bromide should be capable of proof by analytical methods.

In either case the exposure necessary to produce reversal might be expected to bear something like the same proportion to the exposure necessary for maximum density in development that the silver salt decomposed by light bears to the total weight of silver salt present. This latter ratio must be between figures so enormously different that the author cannot attempt to describe it, but with a pure silver bromide gelatine emulsion the proportional increase of exposure is a quite small figure. Mr. C. Bennett found that ten times the exposure that

gave maximum density gave a result on development equal to no exposure at all.

The growth of the image during development. The exceedingly minute amount of sub-bromide produced by ordinary exposure, according to the decomposition hypothesis, is allowed on all hands to be very, very far from sufficient to furnish by itself an image that can be seen or discovered in any way, except by allowing it to grow. This growth, which means the reduction to the metallic state of the silver bromide that has not been affected by light by the indirect agency of that which has, is a necessary adjunct to the decomposition theory. The physical theory is complete in itself, and needs no supplementing. But the physical theory is in no way opposed to the fact that, under some conditions, the image spreads during development, unexposed silver salt being reduced to the metallic state. The demonstration that the image spreads in this manner, therefore, is no proof of the chemical theory, though it removes a difficulty which, if it existed, would at once condemn the decomposition hypothesis.

But in a gelatine plate, it has never been proved that the image does grow more than an almost negligible amount (if at all), such, for example, as might interfere in the photographing of fine black lines. It is common experience that in the development of a gelatine plate a time comes when the "development is complete," "the exposure effect is exhausted," "there is nothing more to get," "the density ceases to increase," to quote a few common phrases. If the whole image, except an indescribably small fraction of it, is the result of this growth or spreading, why should the growth of the image stop while the developer is still on the plate, instead of going

on until the reduction of the silver salt is complete, and the plate is evenly black all over ? It has been suggested that this growth cannot extend from granule to granule in the gelatine, but only from one part to another of the granule, so that only those granules that have been affected by light by the production in them of a few molecules of sub-bromide are amenable to development. This refinement of the chemical theory appears almost equal to the surrender of it. It formed no part of the original idea, and that the exigencies of the case should require such a suggestion is evident proof of the difficulty found in applying the chemical theory to the results of everyday work.

According to the decomposition hypothesis of the nature of the developable image, all that the developer has to do is to reduce the sub-bromide that is produced by the action of light to the metallic state, this silver, by acting on unaltered bromide, producing more sub-bromide, which is in turn reduced, and so on. The developer, therefore, simply reduces silver sub-bromide to the metallic state. This hypothesis obliges us to believe that there are some substances that can reduce silver bromide, but cannot reduce the sub-bromide, or else these substances are of such a nature that the action of silver on silver bromide to form the sub-bromide cannot take place in the presence of their solutions. The first suggestion seems exceedingly unlikely. With regard to the second, it is known that development is not hindered by ammonia, or by a solution of ferrous citrate and ferrous oxalate, but by mixing the two the author has been unable to develop a developable image, although the silver salt was slowly and in the end copiously reduced.

These difficulties and the need for those out-of-the-way suggestions do not exist if the physical theory is adopted. It is only what would be expected that some substances should be able to reduce the silver bromide that has been made less stable by the action of light without affecting the unchanged bromide, while other substances should be unable to discriminate between the altered and the unaltered bromide. It is often the case that it requires much care to distinguish by chemical means between two different physical conditions of the same substance.

If there is decomposition, that is, if the developable image consists of silver bromide that has lost a part of its bromine, then, as the function of the developer is to remove bromine (leaving the image in metallic silver), exposure and development ought to be to a considerable extent interchangeable. But exposure and development are not interchangeable, for exposure beyond a certain point makes development impossible.

In some cases, however, it is otherwise. In exposing printing-out papers it appears that the exposure may be stopped at almost any time, and the image completed by development. This developable image, therefore, has not the same characteristics as the one we are considering. It may be urged that in printing-out papers organic salts of silver are present, and act as sensitisers, that is, absorbers of bromine, but gelatine is a sensitiser, too, and will absorb large quantities of bromine.

The action of ammonia. One of the most direct pieces of evidence against the decomposition hypothesis is furnished by the action of a solution of ammonia. This reagent, it is admitted, decomposes silver sub-bromide,

leaving half the silver as metal. Therefore, taking cognisance of this reaction only, the application of ammonia to the plate first in development ought approximately to halve the speed of the plate, because the amount of the metallic silver produced by its action would be one half the quantity produced by the initial action of the developer, which, according to this theory, reduces the sub-bromide entirely. Or, if the speed of the plate is not so much affected, certainly development should be retarded by the previous application of the ammonia, because it would give only half the amount of metallic silver to start with. But, as a matter of fact, applying the ammonia first rather quickens development, and tends to increase the apparent sensitiveness of the plate.

An ordinary solution of ammonia is a good solvent for finely-divided silver, the oxygen of the air dissolved in it taking part in the reaction. The previous application of ammonia should, therefore, not only straightaway halve the amount of metallic silver that otherwise would be available, but at once begin to get rid of the other half by dissolving it. As the largest possible amount of silver is exceedingly minute, thousands of times smaller than the smallest quantity directly detectable, and so finely divided, withal, as to be invisible, the ammonia should quickly dispose of it. Now these effects of ammonia are not imaginary effects; they can easily be verified. But, as a matter of fact, ammonia facilitates development. Ammonia does not act on the developable image as it does act on silver sub-bromide. This, therefore, is evidence that the developable image does not consist of silver sub-bromide.

The nature of the developable image. The author

believes that all the facts known to bear on this subject agree with the supposition that the developable image consists of particles of silver salt rendered less stable but not decomposed, and that no particle can be developed that has not been itself immediately affected by the exposure. It should be borne in mind, however, that light is not homogeneous, and that its effects vary according to its wave length. There may, therefore, be more than one change going on during the exposure of a gelatino-bromide plate. And it is possible that the nature of the developable image varies; it may be different on a gelatine dry plate from what it is on a wet collodion plate, and again different when a Daguerreotype plate is employed.

All ideas as to the exact character of the change that occurs in the silver salt when light produces a developable image are exercises in imagination. It has been suggested that the silver bromide is ionised, that the molecular grouping in which perhaps it exists is modified, or that a kind of crystallisation action takes place; but these and other ideas of the same sort do not serve to correlate the facts that are known, and their usefulness is not apparent.

A working hypothesis that the author ventures to indicate in the crudest of terms for the sake of clearness views the silver bromide either in single molecules or molecular aggregates as if the silver and bromine were flat figures, say like two visiting cards arranged edge to edge in the same plane, as they would be laid upon a table side by side. The change of this group into the developable condition would consist in the rotation of one about the axis common to both until it was in a

plane at right angles to the plane of the other, this rotation at the same time screwing the one away from the other. Such a system would evidently be less stable under certain conditions than the original. By the continued action of light the rotation would continue until the two parts were both again in the same plane, and this would represent reversal—an undevelopable condition produced by a continuance of the change that produces the developable condition. The further action of light producing further rotation, a second developable condition results, but less marked than the first, as the increased rotation has separated the two parts further from each other. As the rotation continues the developable and undevelopable condition alternate, but rapidly become confused, until the two parts are really forced asunder and actual decomposition results. The student can for himself apply this suggestion to all the facts of the case.

CHAPTER XVII.

COLLODION. ITS MANUFACTURE.

PYROXYLINE is a nitrate of cellulose, and cellulose is the essential constituent of purified vegetable fibre, such as cotton, unsized paper, etc. Collodion is a solution of pyroxyline in a mixture of alcohol and ether.

Just as sodium nitrate results when nitric acid acts upon caustic soda, so cellulose nitrate is obtained by the action of nitric acid upon cellulose. But in this latter case it is possible to produce several nitrates according to the extent of the action of the acid, and, therefore, if an approximately definite preparation is desired, it is necessary to control the reaction. Sulphuric acid is invariably mixed with the nitric acid, as it affords a valuable means of regulating its effect because of the readiness with which it combines with the water that is produced. The sulphuric acid is necessary also to prevent the loss of the cotton by its solution in the nitric acid, and it has probably another effect analogous to the toughening it produces in the making of parchment paper. By the further action of the somewhat diluted sulphuric acid, cellulose is changed into a dextrine and finally into glucose. Concentrated nitric acid has a very remarkable toughening effect upon paper that is immersed in it for a few seconds and is then washed.

The changes, therefore, that cotton undergoes when subjected to the action of the mixture of acids may be very complex, and not to be described simply as the

formation of a nitrate, though this is the only change that can be definitely expressed.

When the strongest acids are used at a low temperature (50° Fahr.), and the action is prolonged for twenty-four hours or so, a cellulose trinitrate [$C_6H_7(NO_2)_3O_5$] is produced, which is insoluble in a mixture of alcohol and ether, and is more violently explosive than any other cellulose nitrate. It is the gun-cotton of warfare. By using diluted acids at a higher temperature (130° to 150° Fahr.), and stopping the action after about ten minutes or rather more, the chief product is a dinitrate [$C_6H_8(NO_2)_2O_5$], which is readily soluble in a mixture of alcohol and ether, and is the essential constituent of pyroxyline. By the action of hot dilute nitric acid a mono-nitrate [$C_6H_9(NO_2)O_5$] may be prepared, which is readily soluble; but these changes and the properties of the products are not very definite, and it seems probable that intermediate nitrates are also formed.

Potassium nitrate may be used instead of nitric acid if more sulphuric acid is added to liberate the nitric acid from it, and the salt has the advantage over the acid of being easily obtained pure, and not being liable to decomposition by storage.

The following two formulæ will give an idea of the suitable proportions—

Sulphuric acid, S.G. 1.845	..	18 fluid ounces.
Nitric acid, S.G. 1.45 ..	..	6½ ,,
Water	..	4¼ ,, (Abney).
Potassium nitrate, dry	..	510 grains.
Sulphuric acid	..	15½ drams.
Water	..	1½ ,, (Hardwich).

As soon as the cotton is withdrawn from the acids it should be thoroughly washed, as it seems probable

that a small quantity of acid remaining in it tends to produce a subsequent decomposition. When thoroughly washed and dried, the pyroxyline should be stored in tin canisters or cardboard boxes, so that a small amount of acid that may be given off may escape. If kept in a glass bottle it is more liable to decomposition, apparently because the small quantity of nitrous fumes evolved cannot escape.

Collodion. To make collodion, the pyroxyline is dissolved in a mixture of ether and alcohol (it is not soluble in either separately) in the proportion of about six grains to the measured ounce of solvents, or twelve to thirteen grams to 1,000 c.c., but more or less pyroxyline may be taken acccrding to circumstances. It depends upon the purpose to which the collodion is to be applied whether the solvents must be pure, and in what proportion they should be used. If an "enamel collodion" is desired, that is, a collodion to be used simply to give a protective film to prints or to negatives, methylated alcohol and methylated ether may be used according to the following formula—

Pyroxyline	12 grains.
Alcohol	1 ounce.
Ether	1 ,,
Castor oil	2 drops.

The castor oil gives toughness and elasticity.

Collodion that is to be the medium of a sensitive salt, as in the wet-collodion process for negatives, must have the castor oil omitted, and the solvents must be pure and of a proper strength. The ether should be of specific gravity .725, and the alcohol about .805 to .82. The higher the specific gravity of the alcohol the more

water it contains, and the water introduced thus unwittingly by those who have no technical knowledge of these matters is a very important item in the preparation.

In cold weather about a tenth part of the alcohol may be omitted and a corresponding amount of ether added, that the solvents may be more volatile. But the amount of license in varying the proportions of the solvents is not very great without the sacrifice of desirable qualities. Ether, being the more volatile of the solvents, causes a more rapid setting of the film if in excess, and in coating large plates it may thus be impossible to get the whole film in a sufficiently uniform condition, the top setting before the bottom has drained. Excess of ether also causes the film to be tough and highly contractile, so much so, indeed, that it may spring off the plate. Collodion is used in surgery to form a protective film over wounds, and its powerful shrinkage after it has set is then advantageous. Excess of alcohol causes the film to be slow in setting, less contractile, and therefore more firmly adherent to the glass plate when such a support is employed ; it makes the film more porous and soft, and therefore allows a more rapid penetration by any solution that may be applied to it. A greater excess of alcohol makes the collodion thick and glutinous. A certain proportion of water is often desirable in collodion when it is to be employed as a medium for sensitive salts, as it makes the sensitive film more opaque and creamy, and therefore capable of giving a more vigorous picture. But too much water makes the collodion thick, and the film it yields is "reticulated" as if it had shrunk and formed a network of fine cracks, and it is so "rotten" that a gentle stream of water would wash it off the plate.

CHAPTER XVIII.

COLLODION POSITIVES AND NEGATIVES.

THE wet-collodion process, whether for positives or negatives, is very different from the working of gelatine plates, both in theory and in practice. In a gelatine plate the bromide of silver with a little iodide is diffused through the gelatine, and by exposure to light and development the silver salt is reduced to metallic silver. But in a wet-collodion plate the iodide of silver, with perhaps a little bromide, held in position by the film, has also a solution of silver nitrate in close contact with it, and in development it is chiefly the silver reduced from this solution by the developer that deposits itself upon the so-called latent image. The development of a wet-collodion plate is therefore a process of intensification rather than development, as these terms are understood in connection with gelatine plates.

As the developer has to deal with a solution of nitrate of silver instead of with an insoluble silver salt, it must be very much weaker that the silver may be reduced to the metallic state only so slowly that it can select its place of deposition, and, in fact, would not be deposited at all except for the slight disturbance caused in the solution by the latent image in its immediate vicinity. Now a simple solution of ferrous sulphate or pyrogallol acts almost immediately upon nitrate of silver, giving a copious deposit of the metal; therefore it is necessary to restrain the action, and this is done by the addition of an acid.

Alcohol is also an ingredient in wet plate developers, but it is added merely to facilitate the flow of the developer, and must be increased as the silver bath gets old and alcohol accumulates in it. The silver bath is the solution of nitrate of silver into which the collodionised plate is dipped to render it sensitive.

The collodion used has first to be "iodised," that is, to have a soluble iodide, or more generally an iodide with a little bromide, dissolved in it, and it is customary to dissolve these salts in half the alcohol needed for the collodion, and to mix it with the solution of the pyroxyline in the rest of the solvents only as may be required; for iodised collodion changes very much more rapidly than plain collodion.

Wet-collodion process. The general manipulations necessary for producing a wet plate picture (positive or negative) are as follows: First the plate must be scrupulously cleaned and polished, as with tripoli powder and alcohol or the equivalent; a little ammonia may be added to the tripoli and alcohol. The tripoli cleans by a polishing action, and the alcohol and ammonia dissolve greasy matters. If the glass is *thoroughly* clean, it may at once be coated with the iodised collodion; but most operators prefer to give a substratum of albumen, which makes certain the adhesion of the collodion film. For the substratum may be used—

White of	1 small egg.
Water	1 quart
Ammonia	4 drops

thoroughly mixed and filtered. The cleaned plate may be well rinsed with rain or distilled water, drained, and while still wet some of the albumen solution is poured

over it. When the substratum is dry the plate may be used at once or stored for use when required. The next operation is coating with iodised collodion, and this is done by pouring it on in the manner described for the application of varnish to gelatine plates, taking especial care to rock the plate to and fro that the collodion may not flow in ridges. When the collodion ceases to drop from the glass, and the film is in just that condition that it will receive an impression when touched by the finger, the plate is ready for immersion in the silver bath.

Purest silver nitrate ..	30 to 40 grains	or 60 to 80 grams.
Distilled water to ..	1 ounce	1,000 c.c.

This, with perhaps dilute nitric acid added very cautiously until blue litmus paper is *just* changed towards a red tint by prolonged immersion in the solution, is all that would be needed if silver nitrate solution did not dissolve silver iodide. When the plate is immersed in the silver bath the iodides and bromides in the collodion react with the silver nitrate, thus—

$$AgNO_3 + AmI = AgI + AmNO_3$$

forming the iodide and bromide of silver, which are the sensitive salts required. But if a simple solution of silver nitrate were used, the silver iodide would be dissolved out of the film and the plate rendered useless. It is therefore necessary to add enough iodide to the bath to prevent its further action in this direction. Some prefer to saturate the bath with iodide of silver by putting a couple of coated plates into it; but it may just as well be done in a direct way. To this end dissolve the silver nitrate in a quarter of the bulk of water required, and add to it about two grains of potassium iodide for every ounce of solid silver

salt used, or half a gram to 100 grams. Then add the rest of the water and a precipitate of silver iodide will be formed, for this salt is less soluble on dilution. After filtration and acidification (if necessary) as above, the bath is ready for use.

In manipulating wet collodion plates care must always be taken to keep the edge from which the collodion was drained downwards.

Collodion positives. The collodion positive is the form of photograph invariably produced by peripatetic operators, because it is quickly made and rapidly dried, and can be handed in a finished condition to the customer a very few minutes after the exposure. This form of picture is called in America an "Ambrotype," and if on enamelled iron is called a "ferrotype."

As the deposit of silver represents the lights or whites, it is imperative that the metal shall be got as white as possible, and as the shadows are represented by a backing of black velvet or black varnish, it is important that the deposit of silver shall be coarse-grained enough to be transparent, and show something of the black backing through the parts that stand for the half-tones of the subject.

A collodion that gives rather a thin image is advisable, and as nitric acid tends to produce whiteness of the deposit, it may be added to the silver bath a little more freely than stated above, and it is used as the restraining acid in the developer. It is also advantageous to replace some of the ferrous sulphate of the developer by ferrous nitrate for the same purpose, but ferrous nitrate alone cannot be used, because it is so feeble a developer.

The following developer is recommended for positives—

Ferrous nitrate	110 grains.
Ferrous sulphate	60 ,,
Nitric acid	20 minims.
Alcohol	quant. suf.
Water	4 ounces (Abney).

The plate is fixed by flooding it with a solution of potassium cyanide of a strength of about twenty-five grains to the ounce or fifty grams to 1,000 c.c. The cyanide is preferable to hyposulphite in this case, because the deposit of silver is sufficiently granular to resist any appreciable action upon it, and a little reducing effect is often advantageous. Also it is cleaner in its effect and more easily washed away than sodium hyposulphite. After fixing and washing, the plate may be dried by very gently warming it over a spirit lamp flame.

If the film side of a collodion positive is presented towards the spectator, as it must be in a ferrotype, the image is reversed, that is, if the model was turned towards the right, the picture will represent him as facing the left. But if the film side of a glass positive is coated with black varnish, the glass side of the plate becomes the front and there is no reversal.

Collodion negatives. A wet-collodion negative may be regarded as an over-exposed and over-developed positive in which no trouble is taken to get the image any special colour. In the positive the surface is everything, but in the negative the opacity is the only important matter.

The collodion used must give a good film. The iodisers may be varied very considerably, but generally the compounds of potassium, ammonium, or cadmium are employed. Potassium salts do not dissolve freely in

collodion, hence, although they can be employed, they are not so much used as they would otherwise be. Cadmium salts dissolve very freely, and they are stable, but they make the collodion glutinous—an undesirable condition that is modified by keeping the collodion for a few months after adding the iodiser. Ammonium salts dissolve easily, and do not affect the collodion like cadmium salts, but they are unstable.

An iodide alone gives a hard picture; a bromide alone gives a flat picture full of detail. Therefore, when a black and white subject is to be copied, it is advantageous to use an iodide alone, but for ordinary half-tone subjects a mixture of bromide with iodide is preferable. A collodion suitable for positives is given by Hardwich as containing—

Pyroxyline	1½ grains	} to each ounce.
Iodide of potassium ..	1½ ,,	

and the difference advised for negatives is—

Pyroxyline	2½ grains	} to each ounce.
Iodide of potassium ..	2½ ,,	

Four grains of ammonium iodide when that is used alone or five grains of cadmium iodide may be taken to each ounce containing six grains of pyroxyline.

The following is a specimen formula containing both ammonium and cadmium salts and a bromide—

Ammonium iodide	3 grains
Cadmium iodide	½ ,,
Ammonium bromide	1⅔ ,, (Abney)

to each ounce containing six grains of pyroxyline.

In altering an iodising formula, or, indeed, any formula, care must be taken to introduce an equivalent quantity of the compound that replaces the other, and not an equal weight. The following chemical formulæ

stand for equivalent quantities of the iodides and bromides of potassium, ammonium, and cadmium, and the atomic weights put below them show the proportions that should exist between the weights of the salts in exchanging one for another—

$2NH_4I$	$2KI$	CdI_2	$2NH_4Br$	$2KBr$	$CdBr_2$
290	332	366	196	238	272

If it is desired, for example, to replace one grain of ammonium iodide by cadmium iodide, the amount of the latter salt taken must be greater than that of the salt replaced in the proportion of 290 to 366, that is, practically, one grain and a quarter of the cadmium salt must be used.

The action of the developer has already been described. As it has to mix with the nitrate of silver solution that adheres to the plate, it is not advisable, if it were possible, to use a considerable bulk of developer in a dish as is usual with gelatine plates, because the small quantity of nitrate of silver would be diluted to too great an extent. Unless it is purposely desired to reduce the vigour of the negative the developing solution must not be allowed to overflow when it is poured on to the plate, for it would carry away some of the silver nitrate upon which the vigour of the resulting negative depends.

Either pyrogallol or ferrous sulphate will develop the exposed wet-collodion plate. The former gives opacity and fineness of deposit, but the iron salt appears to be more powerful in getting detail, and is preferred, except in special cases. The usual strength of pyrogallol is one grain to the ounce (or two grams to 1,000 c.c.), and if ferrous sulphate is used it may be from twenty to thirty

grains to the ounce (or forty to sixty grams to 1,000 c.c.), though these limits may be exceeded in both directions. A weak developer tends to produce contrast. A strong developer tends to softness, because the detail in the darkest parts is brought out before the lights have time to grow dense.

Whatever developer is used it must be retarded, and acetic acid is generally used for this purpose. Twenty minims of glacial acetic acid to each ounce of developer (or 40 c.c. to 1,000 c.c.) is effective; half this quantity or even less may be used, but the development is liable to be irregular, and stains may be produced.

The developing agent plus the restrainer, with just enough alcohol to make the solution flow easily on the plate, gives the simplest solution available. Many modifications have been suggested, chiefly with regard to the ferrous sulphate developer. Instead of sulphate of iron, the double sulphate of iron and ammonium may be employed, or copper sulphate may be used in addition to the ferrous sulphate, and in each case the solution is made more stable. Sulphate of iron solution in ordinary bottles slowly oxidises, and thus loses its developing power.

A wet-collodion negative as developed is often too thin, and requires intensification or "redevelopment." This is simply a continuation of the developing process after washing the plate, but as no more detail is wanted the redeveloping solution may be more restrained. No alcohol is needed, because the simple aqueous solution will flow well over the washed plate, but a little silver nitrate must be added to supply the metal for deposition upon the image. A few drops of a solution of silver nitrate

containing ten grains to the ounce or twenty grams to 1,000 c.c. is added to the redeveloper immediately before it is applied to the film.

Other methods of intensification, such as those given for use in connection with gelatine plates, are available after fixing.

For fixing collodion negatives hyposulphite of soda is to be preferred to potassium cyanide for the same reason that it is preferred for gelatine plates, though there is less probability of the cyanide attacking the image of a collodion film. The hyposulphite of soda may be four ounces to the pint or two hundred grams to 1,000 c.c., and the cyanide may be twenty-five grains to the ounce or fifty grams to 1,000 c.c.

CHAPTER XIX.

COLLODION DRY PLATES, SENSITISERS, AND EMULSIONS.

In the wet-collodion plate the sensitive film is moist with a solution of silver nitrate, and in the last chapter the importance of this silver solution for development was pointed out. The question at once arises—May not this silver nitrate be washed off the plate so that the plate may dry without crystallisation on its surface, the dry plate be exposed, and the silver nitrate restored at development, as, indeed, silver nitrate is added in redevelopment? If the silver solution was of no use except in development, this process would be practicable, but as a washed plate is very much less sensitive than one not washed, we have proof that the silver nitrate solution exercises an important function during the exposure. How the silver nitrate causes this increase of sensitiveness is not known, because it is not known how light acts in producing a developable image.

Sensitisers. If pure chloride of silver is dried by those careful means that only the chemist knows how to employ, it may be exposed to light without changing colour. But chloride of silver that is wet is partially decomposed by the action of light and chlorine is set free. If the chloride of silver is wet with a solution of silver nitrate, the darkening by the action of light is more rapid. In these cases the water and the nitrate of silver solution are "sensitisers," and the latter is a more powerful sensitiser than the other.

SENSITISERS.

In 1862, Poitevin showed that certain substances were not decomposed by light unless an absorber of the element liberated (chlorine, in the case of silver chloride) was present. In 1865, Dr. H. Vogel took up the question, and gave considerable attention to it. He showed that the sensitiser was probably necessary, and certainly advisable, to enable light to produce a developable image; and that a great many substances that absorb or chemically combine with the halogens (iodine, bromine, chlorine) act as sensitisers, but that the power of sensitising is not proportional to the vigour of combination with the halogens. Moreover, the sensitiser that is most active toward silver iodide is not the most active towards a mixture of iodide and bromide as generally used in the collodion process.

It is assumed by many that because most sensitisers can act after the manner of (in chemical language) reducing agents, and because many reducing agents act as sensitisers, that the action of the sensitiser is a reducing action, and that its function is to take up the halogen liberated by light in the production of the developable image. The sensitiser may act in this way when decomposition is produced by light, but it has not yet been proved that any decomposition of the silver salts takes place in the production of the developable image, and the action of the sensitiser in this case is therefore not known. If the sensitiser performed this duty and nothing more, the most powerful reducing agent should be the most powerful sensitiser, but this has not been found by Dr. Vogel to be so. This matter is further referred to in the chapter on the nature of the developable image.

On a wet-collodion plate the silver nitrate solution

adhering to it is necessary during exposure, and the silver salt must not be allowed to dry on the plate, because it would crystallise and produce irregularities. If a dry collodion plate is desired, therefore, the nitrate of silver solution must be replaced by some other sensitiser that will dry evenly. For this purpose the following substances, or extracts of them, have from time to time been recommended: Gelatine, tannin, gallic acid, albumen, tapioca, rice, eggs, raisins, honey, sugar-candy, raspberry syrup, jelly, ale, porter, gin and water, stout, wine, tea, and coffee. This list is the result of a want of scientific method on the part of many photographic experimentalists. Instead of working with pure substances or mixtures of pure substances, uncertain household preparations were often employed, and when another experimenter essayed to prepare plates after the formula given, he met in many cases with failure, for the gin and water of one locality may be very different from the gin and water of another, although the consumers take every care to add exactly the same proportion of water.

These substances, here called sensitisers, were generally called "preservatives," and were so called before their sensitising action was clearly understood. Moreover, "sensitising the plate" is an expression generally applied to the change that takes place when it is immersed in the silver bath. The word preservative is very justly used, for the material employed as a sensitiser must be more than a sensitiser; it must form a protective coating over the film.

Collodion dry plates. To prepare dry collodion plates by the "bath process," the plates are treated much as already described until they are put into the silver bath.

That a more complete action may take place, the plate remains rather longer in the bath; it is then removed, washed, flooded with the preservative, and dried.

The exposure necessary may be from that needed for a wet plate to twenty or thirty times as long, according, partly, to the developer. When about to develop, the preservative, having done its work, is washed off, as in some cases it would interfere with the further operations. Dry collodion plates are preferably developed like gelatine plates, and with similar developers.

Collodion emulsions. It will be observed that the action of the silver bath in preparing a dry collodion plate is merely to form the silver salt in the film. As the bromide and the iodide are added to the collodion, it appears but natural to add the nitrate of silver, too, and so transform the "iodised" or "bromised" collodion into a collodion "emulsion." The silver bath is then dispensed with, for the sensitive salt is in the collodion. The first collodion emulsion that gave useful results was prepared in 1864, and was due to the labours of Messrs. Sayce and Bolton, who used bromides only in its preparation.

The simplest method of preparing a collodion emulsion is to make a collodion with a suitable quantity of a bromide, but with enough alcohol omitted from it to dissolve the silver nitrate in, and to add the solution of the silver nitrate in the alcohol with constant stirring or shaking. The silver nitrate added must be a little in excess of that required to form silver bromide with all the bromide present. The emulsion so produced is not in its best condition, but should stand for from twelve to twenty-four hours to "ripen." At the end of this time the emulsion is more creamy and more sensitive, and prepared glass

plates may be coated with it. When the film has set, the plate is washed and the preservative applied.

Instead, however, of washing each individual plate the emulsion itself may be washed. To effect this the solvents are evaporated or distilled off and the residual pellicle is washed with water. The water remaining after squeezing is washed out with alcohol, and the pellicle is redissolved for use. Plates coated with such an emulsion do not need washing, and can be used without a preservative, but a preservative is recommended if reliable working is considered a desideratum.

CHAPTER XX.

THE MANUFACTURE OF GELATINO-BROMIDE PLATES.

THIS is not the place to enter into the technicalities of the making of gelatine plates, as this volume is intended for the photographer and the student, rather than for the manufacturer. The photographer at the present time does not make his own plates any more than he makes his own apparatus, though, indeed, he may do both as occasion may require.

It has already been explained what a collodion emulsion is and how it may be prepared; a gelatine emulsion is quite analogous, but, instead of pyroxyline dissolved in alcohol and ether, there is gelatine dissolved in water; and instead of the film on the coated plate solidifying by the evaporation of the solvents, as in collodion, it sets to a jelly by the cooling of the warmed mixture, and afterwards dries slowly. But there is a great difference between collodion and gelatine in the influence that the medium has upon the sensitive salt; for while collodion has so little effect that it may be considered inert, gelatine is an energetic sensitiser. The collodion emulsion ripens by standing for a few hours; but the gelatine emulsion, by a few days' warming or a few minutes' heating to the temperature of boiling water, is exalted in sensitiveness to a degree that seemed incredible at first.

It appears that the first formula for making a gelatino-bromide emulsion that was published was due to Dr. Maddox, who, in 1871, made known some experiments

he had performed with the object of replacing collodion with gelatine.

When a soluble bromide is mixed with silver nitrate, silver bromide is produced with the nitrate of the other base. Thus with potassium bromide—

$$AgNO_3 + KBr = AgBr + KNO_3$$

The importance of washing away the nitrate was pointed out by Mr. Joshua King in 1873.

In 1878, Mr. Charles Bennett prepared a very sensitive gelatine emulsion, and by its means produced some instantaneous negatives that astonished those who saw them. Bennett's improvement consisted of keeping the emulsion at a temperature of about 90° F. for six or seven days. This tedious procedure was shown to be unnecessary by Mr. G. Mansfield in the following year. He heated his emulsion by means of boiling water, and got sensitiveness in minutes instead of days. The highly sensitive condition of silver bromide is obtained only when the heating takes place in the presence of gelatine, and apparently only when the soluble bromide is in excess, so that some remains after it has changed the silver entirely into bromide. The emulsion when first prepared appears orange-coloured if looked through, but after cooking it transmits grey light. The change of colour indicates that its absorptive action upon light is different, and as a matter of fact the "boiling" of the emulsion confers a slightly increased sensitiveness towards the less refrangible light.

Gelatine jelly when kept melted for a considerable time, or when heated to the temperature of boiling water for a short time, loses its power of setting. Mr. W. B.

Bolton had, in 1874, recommended that only a little of the gelatine should be used in preparing the emulsion, and the rest added afterwards. This modification became of great importance, and was speedily adopted when gelatine emulsions were heated to gain sensitiveness. Many experiments have been made to get rid, as far as possible, of the gelatine in which the emulsification and boiling take place by means of centrifugal apparatus, so that the pure silver salt in its high state of sensitiveness may be mixed with fresh gelatine. This process appears to be very desirable, but it is not generally adopted.

The variations in the methods of making gelatino-bromide emulsions are innumerable; many formulæ have been published, and manufacturers are careful not to allow the details of their processes to get known.

The following method of preparing a slow emulsion for landscape work by Mr. W. K. Burton will serve as an illustration, and can easily be followed by the student who wishes to experiment in this direction. He says—

"I will give a formula, although I claim no particular merit for it, except that I have tried so to adjust the details that the process may be as simple as possible, and that the chance of failure may be reduced to the minimum.

A. Nitrate of silver, 200 grains; distilled water, 3 ounces.

B. Bromide of potassium, 160 grains.
Iodide of potassium, 10 grains.
Nelson's No. 1 gelatine, 40 grains.
Hydrochloric acid, 2½ minims.
} Water, 3 ounces.

C. Hard gelatine, 150 grains.

D. Hard gelatine, 150 grains.

"The gelatine of B is allowed to soften. At the same time water may be poured over the lots of gelatine C and D (kept separate one from the other) to let them swell.

"A and B are now heated to 120° F., and A is poured into B slowly, with vigorous stirring. The emulsion thus formed is allowed to stand for ten minutes with occasional stirring. Meantime, as much of the water is squeezed out of the gelatine C as is possible by wrapping it in a towel or similar piece of cloth, and wringing the cloth round.

"After ten minutes the emulsion (having been allowed to remain without stirring for at least two minutes to allow any granular bromide which may have been formed to subside) is poured over C, heat being, if necessary, applied to melt the gelatine. When the gelatine and the emulsion are thoroughly incorporated, the jar containing them is set on one side to allow the whole to set into a stiff jelly. In cold weather there is no difficulty in getting the emulsion to set, but if the weather is warm it should be allowed to stand in a vessel containing water with a lump or two of ice in it. Once thoroughly set, the emulsion is washed in any of the well-known ways, being either squeezed through canvas, or otherwise cut into small fragments. When it has been washed thoroughly and drained, so that no more water will drain from it, D (having had as much water as possible wrung out of it) is added. The whole is melted up, and one half ounce of pure alcohol is added, when it is ready for coating plates.

"The quantity of emulsion that I have described should serve to coat a dozen 10 × 8 plates. A skilled coater could make it cover a dozen 12 × 10 plates without any part being too thin."

The washing of a gelatine emulsion is preferably done by squeezing it under water through netting of small mesh. It is thus finely divided, and the water readily

gains access to every part. Twice squeezing through netting under clean water and well washing under the tap will probably be sufficient. If the excess of soluble bromide (which is necessary during the boiling in order to obtain increased sensitiveness) is not washed away, a considerable loss of sensitiveness will result.

A fairly sensitive emulsion may be prepared by means of ammonia and without boiling. The ammonia should be in such quantity as just to redissolve the oxide of silver that it precipitates when first added to the nitrate of silver. This method has the advantages that all the gelatine may be added at once, as the temperature of about 95° F. for the short time required does not materially decompose it, and that a slightly acid or slightly alkaline condition of the gelatine, or any of the salts used, exercises no detrimental effect.

CHAPTER XXI.

THE PRINCIPLES OF ORTHOCHROMATIC PHOTOGRAPHY.

THE visibility of colour obviously depends upon the capability of the human eye. If the average seeing power of the majority is taken as the standard, there will be found a very large number of deviations. Some will see more in the sense of being able to distinguish colour that is no colour to the majority, and others will see less. Those who are called colour-blind have a still more limited range. In referring, therefore, to the visibility, luminosity, or the intensity of light, it is understood that reference is made to the average seeing capacity of the majority of individuals.

The visual intensities of lights of different refrangibilities are far from being proportional to the photographic power of the same lights, and advantage is taken of this fact in selecting a light that shall be comparatively safe in which to manipulate sensitive materials. A yellow light may be made quite bright enough for such operations, but yet of such feeble photographic power that the most sensitive plates are not apparently affected by exposure to it for a few minutes. This is a great convenience, but the difference between visibility and photographic effect is sometimes disastrous in photographic results. The yellow of a picture which is light to the eye may be shown dark in a photograph of it; dark red may show as black, while dark blue may produce the same effect as white or light grey. Such a total change in the

disposition and proportion of light and shade generally makes a photographic copy of a brilliantly-coloured picture taken on an ordinary plate worse than useless.

If the photographic activity and the brilliancy of light were uniformly proportional, these anomalies would cease; and accordingly attempts are made to cause the sensitiveness of the plate to be more nearly proportional to the visual brightness. To make the two exactly proportional is not yet possible, and it may well be doubted whether it ever will be. The differences, however, can be so markedly and usefully diminished that with proper care and suitable control of the light any coloured object can now be photographed without showing sensible errors in the visual depth of tint in any part.

The only perfect colour scale is a continuous spectrum, and a plate cannot be said to be perfectly orthochromatic unless, when a continuous spectrum is photographed upon it, the densities of the various parts of the photographic image are equally proportional to the brilliancy of the corresponding parts of the same spectrum. For these purposes the solar spectrum may be regarded as continuous, though it has innumerable absorption lines in it, because these lines are most of them immeasurably narrow, and the solar spectrum is convenient because the Fraunhofer lines in it give fixed points for comparison.

In fig. 72 the Fraunhofer lines are drawn vertically, and are marked with their usual letters, and each curve as it rises from the horizontal line indicates an increase of effect, and as it approaches the line a decrease of effect.

Curve 1 shows the brilliancy of an average solar spectrum to the eye. The yellowish green between D and E is the most brilliant, and the brightness rapidly

diminishes to the red at C, B, and A, and to the blue between F and G; the violet from G to H is very feeble, and beyond K there is the ultra-violet, which is invisible. The spectra are shown as produced with prisms, the dispersion becoming greater towards the violet. A normal spectrum, such as is produced by a diffraction grating, the dispersion being equal throughout, would give an almost symmetrical curve.

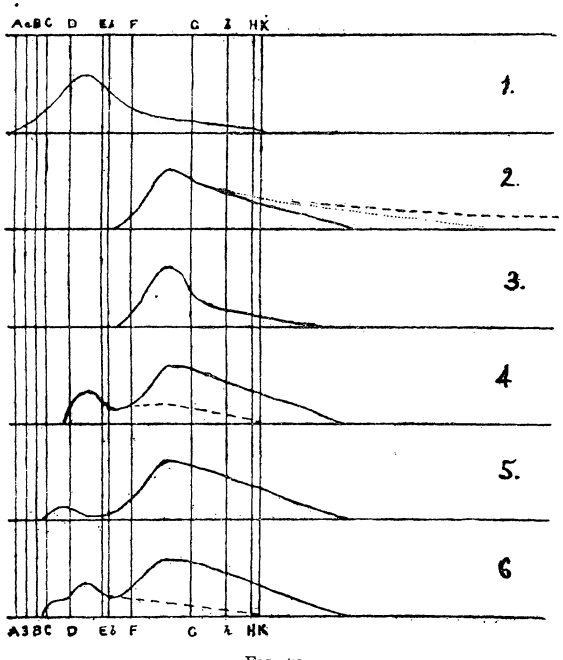

FIG. 72.

Curve 2 represents the spectrum as photographed on an ordinary gelatino-bromide plate. Here the most brilliant

colour is not represented at all, and the maximum of action is in the blue nearly at G. At H and K the action is still very considerable, and it extends a good distance into the ultra-violet. The continuous line on the violet side shows the effect when glass prisms and lenses are used, and as photographers generally use glass lenses this is the most important line. But this side of the curve has but little to do with either the intensity of the radiations or the sensitiveness of the plate. It is largely governed by the glass of the apparatus which cuts off the light beyond. The same observation applies to the same side of the curves 4, 5, and 6, and accounts for their similarity. By using quartz lenses and prisms instead of glass, the intensity of action follows the dotted line, but even this does not indicate the sensitiveness of the plate, but only the failure of the solar radiations because of their absorption by the atmosphere. A magnesium light near to the apparatus gives the effect represented by the broken line, and it would have to be extended a long way beyond the margin of the figure to show the limit of the photograph of this spectrum. And the true limit of the sensitiveness of gelatino-bromide plates is much further still.

Curve 3 shows a photograph of the solar spectrum taken on an ordinary plate but at sunset, and although no glass was used here, the atmospheric absorption is so much greater when the sun is low, that the violet and ultra-violet are very much more enfeebled than when the glass apparatus was employed with ordinary daylight. This increased atmospheric absorption with a low sun is an important item in some practical work.

These curves show the general results produced by

ordinary exposures. But even ordinary plates are sensitive to green, yellow, and red to a very small extent—to so small an extent that it is impossible to show it in these diagrams. The many colour-sensitised plates now obtainable have the sensitiveness to these colours, or to some of them, very largely increased, though still very small compared with what is really required. To compensate for the remaining deficiency, it is usual artificially to reduce the intensity of the colours to which the plate remains too sensitive by causing the light to pass through a yellow, orange, or reddish screen before it falls upon the plate.

Curve 4 shows the spectrum taken with glass apparatus on a commercial orthochromatic or isochromatic plate, or a plate described as sensitive to yellow and green. Here the added sensitiveness to the yellow and green is very marked, but there is still a great preponderance of effect in the blue. This can be reduced by passing the light through a yellow glass, and the broken line indicates roughly how such a procedure affects the result. It will be noticed that the curve (with the yellow glass) approximates in general character somewhat to the brilliancy curve No. 1, and such plates as these, by suitably regulating the light, will be useful for all colours except when red is present.

Curve 5 gives the result of using a Lumière "red and yellow" sensitive plate. This plate is obviously less useful for general work than the preceding one, but would be specially useful where red sensitiveness only is required, as in certain photo-mechanical operations, if employed with a red screen to cut off the light that acts so strongly in the blue and violet.

Curve 6 is drawn from a spectrum taken on one of Lumière's "panorthochromatic" plates, which are sensitive to red, yellow, and green. Here the special sensitiveness shown in curves 4 and 5 is combined, and the effect when a yellow screen is employed, as roughly indicated by the broken line, is a near approximation to the brilliancy curve of No. 1. Such a plate used with discretion, and with a carefully-selected coloured screen, should well represent almost all pigmentary colours.

The "spectrum" plates of Messrs. Cadett and Neall show an even less want of sensitiveness in the green at E and *b* than indicated in curve 6, and are practically non-sensitive beyond the C line, the less refrangible red being reserved as a convenient light to manipulate the plates in. Messrs. Sanger Shepherd and Co. prepare carefully-measured coloured screens adjusted to the "spectrum" plates, and by using these plates with such a screen the photographer has the nearest approach to orthochromatism that is, at least commercially, possible at the present time.

The effect of certain dyes in increasing the sensitiveness of silver compounds to certain colours was discovered in 1873 by Dr. H. W. Vogel. His idea seems to have been that the light stopped or absorbed by the dye was caught or trapped by it, and so was enabled or obliged to act upon the silver salt in its immediate presence. That yellow light, for instance, which, under ordinary circumstances, would pass by the particles of silver compound, when retained by the dye was made effective like the blue light that the silver salt would absorb unaided. But the effect of light upon the silver salt and upon the dye cannot be so separated. Some dyes that are effective form a compound with the silver bromide that may be

freed from the gelatine it is prepared in, and introduced into fresh gelatine without losing its changed properties; or a plate that has been treated with a solution of suitable colouring matter may be washed until the film is colourless without removing the dye, because it has entered into combination with the silver salt.

Practically speaking, all colour-sensitised plates made at the present time are sensitised by means of dyes. But in 1880, Sir William Abney succeeded in preparing a collodion emulsion of silver bromide with which he photographed the solar spectrum considerably beyond the visible red. It is well known, too, that different silver salts, or different conditions of the same salt, vary in the way in which they are affected by light. Therefore, special colour sensitiveness can be obtained in various ways, but the most convenient method is by the use of dyes.

In January, 1883, Messrs. Tailfer and Clayton secured a patent for the preparation of orthochromatic plates by means of an ammoniacal solution of eosine, and Messrs. Edwards and Co., securing the right to work under this patent, did more than any other firm in this country to demonstrate the advantages of such plates and to popularise them when they were first introduced.

CHAPTER XXII.

THE PRACTICE OF ORTHOCHROMATIC PHOTOGRAPHY.

It might be inferred from what has already been stated that it would be desirable to use, in all photographic work, a combination of a colour-sensitised plate and a light-absorbing screen that would give the nearest approach to a uniformity of proportion between density and visual brilliancy. But by so doing a very large proportion of the sensitiveness of the plates used would be thrown away, and other inconveniences would follow. The usual rule, therefore, is to restrict the use of orthochromatic methods to those subjects that would be represented obviously falsely by ordinary plates.

There are many different opinions as to when it is, on the whole, desirable to use colour-sensitised plates. There can be no doubt, however, that they are necessary for scientific experiments, in which red and yellow light have to be dealt with. They are also necessary in photo-micrography when the slide is stained to a reddish or yellowish colour, unless it is an advantage to have the stained part showing much darker than it appears on the slide. The photography of flowers, when that is necessary, demands the use of orthochromatic methods, and the same may be said concerning most dyed fabrics, especially when the colours are bright. Coloured pictures, by common consent, may also be classed with objects requiring special methods, except perhaps when the colours are low in tone. When the object to be photographed

is yellow, as a faded silver print, or when the light used is perforce of a yellowish kind, as gas or ordinary lamp light, then yellow sensitive plates will be advantageous as shortening the exposure. In portraiture, if the subject has yellow freckles or similar irregularities in the skin, these will show darker than they should if an ordinary plate is used, and this may be obviated by using colour-sensitised plates with a suitable screen. Ordinary portraiture, unless the subject or the costume is exceptional, and the photography of objects of a uniform colour, such as stone buildings, statues, wood carvings, drawings and prints in black pigment, and many other such objects, as a rule, do not require specially sensitised plates. They are advantageous when there is a fog or a bluish mist, because the yellow screen stops much of the light reflected from the fog, and so gives a clearer image. Ordinary plates exaggerate fog because of their great proportion of sensitiveness to the violet and ultra-violet. But landscape work, when done under those conditions that prevail when the most of it is undertaken, does not seem to benefit very much by the use of such special methods. The elimination of "atmosphere" is not desirable, and there is so much white light reflected from ordinary foliage that the rather deficient sensitiveness to green of ordinary plates is not always very obvious in the result. It should be noted, too, that in an ordinary landscape much of the foliage is often very dark indeed, and there is not much fear of getting it too dark in the print. The lighter greens of grass, and the yellows of sand, are liable to come out too dark without extra precaution. For these, certainly colour-sensitised plates are desirable, and their advantage is also marked when the sky is partly or wholly blue.

COLOUR SENSITISING.

The preparation of colour-sensitised plates has now practically passed out of the hands of photographers, as the preparation of ordinary plates has. The sensitising of plates, or the preparation of a specially sensitised emulsion in small quantities, was always a very uncertain operation, for various samples of dyes bearing the same name, and supposed to be identical in composition, often give very different results. One sample may serve excellently, while another is useless. These and other difficulties are more easily overcome by the manufacturers who buy large quantities of material than by the photographer or experimentalist.

Many hundreds of dyes have been examined as to their advantages for sensitising purposes, but it appears that a comparatively few are actually employed. The following formulæ are given rather as illustrations and to serve as preliminary exercises for those who wish to experiment in this direction, than with the idea that anyone will prepare his own colour sensitive plates. The difficulties above referred to as to the names and qualities of the dyes must be borne in mind.

Erythrosin, or rose Bengal, will sensitise for the yellowish green. Messrs. Mallmann and Scolik recommend to dust the plates and to soak them for two minutes in a bath of—

Ammonia	2 parts.
Distilled water	200 ,,

and then to immerse them for from one to one minute and a quarter in the following solution—

Erythrosin (1 : 1,000 of water)	25 parts.
Ammonia	4 ,,
Distilled water	175 ,,

While the plates are in the baths the liquid should

be kept in motion. The plates are drained and then put to dry. They are salmon-coloured. It is preferable to wash the plates before drying them, as this gets rid of a tendency to irregularity without diminishing the colour sensitiveness. The general sensitiveness is much increased. Curve No. 4, page 413, will serve to indicate the effect of this treatment.

Cyanine increases the sensitiveness to red. Dr. Schumann recommends the following bath—

Distilled water	200 parts.
Ammonia (strong)	2 to 4 ,,
Absolute alcohol	10 ,,
Cyanin solution (1 : 500 absolute alcohol)	5 to 10 ,,

The plates are first soaked for two minutes in a mixture of from a quarter to four parts of strong ammonia to two hundred of water, immersed in the above bath for two minutes, drained and dried. They will not keep in good condition for more than two or three days, and must be developed with a rather weak, well restrained developer, as they are liable to give fog. Curve 5, page 413, gives a general indication of the sensitiveness of plates so prepared.

Sir William Abney finds that cyanine may be used in conjunction with the erythrosin bath given above by adding to it five parts of an alcoholic solution of cyanine (1 : 1,000). Or the plates treated as specified by Messrs. Mallmann and Scolik may be washed and dried, and then soaked for two minutes in the following bath—

Cyanin	1 part.
Alcohol	100 parts.
Water	9,000 ,,

The plate is then washed with alcohol diluted with nine times its volume of water, and then with water alone, till all greasiness has disappeared, and exposed while still moist:

The tendency of cyanine to give foggy plates may be very much reduced, according to Dr. Eder, by converting the ordinary iodo-cyanine into chloro-cyanine, by heating it with dilute hydrochloric acid in a water bath, evaporating to dryness, warming to get rid of the acid, and dissolving in alcohol.

Mr. George Higgs finds that "alizarine blue S" or "cœrulean S," when purified, is very advantageous for increasing sensitiveness to the red and infra red. He recommends the following bath—

Purified dye	1 part.
Water containing one per cent. of ammonia,	10,000 parts.

The plates do not keep longer than a day.

Since these dyes were introduced, others have been found that give superior results; and the best for giving sensitiveness to all colours, including red, are stated to be orthochrome T, suggested in 1903, and pinachrome in 1904. For use, one gram of either substance is dissolved in 500 c.c. of warm alcohol, and to this solution 500 c.c. of water is added. This solution of one in a thousand is stable. For use, it is diluted to fifty times its bulk, and it is sometimes recommended to add half as much of ammonia as is taken of the one in a thousand solution. Plates are allowed to remain in this bath for two minutes washed, and dried. It is stated that plates so sensitised will keep in good condition for a few months.

Concerning the use of dyes in general, Mr. C. H. Bothamley says that, if added to the emulsion, two to four milligrams per 100 c.c. of melted emulsion is sufficient. He states that the most efficient processes are those in which the prepared plate is dipped into a dye solution,

and recommends an immersion for two or three minutes in a solution containing—

Dye solution (1 part in 1,000 parts of water)	1 to 2 volumes.
Ammonia (10 per cent.)	1 ,,
Water	8 ,,

The plate is then drained and dried in a pure atmosphere. The ammonia may be omitted if erythrosin or rose Bengal is used, but five or six times the exposure will then be required.

If a plate could be made perfectly orthochromatic, any light would be as good as any other to work with in developing, but the light would have to be reduced until its effect upon the plate became practically nothing. But as perfect orthochromatism is not yet possible, there is always one or, it may be, two tints that have their visibility in excess of their photographic activity, and this is a guide for the light to be selected. For any commercial colour-sensitised plate a dull red light will generally be found as convenient as any. The ordinary dark room lamp with its yellow medium may have a ruby coloured glass or a red cloth added to it. Even with this it is advisable to keep the plate covered as much as possible during development, and to expose it to the light only when necessary.

The use of coloured screens. The correct method for obtaining correct colour values is to have a coloured screen adjusted to the colour sensitiveness of the plates used, that is, suitable for compensating for their excessive sensitiveness to the more refrangible light, and always to use it. This adjusted compensation is found in the measured screens made by Messrs. Sanger Shepherd and Co. for Cadett's spectrum plates. In the open air they

require the exposure to be increased about forty times, and it is this prolongation of the exposure that leads to the use of lighter screens. But any such modification is a compromise. When colours are concerned, a colour-sensitised plate without a screen is but little better than an ordinary plate; the lightest screen that needs an increase of exposure by two or three times gives a further improvement; and so the photographer may progress until he arrives at the perfectly adjusted colour screen with the considerably prolonged exposure. How much error is permissible for the sake of convenience is a purely practical question, and must depend upon the subject. On the other hand, it is not impossible to use a screen unsuitably or too deeply coloured, and to cause blue to photograph as if it were black and yellow as if it were white. But this is not a common mistake, and often when this error is supposed to exist, it would probably be found that the screen was really too light and that the anomalous result was due to some other and undetected fault.

When the sun is low the great thickness of the atmosphere that the light has to pass through reduces the amount of the more refrangible light, and it is often considered that a coloured screen then becomes unnecessary. But the effect obtained without one will approximate to a photograph of the scene by full daylight instead of by evening light. When artificial lights of a yellow colour are used as illuminants, such as gas flames, paraffin lamps, incandescent electric lamps, a given coloured object may be photographed without a screen, getting about the same result as if the photograph had been taken by daylight through a coloured screen requiring an increase of exposure by about four times.

The position of the coloured screen may be anywhere between the source of light or the object and the plate. Artificial lights may be enclosed in a lantern after the manner of a dark room lantern, and this has the advantage that the defining power of the lens cannot be interfered with. The most usual place for the screen is against the lens, immediately in front or behind, or more rarely in the diaphragm place. The screen must then be of carefully selected material and with parallel sides, as it becomes, from an optical point of view, a part of the lens. A screen immediately in front of the plate is generally awkward to manipulate, but in that position its optical perfection is not so necessary. In all cases it is important to focus with the screen in position, for the best focus of white light will rarely be the same as that of the coloured light transmitted by the screen.

Kinds of coloured screens. As to colour, certainly glass screens are the safest unless the proposed screen can be tested by means of a quartz spectrograph. Spectroscopic observations by the eye are of no use whatever, because when using dyes the danger lies in the dark violet and the ultra-violet. Almost all yellow dyes transmit such light. Multiple yellow, for example, allows much violet to pass that the eye can scarcely detect, but that renders it useless for this purpose. Naphthol yellow and brilliant yellow transmit a little ultra-violet, though too little to be of practical importance. With such yellow dyes as those last named it is easy to overstep the mark, and in effect to cut the blue out altogether. This may be obviated by reducing the intensity of the colour, or, if the screen is to be placed against the diaphragm, by cleaning off a small patch in the middle of it, that a little

white light may pass through. This last method is not to be recommended for general purposes, as obviously the smaller the diaphragm inserted in the lens the greater will be the proportion of white light. The advantages of glass screens are that they are permanent in tint, the absorption is more gradual from red to blue than that given by dyes, and there is no risk from the possible transmission of ultra-violet light. On the other hand, almost all yellow glass approximates to a brown colour, and this means much loss of useful light, and the glass must be taken as it is, its tint cannot be adjusted or varied in any way. As said before, all screens are only approximations to what is really wanted, except such as are carefully adjusted by measurement to a specific kind of plate. The most perfect control of depth of colour is obtained by the use of a glass cell fixed against the lens, into which any required solution of any possible strength can be introduced. Such cells are expensive, because the sides must be parallel and optically worked. They are not to be recommended for general work, as they involve risk of accident, such as leakage, and solid screens can be made that answer all ordinary purposes.

The construction of coloured screens. Coloured screens may be made by coating thin patent plate glass with either collodion or gelatine* in which the dye is dissolved. Two pieces of glass may be coated and cemented together face to face with Canada balsam and bound with tape. Those accustomed to work with such materials will understand the manipulation ; others will find it more easy to take a plate already coated, such as a lantern

* Varnish may also be used, but the warming is very liable to change the colour of the dye.

plate, fix out the silver salt and thoroughly wash the film, and then immerse it in an aqueous solution of the dye until the film has taken up as much as required. The plate is rinsed and allowed to dry. This is the most convenient way of testing a number of dyes for the purpose of selection. Thin glass, such as is used for covering microscopic objects when mounting them, may be coated when the screen is for the diaphragm place, or a coloured collodion film may be stripped from the glass and attached to a diaphragm. It is not safe to recommend any particular dyes because of the uncertainty referred to above, but aurantia, brilliant yellow, naphthol yellow, and ammonium picrate may be mentioned as having been found useful. For the last, the coating solution may be made by neutralising a saturated solution of picric acid with ammonia, and dissolving twenty grains of gelatine in each ounce. The testing of coloured screens is referred to in a subsequent chapter.

CHAPTER XXIII.

PHOTOGRAPHY BY ARTIFICIAL LIGHT.

THE advantages of artificial light are not only that it enables photography to be carried on in dark places and at times when daylight is not available, but that by its constancy when properly attended to it conduces to uniformity of result, and thus to the minimising of failure. A great deal of the photography done in connection with the production of printing blocks is carried out by the aid of electric lights, daylight being entirely discarded, because of the greater certainty of success when a method is used that is never interfered with by variable atmospheric conditions.

The electric arc light is generally the most powerful, and is especially to be recommended because of its richness in those rays to which photographic plates are most sensitive. It has been adapted for photo-mechanical work, copying, enlarging, portraiture, and all indoor work, with complete success.

Incandescent electric lamps give a markedly yellow light, comparable with gas and paraffin lamp flames. By increasing the current the light is whiter, but the "life" of the lamp is shortened. The ease with which these lamps may be manipulated, their perfect silence, and the readiness with which the light required may be divided and spread over any area, are great advantages.

For those who have to use gas, the incandescent system of Welsbach is to be recommended. The full size

mantle gives an illumination of about sixty candle-power when at its best, and its richness in blue light and consequent whiteness are so remarkable when compared with ordinary gas flames, that if one part of a white surface is illuminated with the incandescent light and another part with a first-class argand burner of the ordinary pattern, the latter will appear almost a brick red because of the contrast. By reason of the whiteness of the light, it is for ordinary photographic purposes about one and a half times as effective as a gas flame of the same visual intensity.

Acetylene gives an excellent light for photographic purposes. There are several thoroughly reliable generators now obtainable. The smallest, taking a charge of one pound of calcium carbide, are specially useful for work on a small scale. Self-contained lamps are not desirable, because of the tendency to overrun them, which procedure may lead to danger, and will certainly result in a loss of economy.

Gas and paraffin lamps give a light poor in violet, and thus they are eminently suitable for orthochromatic work. Gaslight with no coloured screen gives about the same effect as daylight with a yellow screen that would be called commercially of "medium" tint. If orthochromatic effects are not desired when gaslight is to be used, still the exposure will be shortened if yellow sensitive plates are used.

The use of magnesium. The light given by burning magnesium is richer in ultra-violet light than even the brightest daylight, and as the metal readily burns with a very brilliant flame, it is especially useful. Magnesium lamps that pay out the ribbon as it is burned are trouble-

some to keep in order, but it is generally sufficient to cut off the length required and burn it without the aid of a lamp. Magnesium burned in oxygen is stated to have about twelve times the actinic value of the same weight burned in air, and there is the additional advantage of burning it in an enclosed space that the smoke is retained in the vessel used.

Mr. J. Y. McLellan, in 1882, devised a lamp for burning magnesium in oxygen, that consisted of a glass globe supported on a gas holder that contained the oxygen. The globe was filled for each operation, and the ignited magnesium ribbon introduced at an opening in the top. This type of apparatus, but of an improved form, has been made commercially by the Platinotype Company since 1899. The magnesium is placed in position in the glass combustion chamber, and ignited when desired by making an electrical connection that allows a current to pass through a piece of thin wire to heat it.

Flash lights, as the name indicates, are not continuous. The flash may be made of such short duration that instantaneous effects may be secured without the aid of a shutter. Magnesium powder lends itself very advantageously to work of this character, and numerous flash lamps have been devised in which the powder is blown by a puff of air into a flame. A convenient type of such apparatus consists of a small pipe with its end bent upwards at right angles, and surrounded with some material upon which spirit may be poured to give the flame. Before lighting the spirit the charge of magnesium is put in the pipe, and when the flame is at its best, a puff from the mouth, or bellows, or an indiarubber ball, drives the powdered metal into it, and at the same time

increases the temperature by the blow-pipe action. The duration of a flash so produced will vary from perhaps an eighth, or more generally a quarter, of a second up to more than a second. Some lamps on this principle give a "continuous flash," being arranged for a prolonged current of air, and provided with a large reservoir for the magnesium. By using a blast of oxygen and a gas flame, an exceedingly powerful and continuous light may be obtained, as is exemplified in the magnesium lamp devised by Mr. E. J. Humphery in 1893, and introduced by the Platinotype Company. This lamp has since been replaced by the one described above.

With the simple lamps it is easy to arrange a number of them to flash simultaneously by connecting the pipes of them all with indiarubber tubing to an air reservoir or a similar apparatus, so that one puff may actuate them all. It is desirable not to put an over-dose of magnesium into the lamps, but to increase the number of lamps if more light is wanted, or a considerable proportion of the powder may be driven through the flames without being burnt.

If a quicker flash is wanted, the magnesium must be mixed with some substance that will effect its rapid combustion. *All such mixtures should be regarded as dangerous*, and made only a few grains at a time by mixing the separately powdered ingredients on a piece of paper with a mixer made of card, wood, ivory, or similar material, on no account letting any metal come into contact with them. Some mixtures of this character are stated to be harmless, and they certainly vary in the risk they cause, but it is desirable to take the above precautions with all, and then, with common intelligence,

there need be little fear of accident with any of them. The ingredients must all be carefully dried and finely powdered *before they are brought together.* If used as purchased, though apparently dry, the combustion will be much retarded.

1.—Magnesium	.. ..	6 grains.
Potassium chlorate	.. .. ..	10 ,,
2.—Magnesium	.. ..	6 ,,
Potassium chlorate	.. .. ..	4½ ,,
Potassium perchlorate	.. ..	4½ ,,
3.—Magnesium	.. ..	6 ,,
Potassium perchlorate	.. ..	9 ,,

More than the above quantities should not be mixed until the worker has had experience with these. The first is simple and convenient, the third is stated to be proof against accident by percussion or friction. A little pile of the mixture may be lighted with a taper or by means of touch-paper, taking care to guard against accidents from the sudden and large burst of flame that they cause. For combustion the powder should be supported on a metal tray, and there should be no combustible substance within two or three feet at least. If lit with a taper it should be of full length, and the face should be turned away. The duration of the flash with these mixtures is generally about the twenty-fifth of a second if they are properly dried, finely powdered, and well mixed.

Dr. Röhmann has recommended a mixture of approximately the following composition for orthochromatic work, as it gives a light rich in yellow and green rays—

Magnesium	.. ..	40 parts.
Potassium perchlorate	.. .. ..	63 ,,
Sodium chloride (table salt)	.. ..	5 ,,
Barium tartrate	.. ..	7 ,,

The intensity of these magnesium lights is very great.

Dr. Eder has calculated that half a gram of magnesium blown by the mouth from a glass tube across a flame gives a brilliancy equal to from 200,000 to 300,000 candles. The increased effect when oxygen is used has already been referred to. Mr. E. J. Humphrey finds three grains of magnesium burned in a flask of oxygen at fifteen feet from the sitter sufficient for a portrait. But the amount required will depend not only on the rapidity of the lens and of the plate used, but upon the colour of the walls and furniture in the apartment, and their nearness to the object photographed. It is advantageous to have those colours that reflect the greatest proportion of photographically active light.

The use of aluminium. The fine aluminium powder sold as "silver bronze" has been recommended for use instead of magnesium, and is stated, weight for weight, to give a more powerful light and less irritating fumes. The powder should be heated before use to get rid of the greasy matter that accompanies it. Small quantities may be heated in a test tube. The powder may be blown through a flame as in an ordinary flash lamp, or a mixture of two and a quarter parts of potassium chlorate to one of aluminium may be prepared, with the precautions given for similar magnesium mixtures, and used like them.

CHAPTER XXIV.

SILVER PRINTING ON ALBUMENISED PAPER.

THERE are many methods of photographic printing, but the oldest of those methods that have ever been commercially important is that in which the sensitive material consists of a layer of albumen which contains certain silver salts, and is supported on paper. This process has been largely replaced by the use of gelatine "printing out papers," which are described in the next chapter, but as it held its own for so long, and for nearly a generation had hardly a rival worth mentioning, it calls for detailed consideration. For many years the common expression "photograph" referred to an albumen silver print, and such expressions as "photographic purples" and "photographic browns" referred to the peculiar colours obtained by this method of printing.

The albumen is mixed with a certain proportion of ammonium chloride before the paper is coated with it, and, after the layer of albumen is dry, it is made sensitive by floating the paper on a solution of silver nitrate of a strength generally of from thirty-five to fifty grains to the ounce. The effect of the silver solution is manifold and somewhat obscure. It acts upon the ammonium chloride in the albumen, and changes it completely into silver chloride, with the simultaneous production of ammonium nitrate, according to the equation—

$$AmCl + AgNO_3 = AgCl + AmNO_3$$

The silver chloride is insoluble, and remains in the

albumen film; the ammonium nitrate is soluble in the water, and passes out, as far as it has time, into the silver bath. The nitrate of silver also acts upon the albumen itself, producing an insoluble compound, the nature of which is but little understood. The production of this compound is, however, of vital importance, for if the albumen were not made insoluble it would be washed off the paper. The stronger the solution of silver nitrate employed the more insoluble and less penetrable does the albumen become, so that a longer floating is necessary with a strong bath than with a weak one to ensure the thoroughness of its action. The excess of silver nitrate in the film, and the greater part of that which clings to the surface, remain in the prepared paper; and in the commercially sensitised paper citric acid or some other preservative is also introduced.

With such a complication it is not to be wondered at that the results are uncertain, and that the changes produced are not understood. But add to this the need of toning to get an acceptable colour instead of a disagreeable red, and we find in this process, perhaps, the greatest number of problems that even photography has ever brought together. It cannot be denied that the majority of prints made by this process are not stable; some last a month or two, some a year or two, a few are apparently unchanged after a decade or two, and still fewer have possibly lasted for a generation; but, although certain conditions that tend to obviate fading are very well known, no one can with certainty say why this difference exists.

It is not possible to state exactly when, or by whom, albumen was first used in the preparation of paper for

photographic printing. Both albumen and gelatine were used before 1851. A committee of the Photographic Society state in a report made in 1855 that they had examined silver prints on albumenised paper which were seven years old. This takes us back to 1848, and this appears to be the earliest record of any reference in connection with the process. It is probable that the idea of employing the albumen was to get brilliancy of image by keeping it on the surface of the paper instead of producing it in the paper, as had been done as early as 1802, when Wedgwood and Davy published their experiments. The albumen, however, profoundly alters the nature of the image.

The preparation of the paper. The albumen used for coating the paper is the white of eggs, and to this is added ammonium chloride dissolved in a little water. The quantity of the salt used may vary between wide extremes, from five grains to forty grains per ounce, but Mr. W. K. Burton says that from what he can gather "eight grains to the ounce is a common quantity of chloride of ammonium to use." After adding the determined proportion of the salt the albumen is beaten up very thoroughly to cause the separation and easy removal of animal membrane and to get a homogeneous solution. Insufficient frothing will not allow of the subsequent removal of membraneous matter, and this will give rise to streaks on the paper.

After settling, the mixture is filtered through muslin or flannel and poured into a flat dish. The sheets of paper to be coated are floated upon the solution and hung up to dry. If a piece of albumenised paper is put into water the coating will be readily dissolved off, and to prevent this in the after treatment of the paper it seems

that some early photographers advocated ironing the coated paper with a hot iron to coagulate the albumen. This, however, is quite unnecessary, as the albumen is made insoluble in the sensitising.

The albumenised paper is made sensitive by floating it on a solution of silver nitrate as described above until the silver solution has worked its way quite through the paper. It is only necessary to add that the coagulation of the albumen by means of the silver solution is not a mere coagulation such as takes place when an egg is boiled, but is the result of the formation of an insoluble compound of albumen containing silver called silver albumenate. The chemical formula that has been suggested for this compound is $C_{72}H_{110}Ag_2N_{18}SO_{22}$.

Thus sensitised albumenised paper when it is ready to be exposed to light is coated with a mixture of silver albumenate, silver chloride, silver nitrate, ammonium nitrate, and when the ready sensitised paper is employed, citric acid or some analogous preservative must be added to the list. Now, complication does not of necessity lead to uncertainty, but it may be worth while to see what is known about the effect produced by light upon these compounds, leaving out the ammonium nitrate and citric acid, as they may be unchanged.

The effects of exposure. Scheele showed that when chloride of silver was exposed under water the silver compound lost chlorine, and what remained was darkened in colour. Our knowledge of this matter is very little, if any, in advance of Scheele's, for no one has satisfactorily prepared a definite compound of silver with chlorine containing less chlorine than the ordinary white chloride. When albumenate of silver is exposed to the light it darkens to

a reddish colour, but the chemical change that takes place is not known—indeed, we have but a very small and fragmentary knowledge of the chemistry of albumen itself. It appears probable that the function of the nitrate of silver is rather to assist the decomposition of the other compounds than to contribute directly to the formation of the colour of the image. It probably takes up the chlorine liberated from the chloride of silver, and so facilitates the production of coloured decomposition substances, besides furnishing more chloride of silver. This change may be expressed thus—

$$Cl_2 + AgNO_3 + H_2O = AgCl + HNO_3 + HClO$$

The HClO is hypochlorous acid, a compound that has been shown to be actually produced when silver chloride and nitrate are exposed to light together. The nitric and hypochlorous acids introduce fresh complications into the problem. Therefore, when albumenised silver paper is exposed to light under a negative, an image is produced which consists of two constituents, and perhaps more, neither of which is known to be of fixed composition.

Toning. When a silver print is plunged into a solution of hyposulphite of sodium to fix it, the coloured albumenate of silver is very little affected, but the darkened chloride is dissolved in great measure, leaving a quantity of metallic silver behind that is probably equivalent to the chlorine expelled from it by the exposure to light. Hence the image is considerably reduced in intensity, and what remains is of an unpleasant reddish tint. To obviate the reduction in intensity it is necessary to expose under the negative until the depth of colour produced is much darker than is desired in the finished print, and to correct the colour it is usual to " tone " the print.

It is customary and advisable, though not necessary, to tone the print before fixing. Toning consists of depositing a fine powder upon it under such circumstances that the powder itself reflects blue light, and this blue, together with the brownish red of the original, gives the rich tints of a skilfully-made albumen print. If the print were fixed in an acidified solution of sodium hyposulphite, it would be toned to a rich brown, because the sulphur precipitated by the action of the acid would cling to the image. But sulphur toning, though very common in the early days of albumenised paper, is not to be recommended, because the result is probably more liable to fade than when gold or platinum is used.

Gold toning is invariably resorted to at the present day. It is possible to get gold precipitated as a blue or as a red powder, according to the size of the particles. Very slow precipitation gives the finer particles which appear red, while quicker precipitation gives less fine particles, which appear blue. Therefore though it is advisable to add some substance to the solution of chloride of gold to cause it to act regularly, care must be taken that the toning action is not too much retarded; for then red gold would be deposited, and the addition of red gold to the red image would give little or no change of colour. It is possible to make a toning bath so slow in action that it cannot overtone, but this is not an advantage, because, if the change of colour *cannot* go too far, it will probably not go far enough. Obviously, from these remarks, the amount of colour change in toning is not an index of the quantity of gold in the finished print.

Whatever formula for toning is employed, it is advisable to neutralise the free acid present in the chloride of

gold by shaking it up with powdered chalk and filtering in an hour or so. If this is not done, as an uncertain quantity of acid is present an uncertain solution is prepared, and the results will not be uniform. When acetate of soda is used, the chalk may be added with the acetate.

To prepare prints for toning, they should be washed until the free nitrate of silver is removed—four or five changes of water will generally suffice—and then put into a weak solution of common salt (containing a pinch or so to the pint), and finally washed about twice. The salt reddens the print, and makes the change of colour in toning more obvious. They are then immersed in the slightly warm toning bath. The following formulæ for toning baths are only examples of many others—

Borax	48 grains	or	12 grams.
Chloride of gold ..	1 grain		0.25 ,,
Water	8 ounces		1,000 c.c.

To be mixed only as required.

Sodium acetate ..	20 grains	or	5 grams.
Chloride of gold ..	1 grain		0.25 ,,
Water	8 ounces		1,000 c.c.

To be mixed at least two days before use.

Sodium carbonate ..	10 grains	or	2.5 grams.
Chloride of gold ..	1 grain		0.25 ,,
Water	8 ounces		1,000 c.c.

Must be used soon after mixing.

Strict care must be taken that no hyposulphite gets into a toning solution. An imperceptible amount such as may adhere to one's fingers or to the dish (if it has unwisely been used for fixing) is quite sufficient to stop toning. It may be found advantageous to increase or diminish the water in the above formulæ to adjust the time in which a satisfactory tone is obtained.

Platinum salts were used for toning silver prints certainly as early as 1856, and from that time forward very many formulæ have been proposed. A slightly acidified solution of platinic chloride (about one grain to fifteen ounces of solution) was used at first, but was very uncertain. It was not until potassium chloroplatinite was made available by Mr. Willis and the Platinotype Company that platinum toning was successful. The failures with platinic chloride may be ascribed to the fact that it may be reduced by the silver image to the platinous salt without any deposition of platinum. The following formula may be taken as an example—

Potassium chloroplatinite	1 grain	or 2 grams.
Nitric acid	2 minims	4 c.c.
Water	1 to 2 ounces	1 to 2 litres.

Fixing, etc. After toning, the prints are washed in two or three changes of water, and then fixed. Hyposulphite of soda, four ounces to the pint, or 200 grams to 1,000 c.c., with enough ammonia or sodium carbonate to make the solution alkaline, is a good formula. The solution must not have been used before, and it must not be overworked. It appears that a want of permanency can more often be traced to imperfection of fixing than to any other cause. The prints are then washed thoroughly and allowed to dry. Simple washing is the best, but there are methods of "hypo-elimination" by the use of chemical substances that act upon the remaining hypo. The action and use of these have been considered in connection with gelatino-bromide negatives.

CHAPTER XXV.

SILVER PRINTING ON "PRINTING OUT PAPERS."

THE most popular method of making silver prints at present in vogue is by the use of what are called "printing out papers," often contracted to the initials P.O.P. These are made by coating a paper that has been prepared with a smooth-surfaced hard substratum, with a gelatine emulsion (collodio-chloride paper is prepared with a collodion emulsion) containing chloride of silver and an organic salt such as a citrate. With the coating machinery now available, it is easier and more rapid to coat paper with such emulsions than to prepare sensitised albumenised paper which requires each sheet to be dealt with separately. Doubtless this facility of production on a large scale, coupled with the fact that such papers will last longer in good condition than sensitised albumen paper, accounts for the fact that albumen prints are now rarely made.

As to the comparative merits of the two classes of papers, there is not much to say. Some prefer the colours given by the newer and others the colours given by the older process. As to relative permanency, there seems very little to choose between them. In working with these "printing out papers," the character of the film must be borne in mind. Albumen prints will stand warm or even hot water, but obviously gelatine prints will not. The surface of collodion is more liable to injury by mechanical means than either of the others.

As these printing out papers are made of many different kinds (and often called by fancy names), it is not possible to give exact instructions for their use. The treatment specified by the maker must be followed, at least at first.

Toning. After printing a little deeper than required, but not so much deeper as is necessary in the case of albumen paper, the prints are washed and then toned. The following is probably the most used of all the toning baths that have been suggested—

Ammonium sulphocyanide (also called thiocyanate)	10 grains	or 20 grams.
Gold chloride	1 grain	2 ,,
Water to	10 ounces	1,000 c.c.

The ammonium salt is dissolved in half of the water, and to this is added the gold dissolved in an ounce or so of water. The addition of the gold causes a red colour which soon disappears. The solution when made up to the bulk is ready for use.

Another formula that is much appreciated is—

Sodium formate ..	15 grains	or 30 grams.
Sodium bicarbonate ..	2 ,,	4 ,,
Gold chloride	1 ,,	2 ,,
Water to	10 ounces	1,000 c.c.

The gold salt is added to the solution of the other ingredients, and the bath is ready at once.

Mr. A. Cowan has recommended the following platinum toning bath—

Potassium chloroplatinite	1 grain	or 2 grams.
Common salt	10 ,,	20 ,,
One per cent. solution of chrome alum	10 ounces	1,000 c.c.

The toning of these prints has led to the revival of combined toning and fixing baths with the addition to them of all manner of detrimental constituents. Such

baths were in use before alkaline toning was introduced, and it is a pity that they have come into fashion again. When baths like those given for use with albumen paper are used for gelatino-chloride papers, they will probably need to be made rather stronger, as the bath cannot be warmed, as is usual for albumen prints.

Care should in all cases be taken against over-toning, as the colour of the print darkens perceptibly on drying.

Many self-toning printing out papers are now made commercially. They contain the toning ingredients, or at least the gold or the active ingredients, in suitable quantity in the film itself.

For fixing, the hypo solution may be rather weaker than for negatives, namely, two or three ounces to the pint.

Development after partial exposure. A few years ago Mr. W. J. Wilson showed that prints on these papers may be developed to complete the image at any stage of the exposure after a certain small minimum. If full printing requires an hour's exposure, development may follow any exposure from about twenty seconds upwards. The print to be developed is put into a solution of potassium bromide until all the silver salts are changed into bromide of silver. A ten per cent. solution of potassium bromide is convenient, and the soaking may be for a minute or two. Further soaking does no harm to the image, but the gelatine itself may begin to soften if the solution is very strong and the immersion is very prolonged. The print is then washed in water for a minute or two and developed. The developer Mr. Wilson recommended is as follows—

Hydroquinone	3 grains.
Sodium sulphite	4½ ,,
Potassium bromide	6½ ,,
Ammonium carbonate	6 ,,
Caustic soda	1½ ,,
Water to	1 ounce.

After development the print is plunged into a bromide or weak acid bath to stop the action, and then toned and fixed.

CHAPTER XXVI.

PRINTING ON GELATINO-BROMIDE PAPERS.

GELATINO-BROMIDE paper, or shortly "bromide paper," is paper coated with a gelatino-bromide emulsion, similar to that used for gelatine plates, but slower. This paper is generally used for photographic recording apparatus in connection with meteorological instruments, also for direct printing, and especially for direct enlargements. Machines have been constructed by which a very rapid succession of exposures on bromide paper can be made, and by arranging that the developing and fixing operations may be done with sufficient rapidity, large editions of direct photographic prints can be expeditiously produced.

Exposure. The various kinds of bromide paper vary considerably in sensitiveness. The so-called "gaslight" papers are coated with so slow an emulsion that the paper may be exposed to ordinary gaslight, provided the light does not shine directly on to it, for the time necessary to fill the frames and develop the prints, without the production of fog. For making contact prints, the best method of exposure is to have a gas or paraffin lamp of a kind that the same intensity of light can easily be reproduced, and to hold the frame at a distance of from one to six feet for the required time.

Development. The variety of developers applicable to bromide paper is practically endless, and there is often little to choose between one and another. The alkaline developers are less trouble than ferrous oxalate, and

in the opinion of most give quite as good if not better results.

The chief points concerning the development of bromide paper, wherein the operation differs from the development of negatives, are that care must be taken to keep the whites pure, stains of all sorts must be strictly eliminated, and the operations must be so conducted that the deposit is of an agreeable colour. There is a tendency, unless suitable developers are used and every care is taken, to produce an image of an unpleasant greenish grey tint. All developers will not work equally well with all kinds of bromide paper, but the following are generally suitable.

Ferrous oxalate. Dissolve neutral potassium oxalate in three times its weight of water, and add oxalic acid till the solution just begins to redden blue litmus paper. Dissolve ferrous sulphate in twice its weight of water and add half a drop of strong sulphuric acid to each ounce by measure.

Potassium oxalate solution ..	6 volumes.
Ferrous sulphate solution ..	1 ,,
Potassium bromide	.2 grain to each ounce.

If half a grain of bromide is used the prints will be much harder. Ferrous oxalate generally gives a good colour. It is well after development to put the prints at once into a very weak acid bath—say one dram of acetic acid to thirty ounces of water—and then to wash well before fixing. The acid prevents stains.

Amidol. This developer gives a colour that is often better even than that given by ferrous oxalate.

Amidol	6 grains	or	12 grams.
Sodium sulphite (cryst.)	15 ,,		30 ,,
Sodium carbonate (cryst.)	.5 ,,		1 ,,
Potassium bromide ..	1 ,,		2 ,,
Water to	1 ounce		1,000 c.c.

Eikonogen. The double strength formula recommended for negative work with ten times its bulk of water. This appears more liable to give a greenish tinge to the image than either of the other developers.

Rodinal. The makers direct that it be diluted with one hundred to two hundred times its bulk of water. But the author recommends twenty times its bulk of water with one to two grains of potassium bromide to the ounce.

Metol. The double strength formula given for negatives with three times its bulk of water added to it.

In working with bromide paper, when a suitable developer is found, the exposure should be adapted to it; the developer cannot be modified to suit the exposure by the addition of bromide without the probability of getting an unpleasant colour. If the ferrous oxalate developer is to be weakened, it should not be diluted with water, but less of the iron salt should be introduced.

If with a good negative the print is too hard the exposure may be increased, doubled for example, and if then the development is too rapid and the whites degraded the developer may be diluted. Increased exposure and dilution of the developer should go together, and will tend to give a grey instead of a black image. On no account must the developer be restrained by the addition of bromide. For a black image the exposure must be short, though of course sufficient, and the developer of full strength. The development will consequently be rapid. In this case more care will be required in the adjustment of the exposure, and in the stopping of the development at the right time.

Fixing, etc. Bromide prints, as all other silver prints, must be fixed in clean hypo, and the alkaline fixing bath recommended for negatives will suit very well, or it may be mixed with an equal bulk of water if that is more convenient. In any case perfect fixing and thorough washing are necessary if the print is wanted to last as long as possible. As the image consists of metallic silver only, a bromide print may well be expected to be the most lasting of all kinds of silver prints, but if imperfectly fixed or carelessly washed it may show a marked deterioration even within a few months of its production.

Treatment after fixing. If a bromide print as washed after fixing is not satisfactory, it is generally better to make another rather than to try to doctor up the faulty production. But there are exceptions to this rule.

In those cases where nothing further than a general cleaning up is required and the getting rid of perhaps a few fine dark lines that have been fitly compared to pencil marks, it is only necessary to see that the print is quite dry, to dip a little pad of cotton wool into methylated spirit, squeeze it to get rid of the superfluous liquid, and holding it between the fingers to rub the surface of the print gently, giving special attention to those parts that need it. This will often effect a very marked improvement, but the operation must not be carried to excess or the surface of the print may be roughened and stained.

Reduction. If it is desired to reduce a bromide print the methods given for the reduction of gelatino-bromide negatives may be used, bearing in mind that there is much less silver in the image than in an average negative, and that the reducing solution can get at the silver from both sides of the film.

Toning. The black or grey colour of bromide prints may be modified in many ways so as to get an image of a warmer or redder colour. But when a bromide print is treated with any of the reagents afterwards described in order to alter the colour of the image, the simple constitution of the print is altered—it is no longer metallic silver in gelatine, but some compound of silver often with a compound of some other metal in addition, and obviously the more complex the image the more liable it is to suffer injury by atmospheric or other influences. Generally speaking, a silver compound is more readily attacked than the metal itself, and an image that consists of two different substances will be damaged by any circumstance that will affect either. This necessary multiplication of the possible points of attack in an image of a complex character is a strong argument in favour of simplicity.

The hypo and alum toning bath has been much appreciated and often recommended. It changes the black or grey image to a sepia colour. The print should be made rather darker to allow for a slight reduction in density. The solution is prepared by heating to boiling seventy ounces of water (three and a half pints, though of course smaller quantities may be taken, if desired) and adding to it ten ounces of hypo. When this is dissolved add gradually one ounce of alum a little at a time. The liquid will be milky white, but should not be filtered. It improves with age somewhat, and may be reinforced, when necessary, by adding a little freshly prepared solution. An entirely new bath reduces the density of the prints rather more than an old bath. If used cold, the bath will require a long time, some hours, to produce the colour required, but if used hot, the change will take

place in a few minutes. The limit of temperature is fixed by the resisting power of the print, and it is generally necessary to treat the print after fixing to an alum bath to harden the gelatine somewhat before it is toned. Some workers recommend a temperature of 110° to 120° Fahr., requiring thirty to forty minutes treatment, but others have suggested 150° Fahr. and about thirty minutes. Shorter times will give a less change, about a third of the period advised giving a warm black rather than a sepia. After toning, the print may be treated to a simple alum bath; in any case it should be well washed. The action of this toning bath appears to be due probably either to a partial change of the silver of the image into sulphide or to a deposition of sulphur upon it, or perhaps to both changes combined.

The ferricyanide method of intensification of negatives (described in connection with the intensification of gelatino-bromide negatives) is applicable also to bromide prints for the purpose of changing their colour. Uranium and copper ferricyanides are the chief salts employed, the ferrocyanides of both these metals being of a reddish brown colour.

The uranium bath may be prepared thus—

Uranium nitrate (or acetate)	2 grains or	4 grams.
Potassium ferricyanide	1 grain	2 ,,
Glacial acetic acid	10 to 20 mins.	20 to 40 c.c.
Water to	from 1 to 2 ounces	1 to 2 litres.

If the ferricyanide is not clean, it is likely to give a brownish precipitate when added to the uranium solution; this must be filtered off. The acetic acid is necessary, because the image toned with uranium is very easily attacked by alkalies; even ordinary hard water will gradually remove the added colour. The smaller amount of

acid will generally be found sufficient. For stock solutions it is well to keep the uranium and acetic acid ready for use, adding the ferricyanide when required. The well-washed print is placed in the solution, and gentle rocking maintained, as the cold black of the image gradually brightens up to a warm black, then changing through reddish brown or sepia to finally a full red. When the desired colour is obtained the print is removed and washed, but the washing water should be slightly acidified (two or three drops of acetic acid to the ounce) for the reason already given. To get a still purer red, the fully-toned print may be treated with hypo to remove as much silver as possible, again avoiding any alkalinity. The toned print should wash clean readily if care has been taken, but if it appears at all fogged it may be treated with a *very* slightly alkaline bath (ammonia or ammonium carbonate) for a short time, or merely washed in unacidified water for a longer time. Either treatment will remove some of the pigment and reduce (in a photographic sense) the toned print.

Ferrocyanide of copper is of a brownish red colour, very similar to the uranium compound, but the ferricyanide is a yellowish green substance also insoluble in water. There are several substances, aqueous solutions of which will dissolve the ferricyanide and not the ferrocyanide of copper, but none hitherto tried are satisfactory, chiefly by reason of staining, except alkaline citrates, such as potassium citrate. This salt was introduced for the purpose by Mr. W. R. Ferguson in 1900. Taking ten per cent. solutions of each, seventy-five parts by bulk of the copper solution may be added to 570 parts by bulk of the potassium citrate solution, and then sixty-

six parts by bulk of the ferricyanide are added slowly with agitation. All trouble in making the solution may be avoided by the use of the "tabloid" preparation of Messrs. Burroughs Wellcome, and Co., one tabloid being dissolved in each ounce of water. The colours produced are very similar to those that uranium gives, but much less sensitive to alkalies, so that no special precaution has to be observed. As with uranium, the red colour may be made of a less brownish hue by treating the toned print with hypo solution of the ordinary strength. And here may be emphasised the absolute necessity of getting rid of all hypo from the prints before toning them by any method of the type under consideration. Any hypo remaining will reduce the ferricyanide and give a coloured deposit, which, of course, cannot be removed without injury to the image. A thorough washing must precede the toning.

A blue image may be obtained by the following bath, the effect of the silver upon it being to produce Prussian blue—

Ammonio-citrate of iron	2 grains	or	4 grams.
Potassium ferricyanide ..	4 ,,		8 ,,
Acetic acid	12 minims		24 c.c.
Water to	1 ounce		1,000 c.c.

This bath is similar in its general character to those already given. The blue image resembles the red image obtained by copper in being attacked by alkalies, and also in not requiring (as the uranium toned image does) any special precautions with regard to this matter.

Professor R. Namias described in 1899 a method by which a silver image can be converted into the ferrocyanide of any metal, whether the ferricyanide of that metal is soluble or not. The silver is first converted into ferrocyanide by means of a five per cent. solution of potassium ferricyanide

containing a tenth of its volume of strong ammonia. Without the ammonia the action is too slow. The print is well washed for about fifteen minutes and then immersed in a one or two per cent. solution of the chloride of the metal, the ferrocyanide of which is desired, containing at least five per cent. of hydrochloric acid to facilitate the change. The silver chloride is then removed with a five per cent. solution of hypo containing five per cent. of boric acid, as the ordinary fixing baths attack the resulting ferrocyanide somewhat. Vanadium gives a yellow, molybdenum a reddish brown, manganese a grey, cobalt a green, and nickel a greenish image. Iron and copper successively used give a violet image.

Toning with gold or platinum is rarely resorted to in the case of bromide prints, because the object of toning with these metals is generally to counteract the redness of silver prints, and bromide prints are grey or black as prepared, the toning of them generally being for the purpose of getting a warmer colour. But if a bromide print is of a disagreeable greenish or rusty colour when a full black is desired, then these processes may be serviceable. The sulphocyanide formula given in the previous chapter may be used for gold. For platinum, two or three grains of the red potassium platinous chloride (or chloroplatinite) may be dissolved to each ounce, adding a drop or two of nitric acid to ensure that the solution is acid. Bromide prints toned by these formulæ contain chloride of silver, and, although the ordinary procedure takes no note of this fact, it seems that it would be better to remove it if unalterableness of the print is valued, by a second fixation and thorough washing. This, of course, will weaken the print somewhat.

Playertype. Mr. J. H. Player in 1896 drew attention to a method of using bromide and similar papers especially serviceable for copying engravings, that at first sight seems hardly practicable. The method has the advantage of giving a direct copy, and is not interfered with by printing matter on the back of the original. The engraving is laid face upwards, the sensitive paper is laid face downwards upon it and pressed into good contact. Exposure then takes place *through the sensitive paper*, using green, yellow, or red light. Three thicknesses of yellow tissue paper held between two sheets of ordinary glass form the best colour screen, and is supported about nine inches above the engraving, a bright gas light being about three inches above the screen. The Ilford smooth Alpha paper Mr. Player mentions as very suitable, though any smooth bromide or similar paper will serve. The exposure will be from three to six minutes, and the developer preferred is—

Hydroquinone	3 grains.
Sodium sulphite (cryst.)	12 ,,
Sodium carbonate (cryst.)	24 ,,
Water to	1 ounce.

Development is carried on until the image at first visible is buried. From the negative so produced prints are made as usual, reducing them a little if necessary to get clean whites.

The reason why a suitable negative should be obtained in this way instead of a hopeless fogging may be explained by the fact that a white backing to a sensitive emulsion largely increases the exposure effect, hence there must be considerably more exposure effect in those parts of the sensitive paper in contact with the white parts of the original than in those parts opposite the black lines.

The other procedure is such as tends to increase this difference. The author has shown that the less refrangible the light is, within the usual limits, the steeper is the gradation of the developed image. This accounts for the advantage of the yellow (or red) screen, and for the fact that yellow tissue paper is better than yellow glass. Finally the developer recommended gives hard results and also, therefore, tends to make the most of the exposure difference.

CHAPTER XXVII.

PRINTING IN SALTS OF IRON.

PASSING from the salts of silver, which are exceptionally valuable for negatives but surpassingly treacherous for prints, we find on turning to the salts of iron simplicity and certainty. When ferric chloride is exposed to the light in the presence of organic matter, it is decomposed, chlorine is given off and ferrous chloride remains, thus—

$$FeCl_3 = FeCl_2 + Cl$$

Other ferric salts are decomposed in a similar way, and the choice of the compound to be used is a matter of practical convenience rather than of theoretical significance.

In 1842, Sir J. F. W. Herschel published several processes by which this change in iron salts could be made serviceable for photographic printing. He found the double citrate of iron and ammonium to be more sensitive than the chloride and to have other advantages, and no one since has found a more suitable ferric salt for most of the processes about to be referred to.

Paper may be soaked in, or floated on, or brushed over with, a strong solution of this salt. The soaking will be found by the inexperienced to be the most easy and satisfactory, and to yield a good vigorous print. The paper when dried by a gentle heat is ready to be exposed under a negative. The exposed print may be developed in many ways, but the most useful probably is by the application of a solution of ferricyanide of potassium. The crystals should be washed and dissolved only just

when required, and the addition of a little citric acid is advisable, especially if the water used is hard. The ferricyanide gives a dark blue insoluble compound of ferrous ferricyanide with the ferrous salt that the exposure has produced, while the unchanged ferric salt is merely washed off the paper. The developed print is washed in water slightly acidulated with citric acid, rinsed in plain water, and dried. A print so prepared has a very brilliant colour, and by mounting, and applying a moderate quantity of encaustic paste to its surface, there results as brilliant a blue print, probably, as any process will furnish.

The ferrous ferricyanide, which is a sort of Prussian blue, is soluble in potassium ferrocyanide. It is decomposed by alkalies such as sodium carbonate with the production of the alkaline ferrocyanide which dissolves in the liquid, and hydrate of iron which remains in the paper and is soluble, after washing, in hydrochloric acid.

A commercial paper for getting blue prints is prepared in considerable quantity, especially for the use of engineers and others for copying drawings. This is coated with a mixture of the ferric ammonium citrate and ferricyanide of potassium, and after exposure needs only washing with water to develop and fix the image. Unless such paper is used within a short time of its preparation, it will not give clean and brilliant prints.

It will be observed that if an ordinary drawing is copied by the above process the copy will have a blue ground with white lines—a matter of little importance so far as working from the copies is concerned. But if ferrocyanide of potassium is used instead of the ferricyanide, there will be to a certain extent a reversal of

these conditions. The ferrocyanide gives Prussian blue with the unchanged ferric salt, and a white compound with the ferrous salt. But this white product ($K_2Fe_2C_6N_6$) so very soon takes up oxygen from the air and turns blue that the actual result in practice is a light blue or greenish blue as it is described on account of the yellow ferrocyanide being present. The rapid changing of this salt and the fact already mentioned that Prussian blue is soluble in ferrocyanide of potassium, make this process less easy to carry out than the one previously described. Herschel gave both methods of development, and the use of the ferrocyanide for getting a positive print from a positive has been since improved by Pizzighelli and by Pellet and Co. Pellet's formula is—

Oxalic acid	5 grams.
Ferric chloride	10 ,,
Water	100 c.c.

A well-sized paper is coated with this solution and dried. After exposure, development takes place in a fifteen to eighteen per cent. solution of ferrocyanide of potassium, and after thorough washing in water, the print is put into water containing from eight to ten per cent. of ordinary hydrochloric acid, which has the effect of clearing the ground and slightly darkening the image. A final washing and drying complete the operations. This method has the advantage of giving a cleaner print than if the citrate as proposed by Herschel were employed.

The paper merely coated with the ferric ammonium citrate may be developed after exposure with a neutralised solution of gold chloride, washed with water and dried. This is Herschel's "chrysotype." The ferrous salt produced by the light reduces the gold to the metallic

state, and the image is of the bluish colour of gold so precipitated. In reducing the gold the ferrous salt is changed back into ferric; if the chloride of iron were used, the developing operation would be expressed thus—

$$3FeCl_2 + AuCl_3 = 3FeCl_3 + Au$$

Nitrate of silver in dilute solution may also be used for developing, and the image is then obtained in metallic silver.

CHAPTER XXVIII.

PLATINOTYPE.

Of all methods of printing by means of iron salts this is the most important, for it gives a good image of as permanent a character as can be imagined. Moreover, certainty is not gained at a sacrifice of beauty, for those who are most entitled to judge of artistic merit admire platinum prints, and some silver papers, such as are called "platino-matt" for example, are made to give results to appear as much like platinum prints as possible.

The early attempts to formulate a platinum printing method, which date from 1844 onwards, failed for the same reason that the first attempts at platinum toning failed. Platinic chloride was employed, and the reduction of this salt gives platinous chloride without of necessity any deposition of metal. Images were obtained, but they soon faded. Before 1854, Robert Hunt had tried the mixture of ferrous oxalate and platinic chloride, but after darkening the impression soon disappeared.

The perfection and practical success of the platinotype process as at present practised are due almost entirely to the labours of Mr. W. Willis, who realised that a lower or platinous salt should be used, so that any reduction of it must give a deposition of the metal. In 1873 Mr. Willis worked out his first method, but his coating contained a silver salt, and he toned the image with gold. In 1878 he dispensed with the silver salt and used a very little of a lead salt. In 1880 the lead salt was done away with and the present simple method introduced.

PLATINUM PAPER.

Preparation of platinum paper. The usual method of platinotype printing consists of coating paper with a solution containing ferric oxalate and platinous chloride. The dry paper is exposed, and then floated upon a solution of potassium oxalate to "develop" the print, and after washing and drying the operation is complete.

Ferric oxalate has been shown by experiment to be the best iron salt to employ. It is not only more sensitive than most other iron compounds, but it gives a better quality of image. A little oxalic acid is always used with the ferric oxalate, as a small measure of acidity throughout the whole process is advisable, if not necessary, to secure prints of a rich full colour, to keep the whites clean, and prevent the precipitation of any iron compound on the paper. The platinum compound employed is the potassium platinous chloride ($2KCl,PtCl_2$), or it may be called potassium chloroplatinite. The double salt is preferred because platinous chloride itself is not soluble in water, while the double salt is readily soluble, and, being easily crystallisable, is purified with facility. The addition of platinic chloride to the coating solution tends to produce hardness in the print, because, as already explained, so far as it is present, a part of the effect of exposure is lost, giving no equivalent platinum deposit. It is usual to add a little of some oxidising reagent to the mixture of ferrous oxalate and platinum salt just before coating the paper in order to get the vigour that is desirable in the print, and to adjust the range of intensity to the density of negatives that it has become customary to produce. Potassium chlorate and potassium dichromate are convenient salts for this purpose; either is similar in effect on the finished result to platinic chloride, but

has the advantage of mixing with the solution without giving an insoluble precipitate. The coating solution may conveniently contain sixty grains each of ferric oxalate and potassium platinous chloride to the ounce, with the oxalic acid and oxidiser as stated.

Preservation of the paper. Paper that is coated with the sensitive mixture and dried must be kept dry—not ordinarily dry, but chemically dry—for otherwise, even in the absence of light, it appears that the iron salt is partially reduced by the paper or the matters used to size it, and the effect is a general fog and loss of brilliancy. The sensitive paper must therefore be kept in an artificially dried atmosphere, and this is most conveniently done by storing it in a canister that has a perforated false bottom, below which is anhydrous calcium chloride. It is customary to prepare the calcium chloride by pouring a solution of it over asbestos, then drying and strongly heating the residue. The asbestos being fibrous, the mixture is more coherent and less liable to allow dust to escape from it than the simple calcium chloride. It is necessary periodically to heat this mixture to rid it of the moisture that it has absorbed.

Exposure. The pads used in the printing frame must be dry, and it is advisable to put a piece of india-rubber cloth or other waterproof material immediately behind the prepared paper. Under these circumstances the paper is pressed between two non-hygroscopic and waterproof surfaces if the negative is varnished. And it is very necessary to varnish gelatine negatives used in this process if good results are desired, unless, indeed, the negative is thoroughly dried by heating it immediately before putting the sensitive paper upon it.

When paper prepared as described is exposed to light, the ferric oxalate is decomposed in proportion to the power of the light that gains access to any part into ferrous oxalate and carbonic anhydride, thus—

$$Fe_2(C_2O_4)_3 = 2FeC_2O_4 + CO_2$$

The platinum salt may suffer slight change, but the amount is so small that the effect is not visible, and it may practically be neglected. With a little practice it is easy to be as certain of the exposure as in silver printing, because the decomposition of the iron salt is accompanied by a well visible though comparatively slight darkening of the yellow coating.

For putting skies in landscapes, for other combination printing, and for getting variations occasionally desirable, a printing-out process would have advantages. The platinotype process as now practised, however, permits of this sort of work. If a sky is required to be put in so lightly that its details cannot be seen before development, it is only necessary to expose a bit of sensitised silver paper (as in a convenient actinometer) by the side of the print, and a very little experience indeed will enable the operator to get any depth of colour in the finished print that he may desire. The image before development is generally quite visible enough for a guide in masking the parts that are already printed.

Hot development. After exposure, the print may be at once developed, or it may be kept for a day or two, observing the same precautions as to dryness as given for the unexposed paper. There are many substances that may be used for developing; even water alone is not without effect, but that which is generally used is a solution of the neutral potassium oxalate. For hot

development the solution should be saturated in the cold with the salt, and it may be made just acid by adding sufficient oxalic acid to it. But the alkalinity of a good sample is not sufficient to make this necessary with the paper supplied by the Platinotype Company. An acid bath tends to cleaner, harder prints and a fuller black colour. It is clear that if the paper is prepared with sufficient oxalic acid, the oxalate of potassium bath may be allowed to remain slightly alkaline (as recommended by the Platinotype Company) without doing away with the acidity of the solution that is in immediate contact with the paper during development. 140° F. is a good average temperature for the bath in hot development, though it may vary from about 100° to 180° to meet cases of over and under exposure, but these extremes should be avoided as far as possible. Development is effected by bringing the surface of the exposed paper into contact with the solution for a few seconds, taking care to avoid bubbles. The necessary duration of the floating may be expected to increase as the temperature of the bath is lower, and to decrease as it is raised.

The development is not an effect analogous to the development of negatives, etc., but simply a matter of causing the ferrous oxalate produced to react upon the platinum salt. The simplest expression for the change is

$$6FeC_2O_4 + 3PtCl_2 = 2Fe_2(C_2O_4)_3 + 2FeCl_3 + 3Pt$$

showing that the ferrous salt takes the chlorine from the platinum, ferric salts and metallic platinum being the result. Pizzighelli and Hübl consider it likely that the ferric oxalate produced as in the above equation reduces a further quantity of platinous salt, presumably thus—

$$Fe_2(C_2O_4)_3 + 3PtCl_2 = 2FeCl_3 + 6CO_2 + 3Pt$$

because they have observed a gas to be given off during development, but they do not appear to have tried experimentally whether ferric oxalate will reduce a platinous salt.

Immediately after development the prints are soaked in dilute hydrochloric acid for a few miuntes (about one of acid to sixty or eighty of water), and they must be changed into a second and other acid baths, allowing them to remain from ten to twenty minutes in each, so long as the slightest appearance of yellowness is imparted to the dilute acid. This is necessary to get rid of the iron compounds. Then, after washing in plain water the prints are dried.

Many variations have been proposed in the process as given above, but no variation gives better results, except, perhaps, in rare cases.

A weak solution of carbonate of soda or of other alkaline salts, such as sodium phosphate, may be used to develop the prints, instead of potassium oxalate, especially when the prints have been over-exposed, or the paper has a tendency to fog by reason of it having been kept over-long. The action of the sodium carbonate appears to be rather to retard the solution of the iron salts, and so to give them time to reduce the platinum salt, than to develop the image in the sense that potassium oxalate develops it. It is advisable not to commit those errors that give the advantage to such salts as these.

Printing-out process. If, instead of using an acid solution of ferric oxalate to coat the paper, a double oxalate of iron and an alkali, such as sodium ferric oxalate, is employed, and the coated paper is not carefully kept dry, the platinum will be more or less reduced during

the exposure, and a "printing-out" process may be devised. A print so obtained only requires washing in dilute acid and then in water to finish it, the completion of the reduction of the platinum taking place when the washing begins if it is not already complete. As such a printing-out process, however, depends upon the moisture present in the paper, it is uncertain. The whole surface of the paper may not be equally moist or equally dry. When examining the print, the part exposed may be accidentally breathed upon, or in other ways get moister or drier than the other part, and thus irregularities will occur. It appears also that if the exposure is rapidly done in a good light the reduction of the platinum will not keep pace with the decomposition of the oxalate, and a very marked increase in depth of colour will take place afterwards, while a slow exposure will give ample time for the platinum to get reduced, and no additional vigour will come during the subsequent treatment. In other ways "printing-out" with platinum has been found to fail practically; though it occasionally yields good results it is at the best uncertain.

Sepia platinum printing. A very insignificant proportion of certain salts, such as mercuric chloride or cupric chloride, if introduced into the solution used for coating the paper in the ordinary way, or for printing out, will effect a marked change in the colour of the platinum in the finished print. The Platinotype Company have availed themselves of this fact in the preparation of their "sepia" papers; and, for the development of prints on the special paper, they at first supplied a solution, which was acid and contained a ferric salt, to be added to the solution of oxalate used for developing. This addition was made

to prevent a degradation of the whites, and the principles of the action of these substances have already been explained. They now supply a mixture of "developing salts" that is sufficiently acid to need no further addition. As the additions necessary to obtain the coloured deposit tend to counteract the effect of exposure, the image before development must be rather more visible than with the hot bath black process.

By adding a little mercuric chloride to the developing solution, the image is produced of a much warmer colour, and by increasing the amount of the mercury salt the neutral grey passes into a very warm black with a marked reddish tint. A bath containing mercuric chloride ought to be kept in the dark, or the mercury salt will be reduced and the metal precipitated.

The brownish image so produced has been sometimes regarded as of doubtful permanency. There is, however, no good reason to suppose that it consists of anything but metallic platinum, for neither mercury nor copper can exist in the metallic condition in the presence of the platinum salt—they immediately precipitate metallic platinum. Moreover, it is difficult if not impossible to get an image with a copper salt in the absence of platinum compounds, and cupric chloride produces the same change of colour as mercuric chloride. And the amount of the second metal present is so small that even if it were precipitated with the platinum, it could hardly be expected to cause so considerable a change of colour. There is little doubt but that these salts cause the platinum to be deposited in a different state, probably in a finer, state of division. This would quite account for all the known properties of the sepia image.

Cold bath papers. In 1888, Mr. Willis introduced his first " cold bath " platinum process, in which the platinum salt is not put upon the paper, but into the solution that is used for developing the prints. The process is therefore analogous to Herschel's chrysotype, which has been already described.

In this process the paper is coated with a solution of the ferric salt, and must be carefully kept dry. To produce the best results it must be exposed to a damp atmosphere until it loses its crispness shortly before development, either before or after exposure. Without this damping, a feeble, grey and granulated image is likely to result.

The developing solution is prepared by dissolving half a pound of a mixture of potassium oxalate with half its weight of mono-potassium orthophosphate in fifty ounces of water, or, say—

Potassium oxalate	100 grams.
Mono-potassium orthophosphate ..	50 ,,
Water to	1,000 c.c.

Three parts of this solution, with two parts of water, are mixed with one part of a solution of sixty grains of potassium chloroplatinite in two ounces of water (or sixty grams in 1,000 c.c.) when required for use. The final solution therefore has the formula—

Potassium oxalate	50 grams.
Mono-potassium orthophosphate ..	25 ,,
Potassium chloroplatinite	10 ,,
Water to	1,000 c.c.

Development is most conveniently done by floating the exposed paper on the solution for a few seconds, watching the appearance of the image, and refloating if necessary.

When development is complete the paper is immersed in dilute acid, and washed as in the hot bath process.

Excellent results were obtained by this process, more brilliant, perhaps, than by any other platinum process, but much care was necessary to avoid a scum of metallic platinum that was almost always produced from settling on the surface of the print. Directly it came into contact with the print it was as immovable as the image itself.

The present cold bath process. In 1892, Mr. Willis introduced the second "cold bath" process, which has now quite replaced the other. In this the paper has the platinum salt on it, and it is treated just like the paper made for hot development, except that the developer is used cold, but not below 60° F., and is somewhat diluted. If potassium oxalate is used, the saturated solution may be diluted with twice its bulk of water, and a saturated solution of oxalic acid added to the extent of one-twentieth of the bulk of solution so obtained. The mixture of oxalate and phosphate given above, but without the platinum salt, is also suitable.

Development may also be done with a brush. A suitable solution for this purpose is made by mixing the diluted developer with an equal bulk of glycerine. By smearing glycerine over the print with the finger-end before brushing on the developer, the image will appear very slowly, coming only as the developer works through the layer of glycerine, and passing through a red colour to a black. By over-exposure and stopping development before it is complete, a reddish image may be obtained, consisting probably of finer particles of metal, and analogous to the sepia image obtained in the usual way. By continued development the deposition of platinum on the reddish image would increase the size of the particles and change the colour to black, as indeed it does.

This cold bath paper is equally amenable to hot development. The exposure must be longer when development is to be done at a lower temperature, therefore an under-exposed print may sometimes be saved by developing it on a warm solution. The hotter the developer the warmer the colour of the image produced, doubtless because the quicker precipitation of the metal gives less time for the particles to increase in size. If mercuric chloride is added to the bath, its effect upon the colour of the image will be very slight, if at all perceptible, when development is done in the cold, unless a comparatively large quantity is added, and then the results are not of practical utility. The colours are unpleasant and patchy, and liable to subsequent change. In this case probably the image is not of pure platinum, but contaminated with mercury or mercury compounds. Dr. A. v. Hübl, in 1901, pointed out that this difficulty might be overcome by using an oxysalt of mercury instead of the chloride. He recommends the citrate and gives the following formula—

Yellow oxide of mercury	1 gram.
Citric acid	5 grams.
Water	20 c.c.

Warm till dissolved. The paper, sized with arrowroot, is coated with a mixture of—

20% ferric oxalate solution	8 c.c.
A 1 to 6 potassium chloroplatinite solution ..	4 c.c.
Mercuric citrate solution	3 c.c.

The developer is a one to four to one to eight solution of potassium oxalate acidified with oxalic acid as usual, and development takes at least five minutes.

The cold bath process has very great advantages as a method of getting prints in out-of-the-way places,

because of the few materials necessary and their easy portability, especially when citric acid is used instead of hydrochloric acid for the washing. For this reason it is used on military expeditions for work in the field.

The gradation of platinum prints. In order to give some idea of the relationship that exists between the gradation of the original object, the negative of it, and platinum prints from the negative, the diagram, fig. 73, is here given. The dotted lines show the gradation or light intensities of the original, and a perfect reproduction would give a line parallel with it. The negative approximates fairly to it except in the two lowest (or thinnest) densities, which are lacking in contrast, and a little lack of density in the densest parts. All negatives representing a full range of exposures give curves of this character. Of the six curves showing prints with increasing exposure, numbers 1, 2, and 3 are under-exposed, because even in number 3 the three densest patches in the negative are all represented by white paper. Number 4 is the best, because this shows gradation all the way, except in the three thinnest patches of the negative, which have what would be called "no printing density." Number 5 is over-exposed, as it shows no white paper, and number 6 is so much over-exposed that it shows strong reversal in its densest parts. With reference to number 4 as being the best print, the lack of contrast at both ends of the scale will be noticed. This is a common fault in photographic prints; it occurs in all negatives of subjects covering a sufficient range of exposures, and is increased in the prints, especially in the "shadows." To obviate this clogging of the shadows, all tendency to under exposure

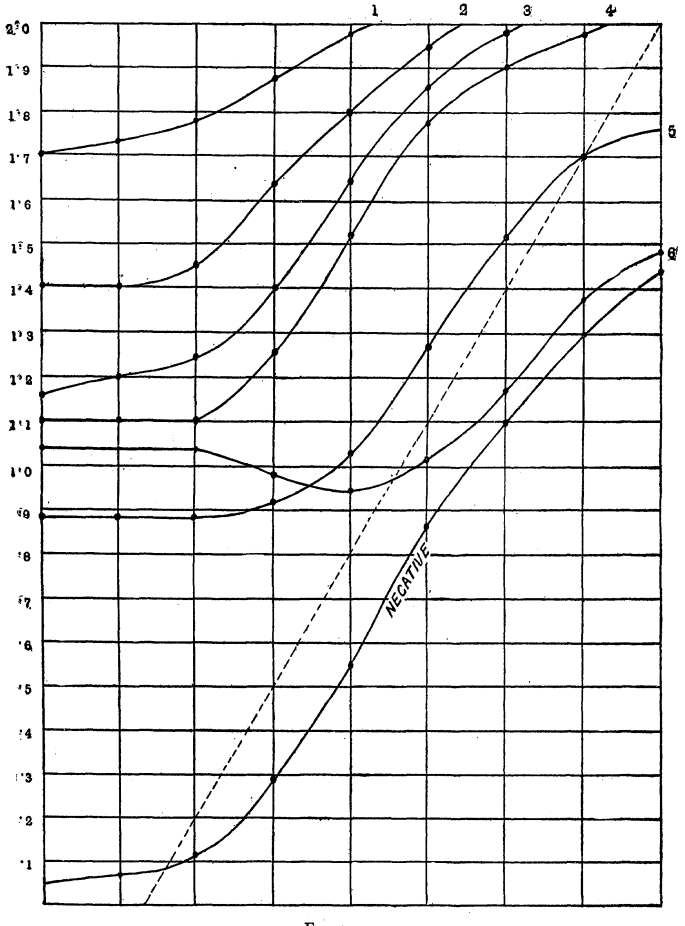

FIG. 73.

The ordinates represent opacity logs. with regard to the negative, and logs. of percentage of light reflected (white paper = 2·0) with regard to the prints.

should be avoided in making the negative, and the shadow detail should be developed to good density.

After treatment. Platinum prints are readily intensified or toned by the use of a solution that is ready to deposit material upon anything that disturbs its equilibrium, just as silver is deposited upon the silver image of a collodion negative during "redevelopment." Such modifications are never to be recommended, and, except perhaps in the case of gold, they merit unqualified condemnation. A platinum print so treated ought not to be called a platinum print at all, because that term has come to mean a definite thing, namely, a print in which the image consists of platinum only. The changeableness of such extra deposits may actually be increased by their contact with the platinum, but, if not, such compound images can never be guaranteed as permanent.

A method of depositing gold is due to Mr. A. W. Dollond. The print is soaked in water, laid on a sheet of glass (opal is convenient), the excess of water is blotted off, glycerine is spread over it with a finger-tip, a few drops of gold chloride solution containing sixteen grains to the ounce are dropped on and mixed with the glycerine by means of a soft brush. The action is kept even by working the brush over the surface of the print, and when the intensification is sufficient, it is washed for a minute or two, sponged over with a metol developer to prevent any remaining gold solution producing subsequent stains, and finally washed for about half-an-hour. This gives a blue-black image, and an amount of intensification that may be useful in under-exposed prints.

The red uranium ferrocyanide may be deposited upon platinum images by putting the prints into a solution

containing one part by weight of each, uranium nitrate, potassium ferricyanide, and glacial acetic acid, with five parts by weight of ammonium sulphocyanide, to one thousand parts of water. The action takes place readily, and is complete in a few minutes.

Methods of depositing other substances in analogous ways have been described, but they are of no practical interest.

Mr. J. Packham, in 1895, showed that an extract of catechu would tone the image of a platinum print to a warm colour. He boils a quarter of an ounce of the catechu in powder in five ounces of water for three or four minutes and adds one ounce of alcohol. For use thirty to forty minims of this extract are added to a pint of water at 130° to 150° F.; the toning is complete in a few minutes, but a cold bath will require a few hours to produce its effect. The author has shown that this toning is due to the action of the extract upon the iron compound left in the print, which it is exceedingly difficult if not impossible to remove completely, and that other substances that give intense colours with iron salts would give similar results, though perhaps not such desirable colours. The fact that the image is toned appears to be due to the fact that the platinum holds the minute residue of iron more tenaciously than the paper alone, and that the residual iron compound is therefore roughly proportional to the depth of the platinum deposit.

The apparent fading of platinum prints. Some platinum prints have been noticed to change gradually to a yellowish brown colour, the colour that is associated by photographers with fading silver prints. The author has shown that this is an effect of the iron residue already

referred to, and may be imitated by allowing sulphuretted hydrogen to act on an ordinary platinum print. To avoid this change, the prints should be well cleared in the acid baths and then well washed, and mounted on good boards. Cheap cardboards that conduce to the fading of silver prints, doubtless from the presence of sulphur compounds (even sulphates in the presence of organic matter and moisture may be reduced to sulphides), will facilitate this change in platinum prints. Such a changed print may be completely brought back to its original colour by unmounting it if mounted and treating it with a mixture of hydrochloric acid and chlorine water, conveniently made by adding a few drops of sodium hypochlorite solution to dilute hydrochloric acid (one of acid to ten or more of water may be used) until the odour of chlorine is distinctly noticeable. Neither hydrochloric acid nor chlorine water alone is effective, though each does something towards the desired end. Certain organic acids and compounds of the kind have been recommended by others since the author proposed this treatment, but they give only partial results. And as they are more troublesome to prepare, and more costly than the simple acid and chlorine, they appear to be in every way less advantageous.

The author's observation that a small residue of iron exists in platinum prints has been confirmed by Dr. Jacoby. The fact that a minute amount of iron is left in the print has led to the statement that there is no perfect fixing agent known for platinum prints. But such a statement is much more calculated to deceive than to instruct. It does not appear that anyone has yet found that platinum prints are sensitive to light. So far as

light is concerned, therefore, the fixing does appear to be complete. They remain slightly sensitive to sulphuretted hydrogen, but if this is to be the criterion of fixing, then we may say that no silver print or negative has ever been fixed. And this is a much more true statement than that platinum prints cannot be fixed, because in the case of the silver print the image itself is changed, while in the platinum print no one has yet shown it possible to affect the platinum image at all, nor has anyone yet shown it possible to change a platinum print in any way so that it could not be brought back easily and thoroughly to its original condition, except perhaps when gold is deposited upon the image.

CHAPTER XXIX.

PRINTING IN ORGANIC COLOURS.

THERE are very many organic substances that are sensitive to light, but, excepting the indirect use of albumen in silver printing, the use of organic colouring matters in photography has been very limited.

It must not be supposed that because albumen silver prints owe their colour very largely to albuminous compounds, and are of very uncertain stability, that all organic substances suffer from a like disadvantage. Practically speaking, nothing is known of the composition of the albumen silver compounds, but the substances about to be discussed are of perfectly definit ecomposition, and their reactions have been established by following out the changes that they undergo under varying circumstances. Albumen itself is colourless; it is only when in combination with silver that it becomes coloured by exposure to light, and the coloured product contains silver. But the organic substances considered in this chapter are themselves coloured, or give coloured products without conjunction with silver or any such metal.

There are many organic substances that are changed in colour by exposure to light. Some light woods darken, the pink colour of certain newspapers fades, and the dyes used in orthochromatic photography are readily bleached. But in these cases it is not practicable to stop the action, and by further exposure a printed image is obliterated.

Willis's aniline process. In 1864, Mr. W. Willis, senior, introduced this process. It is founded upon the

reduction of alkaline bichromates when exposed to light, and the fact that the unreduced chromates give dark coloured products when caused to act upon aniline. A solution of an alkaline bichromate containing a little sulphuric or phosphoric acid is applied to the material (paper, silk, etc.) by floating or sponging. After drying, it is exposed under a positive and developed by laying it at the bottom of a shallow tray, and putting over it a cover, to the underside of which two or three thicknesses of bibulous paper have been attached. The bibulous paper is previously sprinkled with a dilute solution of aniline in benzene, turpentine, or ether. The colouring matter which forms the image is a mixture of mauve or aniline purple, with a black tarry substance, which confers considerable permanency upon it. If the bichromate solution used for sensitising is too acid the image will be green, or blue changing to green. Other volatile organic bases than aniline may be used for developing.

The aniline process described above has been employed for the reproduction of engineers' drawings. There does not appear to have been any other practically useful photographic process in which an organic colouring matter plays a fundamental part until, in 1890, Messrs. Green, Cross, and Bevan introduced the primuline process. This also gives a positive from a positive, and from the character of the results that it furnishes might prove useful in the production of ornamental designs upon fabrics, as well as upon paper and in gelatine films.

Primuline was first obtained by Mr. A. G. Green in 1887. As commercially supplied it is a sodium sulphonate to which the following formula is assigned—

$$C_{28}H_{15}N_3S_3(SO_3Na)\ (NH_2)$$

PRIMULINE PROCESS.

It dyes fabrics, including wool, silk, and cotton, of a primrose yellow colour, by merely treating them with its aqueous solution. Paper may be superficially coated by flotation, and the dye may be dissolved with gelatine for the production of films upon glass. By immersing the dyed material in a dilute and strongly acidified solution of sodium nitrite (paper is floated on the solution), the primuline is diazotised *in situ*, being converted into a salt of a base having the formula—

$$C_{28}H_{15}N_3S_3\ (SO_3Na).\ N_2.OH$$

This diazo-derivative has the property of forming differently coloured materials when treated with various reagents, and also of being decomposed by light, with evolution of nitrogen. It is only necessary, therefore, to expose the dyed and diazotised surface under a transparency until the light has just destroyed the compound under the clearest parts of the transparency, and then to apply the developer, to get a reproduction of the image of the transparency. The developers used are quarter to half per cent. solutions of phenols or amines, the former dissolved with an alkali and the latter with an acid. β-naphthol gives a red, β-naphthol disulphonic acid a maroon, phenol a yellow, resorcin an orange, and pyrogallol a brown image. These are employed in alkaline solutions. Phenylenediamine hydrochloride gives a brown, α-naphthylamine hydrochloride gives a purple, and eikonogen a blue image, and these are used in slightly acid solutions.

The products of the destruction of the diazotised derivative by light are yellow, and no method has yet been devised for getting rid of them. Therefore the design of the colour stated above is always produced on a yellow ground. It may be remarked that in processes

in which light forms the image by the destruction of colour or the colour-producing material, the effects of over and under exposure are reversed as compared with their effects under the more usual conditions in which light produces the image directly.

Diazotype. In 1889, Dr. A. Feer introduced a process in which a solution of a diazo-sulphonate mixed with one or other of the developers mentioned in the previous process, or analogous substances, is caused to impregnate paper, fabric, etc. The diazo-sulphonate is of itself unable to give the characteristic reactions of diazo-bodies, but on exposure to light it is decomposed with liberation of the diazo-derivative, and this at once produces a characteristic colour with the other substance. The image is thus printed out directly from a negative, and the unaltered sensitive mixture is washed out in water or very dilute hydrochloric acid.

CHAPTER XXX.

CHROMATED GELATINE.

By far the greater number of methods of getting prints from photographic negatives are based upon the changes produced by light in a mixture of potassium or ammonium bichromate with gelatine or some organic substance that behaves in a similar way.

Mungo Ponton, in 1839, showed that paper dipped into a solution of potassium bichromate and dried, would furnish a negative photograph if exposed to light beneath a drawing. A faint yellowish brown tint was produced where the light had acted, and the changed chromium compound (chromate of chromium) was insoluble in water, while the unchanged chromate might readily be washed away.

If a film is made of a mixture of gelatine and potassium bichromate and is then exposed to the light, it will be found that where the light has acted the gelatine has been made insoluble, or less soluble, in hot water and in certain solutions that dissolve unchanged gelatine. In 1852, Fox Talbot patented a method of coating steel plates with such a film, exposing beneath a negative, and washing. He says that thus not only is the unchanged chromate removed, but the greater part of the gelatine is washed away from those parts not affected by the exposure to light. Talbot then proceeded to etch the plate with platinum chloride, the gelatine adhering to the plate resisting the action of the etching solution in proportion to its exposure. It has been stated that

Talbot's image in gelatine differed from a carbon print only in having no pigment in it. It was, however, as different from a carbon print as two results produced by the same reagents can be, and this will be obvious on a little consideration when "pigment printing" is treated of.

When a film of chromated gelatine is exposed to light under a negative and then put into cold water, it will be observed that those parts acted on by light (which are less soluble in warm water) absorb water less freely than the unchanged gelatine, and also swell up to a less extent. It is possible, therefore, to get the design in relief by the mere soaking in water. But in proportion as the changed gelatine refuses to absorb water, so will it "take" a greasy ink such as is used in ordinary letter-press or lithographic printing processes. By applying such an ink with proper precautions it is possible to get impressions in greasy ink after the manner of ordinary lithographic methods. Paul Pretsch, in 1854, patented these uses of chromated gelatine.

M. A. L. Poitevin, in 1855, obtained protection for mixing pigments with chromated gelatine, exposing under the negative, washing away the gelatine that remained soluble, and so getting a pigment print, or, as it is less advisedly called, a "carbon print."

These are only the very beginnings of the applications of chromium compounds mixed with organic matter to the purposes of photographic printing. It will be seen that any reagent or circumstance that affects the solubility of gelatine, or that causes it to swell or to shrink in bulk, is important; and to these may be added those procedures that are found to break up the surface of gelatine or cause "reticulation," because when a smooth surface

is desired such an effect is to be avoided, but in certain photomechanical processes, reticulation is purposely brought about to get a surface that will the better hold the ink.

The following details are chiefly derived from Dr. J. M. Eder's essay on the reactions of chromates on organic bodies, and some of the statements are quoted verbatim from a somewhat condensed account of it that was published in the *Photographic News* for 1878 and 1879.

Gelatine dissolves in acetic acid as easily as gum in water, so that carbon prints can be developed by the cold acid. Weak hydrochloric, sulphuric, and oxalic acids have the same effect; added in very small quantities to the water they will dissolve out the gelatine without decomposing it. Hot water will develop carbon prints more quickly and with a more refined effect, but plates for photomechanical printing are better developed by acetic acid, because warm water penetrates and softens the exposed gelatine, and thus causes unequal swelling and contraction.

Potassium and sodium carbonates and magnesium sulphate confer fluidity upon a concentrated solution of gelatine. Weak solutions of soda and potash dissolve and decompose gelatine slowly in the cold, much more quickly when heated. Ammonia acts only as a weak solvent.

Very small quantities of carbolic acid are useful in gelatine to prevent putrefaction, but larger quantities precipitate the gelatine. But carbolic acid will not prevent a film of chromated gelatine from getting insoluble even in the dark, as this is due to the spontaneous decomposition of the chromium compound. Salicylic acid is also a useful antiseptic, and gelatine films containing it dry more quickly than the pure jelly.

A weak solution of chromic acid precipitates gelatine, and the precipitate melts when heated. But if the gelatine treated with chromic acid is dried, even in the dark, it becomes insoluble, while gelatine treated with the chromates and dried in the dark remains soluble. Hence a crude bichromate of potash containing free chromic acid is to be avoided.

Gelatine, with potassium bichromate not in excess, dries to a transparent layer without any signs of crystallisation, but too much of the salt will cause crystallisation, and so give a useless film. A good gelatine that can take up five to ten times its weight of water may be mixed with three to four times its own weight of the bichromate without getting crystallisation on drying; but an inferior gelatine that takes up only three to six times its weight of water will stand only twice its weight of the bichromate. But one-third to one-fourth more of ammonium bichromate may be added than of the potassium salt. If the drying of the films or coated glasses is done at a high temperature, 40° C. to 50° C., nearly double the amount of the potassium compound may be added, and a still larger proportion of the chromate may be used if the film is to be dried upon paper.

Heating a mixture of gelatine and potassium bichromate to the boiling temperature for sometimes so short a time as fifteen minutes will render the cooled, solidified gelatine insoluble in hot water, and in general the treatment of gelatine with the bichromate, as in sensitising carbon tissue, raises the temperature at which it will dissolve in water some 2° to 5° C. Rapid drying at a low temperature tends to avoid insolubility.

Chromated gelatine films, if kept dry and in a dry

atmosphere, as in a box with a desiccating agent, may be kept in a soluble state for a long time, probably indefinitely, but if kept in a moist atmosphere they soon become insoluble. An atmosphere saturated with moisture will cause sensitised carbon tissue to become quite insoluble in a week.

Concerning the reticulation of gelatine films, increase of the bichromate tends to produce grain. A certain temperature in drying may give a grain, while a higher or lower temperature would give a smooth surface. Some substances that tend to keep gelatine liquid, as acetic acid and calcium chloride, tend to produce a grain, even in drying at a low temperature. Thick films and concentrated solutions of gelatine give a coarse, rough grain. If two plates are dried at the same temperature, the one to which the air has better access will have the coarser grain.

Air-dried gelatine films contain about seventeen per cent. of water. Sensitised films are more sensitive when kept over water, and less sensitive when kept in an artificially dried atmosphere, but as stated before the moist condition is conducive to insolubility. Hence to preserve a sensitised film it should be kept in a chemically dried atmosphere, and to regain sensitiveness it may be placed in a moist atmosphere until flaccid shortly before being required for use.

Concerning collotype plates, which have sensitised gelatine films exposed and soaked in water, dilute nitric acid (one to six) lowers the relief, and promotes the appearance of the most delicate tones. The following substances increase the power of the films to take up ink: Alkaline dichromates, alum, the soluble chlorides,

dilute hydrochloric, sulphuric, and nitric acids. Potash, borax, and potassium cyanide tend to clear the plate. Sodium acetate and sodium hyposulphite, and the chlorides of calcium, zinc, and sodium keep the films moist after printing, without making them sticky or letting them decompose. Collotype plates dipped in a six per cent. solution of zinc chloride, become harder, and are able to furnish a greater number of impressions.

If the yellow potassium chromate (K_2CrO_4) is used for sensitising carbon tissue, it will require an exposure of from twenty to fifty times the length necessary when the dichromate is used. But the monochromate of ammonium does not show this lack of sensitiveness, probably because the ammonia is volatile, or because it is decomposable. Hence ammonia may be added to potassium bichromate without loss of sensitiveness, and films prepared with the mixture retain their sensitiveness for a longer time.

As to the actual chemical change produced by light in a mixture of potassium bichromate and gelatine, Dr. Eder concludes from his experiments that a chromate of chromium is formed, and that the gelatine associated with this compound in the part insoluble in water after the exposure is not changed in its chemical composition. The organic matter, therefore, that is oxidised at the expense of the chromium salt appears to remain soluble in water, and to be washed away.

CHAPTER XXXI.

PIGMENT PRINTING (CARBON PRINTING).

As stated in the last chapter, M. Poitevin, in 1855, sought to get photographic prints in pigments with chromated gelatine or its equivalent, exposing a film prepared with the mixture under a negative, and then washing away the parts remaining soluble. The gelatine where made insoluble by the light would retain the pigment. This process, however, could not give half-tones, because, as the insolubility of the film starts from its outer surface, in all those parts except where the action of the light thoroughly penetrates the film there will be a layer of soluble gelatine, etc., underlying the insoluble parts. All, therefore, except the deepest shadows, would be loosened on development from the supporting paper, and washed away.

In 1858, Mr. John Pouncy devised a method, and he appears to have practised it with considerable success, which he described as follows: "I coat the paper or surface which is to receive the picture with a composition of vegetable carbon, gum-arabic and bichromate of potash, and on this prepared surface I place the negative picture, and expose it to the light in the usual way; afterwards the surface is washed with water, which dissolves the composition at the parts on which the light has not acted, but fails to affect those parts of the surface on which the light has acted; consequently, on those parts of the surface the colouring matter remains in the state in which it was applied. . . . Other colouring matter may be employed." The results given by this method were not

of that precise kind looked for in a photograph, and were not much appreciated at the time. But a few years ago this process was reintroduced, and since then it has been much practised. It will be observed that the gum is different from gelatine in not forming so distinct a film on the surface of the paper. When applied in a small quantity, as it must be, the half-tones and details in the lights are preserved, because of the inappreciable thickness of the coating. Details of this method as at present practised are given subsequently.

It was in 1858 also that Mr. J. C. Burnett pointed out the reason for the washing away of the half-tones when a gelatine film is employed, and that it might be remedied by exposing the sensitive film through its support —printing, that is, on the back instead of the front of the coated paper. The Abbé de Laborde in the same year, and Mr. W. Blair, of Perth, in the following year, both made the same suggestion, and, as a matter of fact, good pigment prints were produced in 1858.

M. A. Fargier, in 1861, did away with the awkwardness of exposing the back instead of the front of the sensitive material, by forming his film of sensitised and pigmented gelatine upon glass, exposing the face of it under the negative, coating the exposed film with collodion, and then developing in hot water. As that part of the film in contact with the glass remained soluble, the film left the glass when development began, but it was held together by the coating of collodion, and when completely developed, it was caught upon a sheet of paper coated with gelatine, the paper taking exactly the place that the glass plate had occupied originally. The mounted picture thus produced had the collodion film still on

its face, but this was removed by a mixture of alcohol and ether.

Although the necessities of pigment printing were recognised and provided for in these inventions, the methods proposed do not include a process that could be practically adopted for the commercial production of photographs. In 1864, Mr. J. W. Swan obtained protection for a process of carbon printing which was afterwards worked on a large scale by Messrs. A. Braun and Co., and which furnished results of such a quality that they have never been surpassed. Mr. Swan spread his pigmented and sensitised gelatine upon paper, and so prepared what is now called " carbon tissue," or pigmented tissue. This was exposed under the negative in the usual manner, and then the procedure varied according to whether the finished picture might be inverted or whether it had to be non-inverted. The production of an inverted picture is the simplest, and the modern method working on the same principle is called " single transfer," because the exposed film is transferred only once. To effect this, Mr. Swan cemented the exposed tissue face downwards upon the surface where the picture was to remain by means of a layer of albumen. It was then developed with warm water, the paper that formed the original support of the gelatinous film readily skinning off when the soluble gelatine began to soften. But when a non-inverted picture was required the development took place upon a " temporary support," and the picture was afterwards transferred to its final support. This process is called in modern language " double transfer," for obvious reasons. Mr. Swan's method of double transfer was to expose the tissue as before, and to cement it face downwads

upon paper by means of a solution of indiarubber in benzene. Development was performed upon this temporary support, and then the paper that was permanently to carry the picture, having been previously coated with gelatine made almost insoluble by means of alum, was well wetted and forced into contact with the print. When dry the temporary support, still cemented by the indiarubber to the face of the picture, was removed by moistening it with benzene to soften the indiarubber.

With these methods, carbon printing became a practical fact. There have been only two other improvements in matters of detail that are important enough for notice, namely, the doing away with the indiarubber to cement the exposed print to its temporary support by Mr. J. R. Johnson in 1869, and the preparation of a flexible temporary support by Mr. J. R. Sawyer in 1874. Mr. Johnson showed that a surface impervious to water would hold the film during development if merely squeegeed upon it, without the use of any cement. Mr. Sawyer's support is prepared by coating paper with gelatine mixed with chrome alum, so that the layer when dry is insoluble, and this film is treated with an alkaline aqueous solution of lac. When dry, the surface is subjected to great pressure between polished plates.

The manufacture of the tissue. The pigmented paper, or " carbon tissue," used in printing by this process is manufactured by coating paper with a solution of gelatine and sugar mixed with the desired pigment. Soap is sometimes used instead of, or in addition to, the sugar. It appears that these last ingredients give a greater possibility of sensitiveness, besides keeping the film from

getting too hard and brittle. The coating is generally done by means of machinery.

The permanency of the finished print depends upon the nature of the pigment employed, and although a considerable assortment of colours is available as having no injurious effect upon the gelatine or the bichromate, it is not always easy to get just the tint desired. Commercially, it is necessary to prepare tissues giving the "photographic brown" and "photographic purple," merely because it has become fashionable to have photographs in such colours. The cochineal lakes lend themselves readily to the preparation of such tints, and they were at first used for that purpose. But as cochineal colours are fugitive, pigment prints containing them as an ingredient gradually change colour. Alizarine lake is now universally employed instead, and it is far more permanent. But if a simple unchangeable pigment is used, such as carbon (lamp black, bone black, Indian ink, etc.) or oxide of iron (Venetian red), then the finished print is unchangeable, except by circumstances that will disintegrate the insoluble or tanned gelatine.

Whatever pigments are employed, it is necessary to avoid any colouring matter that would react with the gelatine to make it insoluble, or that would be injuriously affected by the bichromate or by hot water or alum solution. The colour should be finely ground, and the gelatine mixture must be very carefully made uniform. If the coated paper is kept for a short time in a horizontal position before the gelatine has set, the coarser particles of the pigment settle down more or less; and there is advantage in this, because the upper surface of the gelatine, which gives the details in the lights, has the finer pigment,

and is therefore more delicate, while the shadows showing the coarser particles have, perhaps, a slight appearance of granulation that tends to give them transparency.

The sensitising of the tissue may be done during its manufacture or afterwards. The most uniform and economical method is to add the bichromate to the gelatine mixture before coating. Tissue so prepared will keep in good condition for a week or two with common care, as, for instance, putting it under a weight that it may be pressed together to exclude air as much as possible, and not allowing it to remain in a room where the air is vitiated by respiration and combustion, and especially not near the ceiling of any inhabited room. But with extra precautions the sensitised tissue may be kept for much longer, as stated in the previous chapter. The deterioration of tissue is due to its becoming insoluble in warm water. Therefore, whatever the age of sensitised tissue, it can easily be discovered whether it is fit for use by putting a fragment of it into warm water. If the gelatine dissolves off it is all right, but if water as hot as the hand can bear does not affect it it is useless.

Tissue prepared in the unsensitised condition will keep for a very long time. To sensitise it, it is soaked generally for about three minutes in a three to four per cent. solution of potassium bichromate. Unless the salt is specially prepared to be free from excess of acid, four or five minims of strong ammonia should be added to each ounce of the solid bichromate taken.

There are other methods of sensitising. The paper may be floated on the solution, or a stronger solution may be applied by a sponge to the back of the tissue after laying it face downwards on a suitable surface.

This last method is due to Mr. H. J. Burton, who gives the following formula for the solution—

Water	20 ounces.
Strong ammonia	1 ounce.
Potassium bichromate	4 ounces.

Mr. Burton says: "Have a flat board larger than the sheet of tissue to be sensitised, and cover it with blotting paper, and on that lay the tissue face downwards, first dusting it and the tissue with a flat camel-hair brush, Now pour a small quantity of the sensitising solution into a saucer, and with a sponge of good size wet the back of the tissue evenly with the solution for, say, three minutes, and hang up to dry in a room where there is a fire, but taking care to let the back of the tissue be presented to the fire, and at a distance of about six feet from it."

However the tissue is sensitised, it should not be more than a few hours (eight to twelve at the longest) in drying. It should be dried in a room free from noxious fumes, and obviously the apartment should have only very subdued light, if any, gaining access to it. The tissue cannot be warmed to dry it as gelatine plates are, because of the easy solubility of the coating. Indeed, in hot weather, if the sensitising solution is above 65° F., it should be cooled to below this temperature by putting ice into it to avoid incipient solution of the gelatine. The drying of small quantities of sensitised tissue is much facilitated now that the Autotype Company coat opaque paper. By squeegeeing this upon a sheet of ebonite or ferrotype iron, the sensitive layer is protected from light, and it may be dried even in daylight without harm. As tissue is not sensitive when wet, there is no need of a dark room at all when working in this way. Small

quantities of sensitised tissue, as for experimental purposes, may be dried in a closed box that contains a dish of dried calcium chloride to absorb the moisture.

The exposure. Negatives for pigment printing should have their edges protected from light for an eighth or a quarter of an inch all round, preferably by a semi-opaque substance put upon the glass side. An opaque border is not necessary or desirable. This gives the exposed tissue a border of soluble or partially soluble gelatine which adheres more firmly than insoluble gelatine would to the surface it is transferred to, and so tends to prevent the film "washing up" or leaving the surface it should adhere to during development. The tissue is not in the best condition for exposure when it is as dry as possible. It must be dry to the touch, of course, and so dry that it will not stick to the negative, but it should not be horny. If it is horny it will be advantageous to keep it in a damp place until it just becomes limp. In this condition it is more sensitive and more easily manipulated.

The effect of exposure is invisible, and therefore an actinometer must be exposed simultaneously as a guide to the activity of the light. Several kinds of actinometers suitable for the purpose are on the market. Old tissue is more sensitive than new, because with age, up to the production of actual insolubility, the tissue approaches that condition, and requires a less light effect to induce it. It is advantageous to use tissue that has been sensitised two or three days previously.

Unless sensitised tissue is kept absolutely dry, a condition that can only be approached even by close vessels and desiccating reagents, it gradually (spontaneously, as it is called) becomes insoluble. Light produces insolubility

with comparative rapidity, and after light has initiated the more rapid change, the change will proceed after the light is withdrawn, not so quickly as if the action of light were continued, but much more quickly than if the tissue had not been exposed to light at all. This is called the "continuing action" of light, and was first observed by Sir William Abney. It is necessary on this account to be very much more careful to exclude light from tissue that is to be stored than would appear to be necessary by comparing its sensitiveness with that of sensitised silver paper. The continuing action of light must be allowed for when development does not follow within an hour or two of exposure. When the light is poor, or many prints are wanted from one negative, the prints may be only partially exposed, and if kept in a dark place for a sufficient time before development the under-exposure will be compensated for. This method of printing has been practically carried out on the large scale, but it is very uncertain, and apparently not much utilised by commercial carbon printers. From twelve to eighteen hours will probably double the effect of exposure, and from sixteen to forty-two hours will increase exposure effect about eight times; but very much depends upon the condition of the tissue, and consequently of the air that surrounds it. If kept scrupulously dry the continuing effect of light is quite arrested. A print produced by keeping after a short exposure tends to be harder than one fully exposed, so that a thin negative of a black and white subject will give the same effect as a much denser one when chromated gelatine is exposed under it, if a very short exposure is given, just sufficient to start the action through the transparent parts of the negative only, and then the effect is allowed to continue in the dark.

While the thorough desiccation of the tissue arrests this continuing action, it is only a certain measure of dampness that enables it to proceed. Tissue that is wet scarcely shows the phenomenon, and is in general very lacking in sensitiveness. For this reason the development of pigment prints may be carried out in ordinary daylight without detriment to them. This continuing action is not exceptional—it is shown in even a more marked way by chloride of gold; and, on the other hand, it is not the rule, for paper soaked in a solution of a uranium salt gives a vigorous image after exposure if treated with red prussiate of potash, but the effect of exposure is very markedly lessened by keeping the paper for an hour or two, and eventually dies away.

The development. For development, a pigment print must be "mounted" either on its final support, as in single transfer, or on a temporary support, as in double transfer. The final support for the single transfer process consists of fine white paper coated on one side with gelatine made insoluble. To mount the exposed tissue upon it, they are both plunged into cold water, and as soon as the tissue uncurls (it rolls up more or less when put into water) and is nearly flat, it is drawn out of the water with its face against the face of the transfer paper, and the two are placed upon a flat board, preferably one covered with zinc. The back of the tissue being uppermost, the squeegee is applied gently at first until a fair amount of adhesion is secured between the two papers, and then with a little more vigour. The mounted print is allowed to remain twenty minutes or so before development, and it is convenient when many prints are being treated to place them as they are mounted in a pile with

blotting boards between them. The pile is then turned over, and the prints are in correct order for the next operation.

To develop, the mounted prints are plunged into water at a temperature of 105° to 110° F., and almost immediately the two papers are separated by gently but firmly peeling off the paper that supported the film during exposure. This paper is thrown away. The greater part of the film remains upon the transfer paper, and to wash away the gelatine that still remains soluble, the print is laid upon the top of the water and the water of the bath is laved over it with the hand. The process of development will take a few minutes, but may be prolonged to an hour or two of soaking in cases of over-exposure, and at the same time hotter water may be used. If any part of the print is too dark, a jet of hot water from an india-rubber tube or from a kettle may be applied. A print that is under exposed may be developed in cooler water, and there is thus room for the exercise of skill in producing that quality of print that may be desired.

When development is complete, the print is plunged into cold water, and left there for a few minutes or until it is convenient to proceed with it. It is then passed on to an alum solution, containing from four to five per cent. of the salt, and after soaking until all trace of yellow colour has disappeared from the print, back and front, it is well washed in plain water and hung up to dry.

The tanks used for these processes may conveniently be of zinc for cold water, and of tin when heating is necessary, but as the alum solution would corrode these metals, it is used in an earthenware or leaden vessel.

The double transfer process. In a picture produced by single transfer from an ordinary negative, the object is

shown as if it were viewed in a looking glass, that is, the picture is laterally inverted. To get a non-reversed picture, it is necessary to get another reversal, which shall turn the picture round a second time, so to speak, and bring it back to its proper relationship to the object.

This second reversal can be done in two ways. If many prints are wanted, it is certainly better to effect the change once for all by making a reversed negative; while, if only a few prints are to be made, it will generally be more economical to reverse each print as in the method technically called "double transfer." In printing by double transfer, the exposed tissue is mounted on a temporary support, and transferred from this to its final support.

Although these transferrings are not difficult to effect now that the process of carbon printing has attained to so great a degree of perfection, there is at each transferring a tendency to lose a little of the most delicate parts of the picture; and therefore the method of single transfer is always to be preferred when perfection in the finished result is highly valued. One perhaps gets nearer to a perfect transferring by coating the exposed tissue with collodion before laying it down upon its support for development, but the degrees of perfection attainable by these variations are so little removed from one another that even an acute observer, if unacquainted with the technicalities of the process, would probably be unable to find any superiority in the prints done by the more theoretically perfect methods.

As a temporary support, sheet zinc polished or grained, glass polished or finely ground, may be used, and opal glass is to be recommended as showing the details of the picture more clearly during development. But the

temporary support that is most convenient is that prepared according to Mr. J. R. Sawyer's patent as above described. Whatever support is used it must be waxed before mounting the print upon it, so that it may yield up the print when desired. The waxing composition recommended by the Autotype Company is—

Yellow resin	6 drams.
Pure beeswax	2 ,,
Turpentine	1 pint.

A little of this is applied to the surface of the temporary support, and spread over it with a piece of cotton flannel. After a few minutes it is lightly polished with a clean rubber, and in a few hours the support is ready for use.

After developing and soaking in alum to get rid of the chromium salt and washing, the print may be transferred to its final support at once, but it is better to let it dry first. Paper prepared to receive the picture from the temporary support is coated with hard gelatine mixed with a white pigment. This gelatine must be nearly insoluble but not quite, and a very convenient method of securing the proper condition is to prepare the support without affecting the solubility of the gelatine, and to soak it for half-an-hour or so in a two per cent. solution of alum just before it is used. The print on its temporary support and the prepared final support are put into water at about 70° F., squeegeed together, and hung up to dry. When dry the temporary support will readily leave the print.

It is obvious that carbon prints may be transferred to almost any desired surface, if only it is suitably prepared to receive them. In the "Autotype Manual"* will be found many applications of carbon printing with full practical details.

* Published by the Autotype Company.

CHAPTER XXXII.

PIGMENT PRINTING. OTHER METHODS.

The Velours-Artigue process. M. V. Artigue, of Bordeaux, in 1892, introduced a sensitive paper with a matt surface called "papier-velours," the method of preparation of which has not been published. A very fine black pigment is held to the paper support by means of some colloid substance (gum, gelatine, etc.), and when required for use it is sensitised by floating it on a bichromate solution. After exposure, development is effected, without transfer, after soaking in plain water, by pouring over it a kind of sawdust soup prepared from fine sawdust, and the gentle friction resulting clears away the pigment that has not been properly fixed by the insolubility of the coating produced by the exposure. The developed print is placed in a solution of alum for a few minutes, washed, and dried.

The beautiful results given by this method, and the "control" possible in development, that is, the alteration of the depth of colour in any part of the print by adjusting the application of the sawdust soup to that part, led to a revival of the almost forgotten process devised by Mr. Pouncy described in Chapter XXXI.

The gum-bichromate or Pouncy's process. This gives a surface that is not so susceptible to mechanical injury as the Artigue paper, and as it may be developed by using a soft brush to remove the less soluble parts of the coating, it is particularly adapted for the use of those whose artistic knowledge and ability enable them to

produce the picture that they wish for rather than a photograph of the subject. Such pictures are a mixture of photography and painting in a negative sense (removing the pigment instead of adding it with the brush) and of no value as scientific records.

This method is susceptible of many variations. The following, which will serve as an example, is condensed from an article by Mr. J. Packham, which may be consulted (*British Journal Almanack* 1899, page 806) for minute practical details of every part of the process. The paper is first sensitised by soaking it in a ten per cent. solution of potassium bichromate for two minutes or more, making sure that it is thoroughly saturated, and dried in the dark. The Soudan gum acacia, known as Turkey, occurring in tears, not as a powder, is the best kind of gum. One ounce of a twenty per cent. solution of this is mixed with twelve grains or rather less of vegetable black, or three or four times as much of brown or red pigment, on a marble slab or plate of ground-glass, by putting a few drops of the mucilage on the pigment and grinding them well together with a palette knife. The mixture is transferred to a cup, more mucilage is worked on the slab, transferred as before, the rest of the mucilage is added, and the whole mixed. The sensitised paper pinned on a board is coated with this mixture by means of a two-inch bear's-hair brush set in tin, mixing the pigment and gum thoroughly with the brush first, crossing and recrossing the paper with the brush. Then a four-inch flat badger's-hair brush is held vertically and passed over the surface quickly until the coating is nearly surface dry. The paper is allowed to dry and is then ready for exposure, which requires no special precaution except

that an actinometer must be used. The print is developed by placing it face downwards on a dish of cold water, and after five or ten minutes, or longer if the coating does not seem to be affected, the print is placed on a board and laved with water, or the surface is worked with a large size camel's-hair mop, flowing water occasionally over the print. The development may be modified as desired by the use of the brush, a jet of water from a syringe, warm water, and so on, as is obvious. The washed print is immersed in a solution containing alum and sodium sulphite but no acid, washed, and allowed to dry.

Some prefer to add potassium bichromate to the pigmented mucilage instead of sensitising the paper first. In this case the mucilage may be made of double the strength given above and mixed with an equal volume of the ten per cent. bichromate solution before mixing it with the pigment. Or the paper may be sensitised after it is coated.

The ozotype process was first described by the inventor, Mr. Thomas Manly, in 1899. It is so named because of a supposed connection with ozone, which, however, does not exist. The sized and sensitised, but otherwise uncoated, paper is exposed, the change on exposure being visible, and the print is washed and dried. At any subsequent time, carbon tissue, or "pigment plaster" as it is called in this process, is squeegeed on to the exposed paper; under certain conditions, the exposure effect acts on this, and, after soaking, the backing that originally carried the pigmented gelatine is peeled off and development completed as usual. The advantages of the method are that there is no lateral inversion of the image as in single transfer ordinary carbon printing, no actinometer is needed because

the exposure effect can be seen, and a faulty exposure can be detected at once, that is before development.*

To render the paper sensitive it is coated with a mixture of potassium bichromate and a manganous salt, such as manganous sulphate. On exposure the bichromate is decomposed as usual and the manganese salt is supposed to be oxidised, and so to increase the colour of the visible image. The pigmented gelatine, which is squeegeed on to this, is soaked for half a minute in an acid bath which contains a reducing agent; at first hydroquinone or some other similar developing agent was used, but now ferrous sulphate. Presumably here the reduced chromium compound in the exposed paper dissolves in the acid, giving a chromic salt which, passing into the gelatine, renders it insoluble, and the manganese compound, if oxidised, would convert the ferrous salt into a ferric, or the organic substance into oxidation products, which would also have a tanning effect on the gelatine. The subsequent operations of development, etc., are the same as in other pigment processes.

The Ozotype Company supply all the materials necessary for working the process, and it is from the instructions written by the inventor and issued by them that the following details are taken.

Unless the paper is already prepared it is sized with a solution of fish glue or gelatine, or a sizing solution supplied by the company. Drawing and writing papers may be sized with common paste—

Wheat flour	360 grains	or	20 grams.
Water	10 ounces		300 c.c.

made as usual by boiling and spread with a brush.

* A somewhat similar method was described by M. A. Marion in 1873 and called by him "Mariotype." The paper thinly coated with gelatine was sensitised and exposed. A piece of carbon tissue was then sensitised, squeegeed into contact with the exposed paper, and after from eight to ten hours the print was developed as usual.

The sensitising is done in a darkened room by a solution supplied by the company, or the sensitised paper may be bought ready for use.

The exposure is about of the same duration as for platinum paper, and is continued until the details in the high lights are visible, but light clouds will probably not show.

The print is then washed for ten or fifteen minutes in frequently changed water, and if from any cause the unexposed margins of the paper are not clean, the prints should be put into water containing one minim of sulphuric acid to each ounce (or two c.c. to a litre) until the whites are clean. The print is now not sensitive to light. It may be proceeded with at once, or dried, and finished off at any time within about two months.

The pigmenting of the print is done in an acid bath, the most recent formula for which is—

Water	40 ounces	or 1,000 c.c.
Pure hydrochloric acid	40 minims	2 c.c.
Powdered alum ..	10 grains	½ gram.
Ferrous sulphate, 50, 70, or 90	,,	2½, 3½, or 4½ grams.

The smallest amount of ferrous sulphate is for large work on rough paper or prints from flat negatives. The medium amount is for medium contrast on thinly sized papers. The largest amount is for delicate work on fine well sized papers. Increasing the acid will give greater contrast. The print is immersed in cold water if it has been allowed to dry. The pigment plaster is immersed in the acid solution for thirty seconds (longer for an under-exposed print and a shorter time for an over-exposed print), then the print is put into the acid bath, the two are brought out face to face, and squeegeed together. After remaining between blotting paper for from thirty to forty-five minutes, the development should take place.

For development the water should be heated to from 110° to 120° F. (43° to 48° C.) The print is plunged into the water, and in a few seconds, if the plaster backing seems loosened, it should be peeled off, and development done as with an ordinary carbon print.

The developed print is then put for ten minutes into an alum bath (one ounce to the pint) containing hydrochloric acid (fifteen minims to the pint). The print then is well rinsed and allowed to dry. Mr. Manly has recently adapted the ozotype process to the making of gum prints, pigmented gum being spread with a brush on the exposed print instead of applying a pigment plaster.

The dusting-on process. There is another method of pigment printing capable of giving very fine results, though it is but little practised at the present day. It is generally known as the "powder" or "dusting-on" process, because the pigment is taken in the form of a fine powder, and is dusted on. In this process advantage is taken of the fact that certain sticky substances, such as honey and glucose, lose their stickiness when they are mixed with potassium or ammonium bichromate and exposed to light. Moreover, as the loss of stickiness is proportional to the light that has gained access to the surface, if such a film is exposed beneath a transparency, and a pigment in fine powder is then lightly brushed over it, the colour will adhere in greatest quantity to those parts that have not been affected by the light, and if proper care is taken it will not adhere at all to those parts subjected to the maximum of light effect, and the result will be an excellent reproduction of the *cliché*. If a positive picture is required a positive transparency must be used; if a negative is employed the result is a negative.

J. Obernetter, of Munich, at one time used this process regularly for the reproduction of negatives. His formula and practice will serve to illustrate the general method, though very considerable variations in the sensitive mixture have been made from time to time. His formula was—

Dextrine	4 grains.
White sugar	5 ,,
Bichromate of ammonium	2 ,,
Water	100 ,,
Glycerine	2 to 8 drops.

The mixture is filtered, and the glass plate is coated with it after the manner of coating with collodion, and then dried in a horizontal position at a temperature of from 120° to 170° F. In five or ten minutes the film is dry, and while still warm it is exposed under the negative to be reproduced for from five to fifteen minutes. A slight change of colour is evident where the light has acted. The plate is then made a little warmer than the air where development is to be performed; it is laid upon white paper, and very finely powdered graphite is gently brushed over its surface by means of a soft brush. Blowing or breathing upon the plate increases the ease with which the powder adheres. The amount of glycerine used in the mixture makes the film suitable for varying conditions of the air; it should be decreased or even omitted in a moist warm atmosphere and increased in winter. When development is complete the film is coated with a plain collodion containing eight to ten grains of pyroxyline to the ounce, and is then cut round with a sharp knife. The plate bearing the film is then put into water, and soon the compound film leaves the glass because of the solubility of the under layer of the film. It is at once turned over and brought out upon the plate. If the film were not

turned over the result would be a reversed negative. A thin solution of gum is poured over the film, and when this is dry it is varnished.

Catatype. Messrs. Ostwald and Gros, in 1901, patented a process to which they gave this name because it takes advantage of the catalytic action of finely divided platinum or silver. If a photograph in metallic silver or platinum is flooded with a solution of hydrogen peroxide in ether (preferred because of its volatility), when the solvent has evaporated an invisible hydrogen peroxide image is obtained, because the finely divided metal decomposes the peroxide in its immediate presence. This hydrogen peroxide image may be pressed into contact with a gelatine film, and sufficient of the peroxide will transfer itself to the gelatine, so that if this is then treated with an alkaline solution of a manganous salt, wherever the peroxide is a brown manganese peroxide will be produced. An alkaline silver solution will give a black image of metallic silver, an alkaline lead solution a brown image of lead peroxide, and there are many other obvious ways by which the hydrogen peroxide image.can be developed. If an ordinary negative is treated as stated with hydrogen peroxide, then placed in contact with a paper coated with gelatine or gum, mixed with a pigment, for about thirty seconds, the undecomposed peroxide (in the shadows) will diffuse into the film, and if the latter is treated with a solution of a ferrous salt will oxidise it to a ferric salt, which will render the colloid insoluble. The print can be developed in the usual way with warm water. The process, up to the development, may be completed within two minutes. These are only examples of the applications of the catalytic action of silver and platinum photographs.

CHAPTER XXXIII.

GELATINE RELIEFS AND WOODBURYTYPE.

THOSE methods of printing in which the direct action of light is necessary for the production of each individual proof are considered photographic processes, but when by the action of light a printing surface is obtained that will furnish proofs mechanically, that is, without any further need for light, the process is termed photo-mechanical.

In pigment or carbon printing by the ordinary method, the picture consists of a layer of pigmented gelatine of thickness varying according to the transparency of the negative; it is, in short, a low gelatine relief, but as the gelatine is pigmented and the relief is very low, its appearance when dry is simply that of a surface covered with the varying intensities of colour as desirable to form the picture. Instead of getting this varying thickness of pigmented gelatine by exposing the sensitised film to light and developing, it may be obtained by *casting* coloured gelatine in a suitable mould. This obviously is a photo-mechanical process, and as we owe it to the inventive genius of Mr. W. B. Woodbury, it is called Woodburytype.

By taking advantage of the insolubility of sensitised gelatine when exposed to light, and the fact that the insolubility will penetrate to a greater depth the longer the light acts or the more powerful the light may be, it is possible to get a relief picture from any negative, in which the light and shade of the original are represented by a

proportional amount of relief, the darkest part of the original being represented in highest relief. This gelatine relief, when dry, can be made to give an intaglio or sunk image in a soft metal by simple pressure, or by using an easily fusible substance a cast of it may be taken. The intaglio in metal may be made to reproduce any number of coloured gelatine reliefs by pouring the melted gelatinous mixture upon it, and pressing the flat surface that is to receive the relief into contact with the mould until the gelatine is set. The thickness of the layer of coloured gelatine determines the amount of colour, and as the colours used are more or less transparent, the thicker the layer of colour is the deeper is the tint. The final pigmented gelatine relief, when dry, exhibits so small an amount of relief as to be scarcely noticeable, especially when finished in the ordinary way. A Woodburytype print is, therefore, a pigmented gelatine relief in which the thickness of the relief determines the amount of colour, and therefore the depths of tone of any part of the print.

In this process it is difficult to get a white part of any appreciable extent unstained. In carbon printing there is no analogous difficulty, because the gelatine that remains soluble after the exposure is dissolved and washed away. In the first case the process is mechanical, and every print from the metal relief is alike if proper care is taken; but in the second process very considerable variations may be made according to the taste and skill of the printer, because the solubility of the exposed gelatine film is a comparative matter depending upon the exposure, the temperature of the water used, and the time it is allowed to act.

As a single transfer carbon print, and also a Woodburytype print, is a relief picture, it might be considered that if a mould were made from such a print, reproductions might be multiplied from such a mould. But this is obviously impossible when one remembers that such a mould would be made from a dry gelatine relief, while it is a bulky solution of gelatine that fills the mould in the printing operation. It is necessary, therefore, to prepare a relief which, when dry, is in as high relief as the bulky pigmented solution of gelatine is required to be to get the necessary contrast in the picture.

The analogy between a Woodburytype print and a single transfer carbon print leads to the same result as far as the reversing of the picture is concerned, and if a non-reversed print is desired, a reversed negative must be employed. It is possible to cure the reversal in Woodburytype by placing the back of the gelatine relief against the metal that is to furnish the mould, but this is not a desirable procedure.

The gelatine relief is prepared by means of a film of sensitised gelatine considerably thicker than is used in carbon printing, and containing very little, if any, pigment. The exposure under the negative must be longer than in carbon printing, and there is an advantage in exposing to the direct rays of the sun, as the light is then less scattered in the film. The development is much the same as in carbon printing but very much more prolonged, and the temperature of the water is considerably raised towards the end. The developing may extend over from two hours to as many days. The relief is hardened with alum, washed, and dried.

In the original process, as patented by Woodbury in

1864 and perfected during that and the following year, the printing mould was produced by pressing the gelatine relief into a lead plate. A hydraulic press is necessary for this operation.

Since then Woodbury modified the production of the metal mould, dispensing with the press. The earliest "stannotype" process consisted of supporting the gelatine relief upon a true surface, as of plate-glass, covering it with tinfoil, and passing them together through a rolling press with indiarubber rollers until the tinfoil was pressed into the relief so perfectly as to be a counterpart of it. The tinfoil was then strengthened by the electro-deposition of copper upon it, and then a glass plate, coated with a suitable resinous cement, was pressed into contact with the copper. The required metal mould was thus made in tinfoil, and strengthened sufficiently for printing from.

The more recent and more generally available stannotype process utilises a gelatine mould for the printing, the mould being coated with tinfoil to preserve it. For this method a gelatine intaglio, instead of a relief, is necessary, and this is prepared by exposing a sensitised gelatine film, and developing it as for the relief, but the *cliché* employed must be a transparency instead of a negative. Before putting the tinfoil upon the surface of the mould, it is covered with a thin solution of indiarubber in benzene, which serves to cement the coating of metal to the gelatine.

The gelatine reliefs prepared as above can be put to other uses than the production of moulds for printing from. One of the simplest of these applications consists of merely placing a piece of paper against the relief, and passing them together through a suitable press. The

paper is made transparent in proportion to the pressure it is subjected to, and as the highest part of the relief causes the greatest pressure, a sort of water-mark effect results. This is the "photo-filigrane" process.

In these methods of Woodbury a perfect gradation of tint may be produced, a result which is practically impossible by any other photo-mechanical process.

CHAPTER XXXIV.

COLLOTYPE (PHOTO-LITHOGRAPHY, PHOTO-ZINGOGRAPHY).

It has already been stated that when light acts upon chromated gelatine it lessens its capacity for absorbing water, and at the same time proportionately enables it to receive greasy matter, such as printers' ink. It is the discriminating power of the prepared lithographer's stone bearing its transfer that makes lithographic printing possible, and a gelatine film exposed under a negative may be printed from after the manner of lithographic printing. All processes in which a gelatine film is utilised in this way are included in the general term—collotype. In the early days of collotype printing it was sometimes called photo-lithography, but that term is now very properly restricted to processes in which a photograph is transferred to stone, and then printed from.

It appears that we owe the idea of "inking up" an exposed chromated gelatine film to Poitevin. In 1865, MM. C. M. Tessié du Motay and C. R. Maréchal secured a patent in connection with collotype printing, the chief points appearing to be certain methods of hardening the gelatine film, and so endeavouring to make practicable what was before only a theoretically possible process. But Tessié du Motay could only get perhaps fifty to one hundred impressions from one film before it became unusable.

'In 1867 an invention was patented in Berlin by Messrs. Ohm and Grossman" (quoted from Mr. J. R. Sawyer), referring to the very important matter of giving

the glass plate that is to bear the collotype film a preliminary coating of an aqueous solution of albumen, gelatine, and bichromate, drying this and exposing it through the glass to light until it is made insoluble. But early in 1869, if not in 1868, Albert, of Munich, appears to have used a similar substratum, and to have produced very successfully large numbers of impressions, over a thousand, from one plate.

Collotype printing was for a long time almost entirely in the hands of the Autotype Company so far as this country is concerned. The following details concerning the process as practised by them are taken from Mr. J. R. Sawyer's description. A glass plate is warmed to 100° F., and is coated with an aqueous solution of a mixture of albumen, gelatine, and bichromate of potassium, and is then kept warm until dry. This first coating is caused, not only to cover the surface of the plate, but to flow over each of its edges to secure it more firmly to the glass. The mixture for the second coating consists of an aqueous solution of gelatine, with a little albumen and the bichromate, to which, when thoroughly mixed, a small quantity of an alcoholic solution of certain gums is added, together with a little nitrate of silver and an alkaline iodide. The gum and the silver iodide are precipitated in a very fine condition. This mixture is applied to the plate in the same manner as the first; after the plate has been exposed to light, allowing the light to reach the film through the glass, and has been washed in warm water. In two or three hours, when the second coating is dry, the plate is exposed under a reversed negative; it is then well washed with cold water, and allowed to dry spontaneously. Prints may then be made from it,

Instead of the substratum given above, Husnik has substituted an aqueous solution of albumen and sodium or potassium silicate (water glass).

There are very many modifications of the manner of preparing collotype plates. It is not necessary to mix any substance with the sensitised layer, as is done in Sawyer's method, because the gelatine surface will become of itself reticulated and able to hold the ink. If proper care is taken the reticulation is very fine, so that the want of continuity in the ink on the proof is scarcely visible without the aid of a microscope. A coarsely grained plate is, however, more easily printed from.

It requires considerable skill to ink up a collotype plate—a skill analogous to that of the lithographer, though with modifications. The presses used at first were of the ordinary lithographic pattern, in which pressure is got by drawing the plate with the paper on it under a fixed "scraper." This principle, however, is not advantageous; a rolling pressure is better, but a direct vertical pressure is generally preferred, at least for small work. Steam presses are now largely used, which turn out prints very much more rapidly than is possible by hand.

Instead of preparing a gelatine film so that it shall be able to resist the wear and tear of being printed, it may be so prepared as to furnish only a very few prints. If only one perfect print is obtained in lithographic transfer ink, the ink of the print may be transferred to a lithographic stone, and will then furnish proofs by ordinary lithographic printing. Such a procedure is termed "photo-lithography," and the print obtained from the gelatine film is called a "transfer."

To prepare a transfer, a thin paper is floated on a

solution of gelatine mixed with a bichromate, or the paper may be coated with gelatine first and then sensitised, as in carbon printing. The negatives for this process must have no half-tones, and the opaque parts are better if they are what is called quite opaque, while the transparent parts are not fogged at all. After exposure beneath such a negative the film is covered with a thin layer of ink by any suitable means, and then floated on or soaked in water. The water swells the gelatine that has not been affected by light, and, by means of warmer water and gentle friction with a sponge or a soft brush, the ink is removed, except from the insoluble parts of the gelatine.

Instead of covering the exposed gelatine film with ink and then removing those parts that do not form the required print, the exposed film may be soaked in cold water, then blotted off, and inked with a velvet roller. In this case, only those parts of the film that have been acted upon by light take the ink. The use of the velvet roller is due to Mr. F. Butter, of Woolwich Arsenal.

Instead of transferring the print to stone, it may be transferred to a prepared zinc plate, and then printed from. This is photo-zincography.

CHAPTER XXXV.

OTHER PHOTO-MECHANICAL PROCESSES.

In reviewing the printing processes already considered it will be observed that we have passed gradually from true photographic processes to photo-mechanical processes, and in doing so we have been gradually passing away from our immediate subject. Therefore, although we have approached matters that well deserve a large space devoted to them, we have treated them in a more summary way. This present chapter deals with by far the most important items of all, but the purpose of this work will be served by a mere reference to principles.

In strictly photographic processes of printing the tones are rendered by even tints, and this result is also realised in the Woodburytype processes. Collotype printing appears to the cursory observer to render half-tones, but it does not do this in the strict sense of the term. The reticulation of the gelatine surface gives a want of continuity in the tints of the print. It is a mechanical imitation of half-tone, though produced spontaneously. In describing the process of photo-lithography it was mentioned that half-tones negatives were not available—the negative must be "black and white" only. This also applies to the other photo-mechanical processes.

But as it is necessary to produce prints from half-tone negatives by mechanical processes many methods have been devised of "breaking up" the tones of a negative so that the half-tones shall be imitated, as they cannot be reproduced, in ways similar to the imitation of half-

tones in engraved plates and typographic blocks. In these cases the print consists of lines or dots or both, and the lines and dots are thicker or nearer together where a dark tone is to be represented than for a lighter tone. Although the ink is uniformly opaque, or nearly so, a semblance of half-tone is realised by varying the proportions of inked and uninked surface. It is important that the lines or dots be so fine as not to be distinguishable as such at the proper distance from which the print is to be viewed.

The need for breaking up the tints of ordinary half-tone negatives to enable them to furnish prints by the mechanical processes has led to many inventions for the purpose. Some of these produce theoretically the desired result, while others give what is wanted apparently by accident.

The grain or stipple may be obtained by the reticulation of gelatine as in a collotype plate, or by photographing the half-tone subject through a network or through one or more lined transparent screens, or the plate on which the grained negative is to be taken may have a preliminary exposure to light through a fine network. By means of powders dusted over or allowed to fall upon or incorporated with a surface that is to furnish a printing surface, a grain may be produced. A plaster cast from a gelatine relief may be transformed by mechanical means into a black and white stipple picture. If a sort of file made of indiarubber is inked and pressed against it, large dots of ink with scarcely any white intervals will be left upon the high parts of the relief, which press into and crush down the inked indiarubber points, while in the hollows the dots will be small, with consequently a large proportion of whiteness remaining. Or if a relief has its surface

covered with ink, and is then traversed all over with a V-shaped tool cutting grooves which have a uniformly level base, finer lines of ink will be left on the higher parts of the relief than upon the lower parts. These are examples of the methods that have been proposed for getting a stipple or grain.

Excluding the photo-mechanical processes described in the last chapter, printing surfaces are of two kinds: those in which the subject is sunk or incised in the plate, called intaglio, photo-engraved, or etched plates; and those in which the subject stands up in relief as in ordinary wood blocks. The first are printed from after the manner of getting impressions from copper or steel engravings or etchings, the ink being caused to fill the depressions and then taken up from these by the paper. In using the second, the ink is merely rolled on to the parts that stand up in relief, and the paper being pressed upon the inked surface takes the ink from the tops of the projections. The first method gives the finest results, but the second has the great advantage of being similar to ordinary typographic printing, and a photo-relief block or typographic block may be incorporated with type and printed from with the type.

Whether an intaglio or a relief surface is desired, the principle of the operations is generally much the same. A suitable surface, generally of zinc or copper, is made to receive a photograph that will allow an etching fluid to attack certain parts only of the plate. For an intaglio plate the image itself is etched, while for a relief block it is the ground that is lowered by corrosion.

In 1852, Fox Talbot patented the production of photo-etched steel plates for intaglio printing, by coating

the plate with chromated gelatine, exposing under the *cliché*, and then washing. The etching was done with a solution of platinum chloride which dissolves iron thus—

$$2Fe + PtCl_4 = 2FeCl_2 + Pt$$

The ferrous chloride and precipitated platinum are easily washed away.

This process, modified by Klic, is one of the methods of producing photogravure plates. A copper plate is covered with a fine dust of bitumen or other similar material to furnish the necessary grain, and warmed to cause the dust to adhere. A carbon print is transferred on to the plate and developed, and the etching is done with solutions of ferric chloride of different strengths.

CHAPTER XXXVI.

REPRODUCING NEGATIVES, MAKING TRANSPARENCIES AND LANTERN SLIDES, ENLARGING, ETC.

Reproducing and reversing negatives. A negative may be reproduced the same size by taking advantage of the reversing action of light. Methods of doing this are given in the chapter on solarisation and halation. In this case the new negative is "reversed," that is, laterally inverted. The method of duplicating negatives by the dusting-on process is described in connection with pigment printing.

A reproduced negative is not reversed when it is obtained by two printings, first by exposing under the original negative to get a transparency, and then under the transparency to get the new negative. The sensitive material used for these operations may be transparency or "lantern" plates, gelatino-bromide plates, or carbon tissue specially prepared with a full amount of extra fine pigment. The carbon process generally gives the finest results with the most certainty. A carbon transparency is reversed, and a negative made from it on an ordinary plate is also reversed. This method is, therefore, very convenient for making a carbon enlargement, because a reversed negative obviates the need for double transfer in the printing. The chief points to attend to in preparing transparencies for reproducing negatives are to get full detail, even if a little fogging is necessary, and to reproduce the gradation of the original without loss.

If a reversed negative is wanted of an object that has to be photographed, the usual method is to fix a mirror

in front of the lens at an angle of 45° with its axis, and so to photograph the reflection in the mirror. The mirrors used must, as has already been explained, be coated with silver on the *front*, and the metal, being exposed, soon tarnishes, and is liable to injury. The mirrors require careful cleaning to keep them in good order, and sometimes need resilvering after a year or so. If, therefore, a reversed negative is wanted only occasionally, it is more practicable to resort to other means though they may be less perfect.

A reversed negative may be obtained by the old, if not well-known, method of putting the sensitive plate with its glass side towards the lens. It is necessary to take care that the glass is quite clean, that the film is protected from injury by the spring or separating sheet of the camera back, and that in focussing the thickness of the glass is allowed for. This last is the most uncertain item in the work, and though it may be neglected when a small stop is used in the lens, and will sometimes even improve the outdoor work of an inexperienced operator by putting the foreground into better focus, it is a matter that needs careful attention in exact work.

Film negatives that are thin enough may be printed from either side and the difficulty of reversal disappears; but it is necessary to bear in mind that some are not thin enough for this purpose. However thin the film is, there is a loss of definition in the print by printing from it in the reverse direction, and whether this loss is harmful or not is easily ascertained by taking a silver print from each side of the negative and comparing them.

The film of a gelatine negative may be stripped off its glass support, and remounted the other way up, or

kept as a film negative. The most convenient stripping reagent is hydrofluoric acid, as suggested by Plener. The film must first be thickened to enable it to withstand the manipulations. This is conveniently done by coating it with gelatine, using a hot solution containing fifty grains or more to the ounce. When dry the negative is soaked for five or six minutes in cold dilute sulphuric acid (one to twelve), and then transferred to an ebonite or celluloid dish containing a solution of sodium fluoride of about five grains to the ounce, to which has just been added about five drops of strong sulphuric acid diluted with a little water. When the film has separated it is put back into the first dish for a short time, then soaked in water for about a minute, squeegeed on to a glass that has been waxed and polished, and allowed to dry. It is desirable to fume the negative with ammonia during the drying to neutralise any remaining acid in it, and to secure the edges to the glass that they may not peel up before the drying is finished. When dry the film is easily separated from its support.

Enlarged negatives. A gelatine negative may itself be enlarged as much as to two diameters, it is stated, and if the gelatine is thicker to a still greater extent, by soaking the negative in water containing about a twelfth of its volume of strong ammonia. In about two hours, perhaps, the film frills off the plate, and if it is not distended sufficiently the temperature of the bath may be raised by adding small quantities of hot water. The film is then caught upon a glass plate of sufficient size and allowed to dry. It is obvious that the film may be turned over before it is put on the new glass and a reversed negative obtained. A solution patented under the name of " cresco-fylma" has

been introduced into commerce that effects the removal of the film from the glass and its expansion with but little chance of failure. The active ingredient for separating is hydrofluoric acid, and for the expansion citric and acetic acids. Glycerine and other constituents are also present. The separated and enlarged film is placed on a new glass, either side uppermost as required, and allowed to dry. It can then be well washed and intensified if need be, for such expansion obviously reduces the density.

But in the majority of cases when an enlarged negative is required, the original must be preserved intact. The enlarged negative must then be made through the medium of a transparency, unless the dusting-on process is resorted to, or, as may be sometimes convenient, a paper print is photographed. Using a transparency, there are two distinct methods available, namely—the transparency may be printed by contact from the small negative, and the enlarging done from the small transparency, or the small negative may be enlarged to a large transparency, and the large negative may be printed by contact from this, or enlargement may take place at both stages. There is something to be said in favour of each plan. In producing the enlargement direct from the small negative, that is, making a large transparency, the flaws of the transparency are not enlarged, and it is easier to eliminate defects. The large transparency offers particular facilities for producing one or many enlarged negatives by a printing-out process, as, for instance, on albumenised silver paper, after the plan proposed and worked by Mr. V. Blanchard. Very excellent results were obtained in thid way, the sensitive paper being exposed rather longer than it would be for a positive print, then washed, fixed, dries,

and waxed. No toning is necessary, and such paper negatives appear on the whole to be more stable than ordinary toned prints. If necessary, new negatives are easily made, and each new negative is as exact a reproduction of the first as is possible.

In favour of making a small transparency and enlarging from it, it may be said that a printing-out process is then available for making the transparency, and that the carbon process lends itself most excellently to this purpose. From a good transparency negatives of any size may be produced with facility.

The negative or transparency that is to be enlarged must be illuminated equally all over, and then it only remains to expose the large plate in the camera with ordinary care to get a successful result.

An evenly-illuminated surface is often difficult to secure. If, for instance, the transparency is fixed in a window, objects at a very considerable distance, even two or three hundred yards away, will cause thin places on the large plate if they are included between imaginary lines drawn from the lens through the extremities of the transparency to the view beyond. The operator may be tempted to think that such objects, being so far out of focus, cannot influence his work, but he will find himself grievously mistaken if he rests upon this assumption. With a good expanse of fairly uniform sky there should be no difficulty when the transparency faces directly towards the sky. The sky also, if it is uniformly brilliant, may be used by means of an inclined reflector; but the reflector must be kept carefully clean, and be large enough to include, as it stands, the whole solid angle formed by the lines that might be drawn into the lens through the

extreme corners of the transparency. If the transparency is 5in. × 4in., and the picture is the horizontal way of the plate, and the reflector inclined at an angle of 45°, a reflector that is 12in. × 10in. will be found to allow no practical margin when the optical centre of the lens used for enlarging is eight inches distant from the transparency. A white surface, such as a sheet of white paper, may be used instead of the reflector, and, all things considered, is generally to be preferred, but exposure will have to be prolonged, and if the white surface is not evenly illuminated the enlargement will suffer.

The simplest method where daylight is employed is to interpose a translucent substance between the light and the transparency. The translucent medium then becomes the source of illumination, and, with a little care, variations in the intensity of the light that different parts of its surface receive may be so toned down as practically to be eliminated. Ground-glass may be used for this purpose, but nothing, probably, can equal opal glass. It has no grain, and its diffusing power is vastly superior to a couple of sheets of ground-glass. Either pot or flashed opal will serve, that which transmits the most light being the most suitable. Whatever is used, it should be placed at least two or three inches from the transparency.

If artificial light has to be used, then the best method is to use an optical lantern, or an equivalent apparatus, as described subsequently in the making of bromide enlargements. But the same principle of arrangement as used for daylight may be employed, that is by getting a sufficiently large and evenly-illuminated surface behind

the negative or transparency. The artificial lights should be distributed over the whole surface that has to be illuminated, and a diffusing medium placed between them and the transparency. It is useless to have one central light, however the diffusing screens are arranged, unless, for example, a large gas flame is used and the transparency is small. As already stated, nothing equals opal glass as a diffuser for such a purpose, and so far as illuminating power goes magnesium is the most powerful. For small work, a piece of burning magnesium ribbon may be moved about behind the opal, but it is not easy to avoid giving more light to one part than to another by this method, unless the negative is very small. Pieces of magnesium may be hung at regular intervals to secure a more even lighting for larger plates.

Another method is to illuminate a white surface, such as of white paper, with a light on each side of it, so shielded as not to shine upon the lens but to cast the greatest possible amount of light upon the white surface. In front of this the negative is to be so placed that no light shines upon it except from the white paper. This method is excellent, if powerful lights such as incandescent gas lamps or acetylene are used, otherwise the exposure will be very long. Prints that have to be copied, whether enlarged or not, may be illuminated in this way with great advantage.

It is not possible to give much practical suggestion as to the exposures likely to be required in copying and enlarging, but the following table extracted from a larger one calculated by Mr. W. E. Debenham gives the proportional exposures as affected by the ratio of the image to the original:

Proportion of image to original (linear).	Distance from lens in terms of principal focus.	Proportional exposures.
$\frac{1}{20}$	$1\frac{1}{20}$	.28
$\frac{1}{8}$	$1\frac{1}{8}$	.31
$\frac{1}{4}$	$1\frac{1}{4}$	.39
1	2	1.0
2	3	2.25
4	5	6.25
6	7	12.25
8	9	20.25
10	11	30.25
15	16	64.
20	21	110.25

Lantern slides are small transparencies intended for use in optical lanterns. They may be prepared by any of the methods given for making transparencies, but they should be different from transparencies specially prepared for reproduction purposes in being rather thinner, and, as a rule, quite clear or free from deposit in the highest lights, and the image must be of a pleasing or suitable colour. The arrangement for making them by reduction in the camera has been sufficiently described. When the negative is of the required size, a contact exposure is preferable as involving less trouble and giving a slide which shows equally well on the sheet, though it is not quite so pleasing when examined in the hand as a slide made from a larger negative by reduction in the camera. The developers used have to be suited to the plates, and when commercial lantern plates are used it is best at first to be guided by the maker's directions. For a neutral grey or black the double strength formula for metol, as given for negatives, diluted with from eight to sixteen times its bulk of water will generally be found effective

DIRECT ENLARGING.

In making slides from black and white subjects, such as diagrams, on gelatine plates, it is sometimes advisable to continue development until the clear parts are clouded over, and after fixing to reduce with potassium ferricyanide and hyposulphite until perfect clearness is regained. This gives improved density in the black parts. Lantern slides may be toned by the processes and formulæ given for the toning of bromide prints.

Enlarging on bromide paper. The simplest method of getting a positive enlargement is to put the negative in an enlarging apparatus, and receive the image upon a sensitive surface. It is possible to get a print in this way on prepared paper not more sensitive than ordinary printing-out silver or platinum paper where direct sunshine is available, but this is rarely practicable in this country. By substituting, however, an emulsion-coated paper that requires a short exposure only and is then developed, the need for sunshine disappears, and artificial lights are quite efficient.

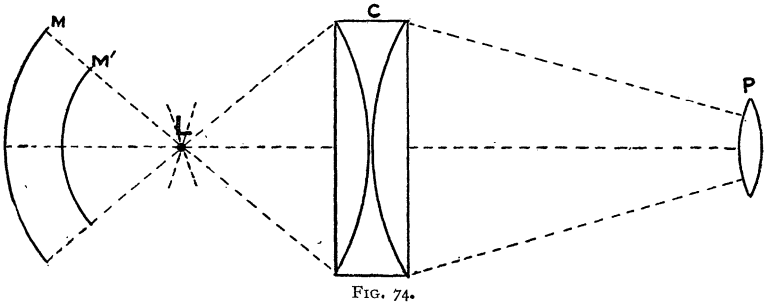

FIG. 74.

Projection lanterns specially made for direct enlarging are now made of a variety of patterns, all on the general principles of the optical lantern, but with a condenser

of the necessary size and a projecting lens corrected for photographic work. The proper relative positions of the light, condenser, projecting lens, and mirror are shown in fig. 74. Unless the illuminant is a point, which is almost realised when an arc lamp is used, it is impossible to arrange the details exactly as shown, but the nearer the approach to the theoretically perfect conditions the better will the results be. The mirror, if of poor quality, will cause uneven lighting of the sensitive paper, and it is then better omitted. It should be of spherical form, its centre of curvature being at the source of light, L, and its diameter will be regulated according to its distance from the light, as shown at M, M'. Direct enlargements may be made without the use of projection apparatus, if the bromide paper is held in the dark slide of a camera that has a sufficient length to permit of the enlargement with the lens to be used, and if the negative can be illuminated evenly all over from behind. The method is the same as the production of an enlarged transparency, and has already been considered.

Details as to the development, toning, and general treatment of bromide prints have already been given, and are as applicable to enlargements as to contact prints.

CHAPTER XXXVII.

PHOTOGRAPHY IN NATURAL COLOURS.

THE ordinary meaning attached to this expression is the production of a photograph either directly in the camera or by printing from a negative, in which the colours of the original shall be reproduced in all their variety of tints as a matter of course. In this sense, the search for a method of getting photographs in natural colours is almost comparable to the search for the philosopher's stone or the elixir of life. The action of light in giving a developable image is similar in effect whatever its colour may be, and the developed image consists only of greater or less quantities of the same material to represent the greater or less effect produced. The colour of the image is the colour of this material, generally grey silver.

It is easy by exposing certain silver compounds to light, as well as by other means, to produce rich and various colours, and it is not surprising that sometimes the colour produced should happen to approximate to the colour of the light that produces it when coloured lights are employed. But there can be no doubt that there is sometimes a more intimate connection than mere accident between the colour of the light and the colour of the decomposition product, especially when chloride of silver is used. If, however, it were quite possible to get a red product by the action of red light, a blue stain by blue light, and so on, it would be necessary to get black where no light had acted, and white that was whiter in proportion as the light was

stronger, before this kind of photography in natural colours became an accomplished fact.

When a sensitive surface is so prepared that it will give polychromatic results, it does not at all follow that the colours produced will match the objects represented. Hunt states that in one of his experiments the sky was crimson, stucco-fronted houses were slaty blue, and the green grass came out brick red. Of course, some experiments were more successful, but in all cases, or almost all, fixing destroyed the colours. T. J. Seebeck, in 1810, appears to have been the first to notice the production of such colours.

Interference heliochromy. Dr. W. Zenker, in 1868, published a small volume "Lehrbuch der Photochromie," in which he summed up the work that had been done in this direction and criticised the theories that had been advanced to account for the results. He suggested that the colours were due to the production of "standing waves" of light in the film. When two similar wave systems meet, as when a ray is reflected back upon itself, the interference produces a wave system in which the nodes and the crests are stationary instead of progressive as in ordinary light waves. The effect of this in a sensitive film of a suitable kind is to produce layers of the product of the light action, and these layers when suitably illuminated will reflect light of the same wave lengths, and therefore of the same colours, as the original incident light. The fact that these layers are really produced has since been proved by the actual photography of them in prepared transverse sections of films, first by Dr. Neuhauss and afterwards by Mr. E. Senior assisted by Mr. W. B. Randles and Mr. T. A. O'Donohue. (For a full account

of Zenker's treatise see articles by Mr. Philip E. B. Jourdain in *Camera Obscura*, August, 1899, *et seq.*)

This phenomenon of stationary waves was worked at by other physicists, with the hope of experimentally demonstrating their existence, but it was not developed into a practical method of colour photography until 1891, when Professor G. Lippmann published the process that bears his name. This method consists of putting the sensitive plate into a case or trough so that its surface may be covered with metallic mercury, and allowing the exposure to take place through the glass. The mercury forms a mirror, and the light, after traversing the film, is reflected back, and the reflected rays meeting the direct incident rays produce the effects already described. The plate used must be so prepared that the particles of the sensitive salt are exceedingly fine, or they will interfere with the proper disposition of the deposit of metal, therefore suitable plates are very slow. The plates must be colour sensitised, so that reds and yellows may produce their effects as well as blues and violets. As the colours depend upon the relative position of the parts of the metal in the film, any circumstance that alters this changes the colours. By breathing on an unprotected film, the colours change immediately. Many precautions have to be taken to prevent the wrong colours from being produced. In spite of all the difficulties that must attend any process of this character, a few marvellously successful results have been obtained. In order to see the colours, it is necessary to arrange so that the illuminating light and the line of vision of the spectator bear definite angular relationships to the surface of the photograph, that the reflected light may enter the eye, and it is usual to cement

a prism of small angle to the front of the photograph to avoid the glare that would otherwise result from the simple reflection from the surface of the plate. It must be admitted that the method seems likely to remain an interesting photographic curiosity.

Professor Otto Wiener in 1895 published the results of his investigations of the colours produced by photographic methods (for a very full account of his paper by Mr. C. H. Bothamley see *Photography* for April and May, 1896), in which he describes a method of distinguishing between pigmentary colours and colours produced by interference. This shows that some of the old results owe their colours to pigmentary matter alone and some of them to a mixture of pigmentary colour and interference effect.

Three-colour methods. Other methods of "photography in natural colours," but which are still further removed from the crude idea conveyed by this phrase than those already referred to, depend upon the fact that, according to the generally accepted theory of colour vision, there are three kinds of nerves in the human eye, which, when excited, produce the sensations of redness, greenness, and blueness (or blue-violet) respectively, and that therefore, all the various colours in nature or producible by art can be exactly imitated by combining these three in suitable proportions, so that the three kinds of nerves may be excited to the same proportionate extent as by the colour imitated. It must not be supposed that such an imitation of a colour is a reproduction of it: spectroscopic analysis would at once reveal the error of such an assumption. The process of imitation depends upon taking advantage of the limited power of discrimination possessed by the human eye.

If, therefore, three photographs are taken through suitably coloured glasses so that each represents that part of the subject that affects one of the three kinds of nerves, and if the images of these three are superimposed upon the screen by the use of an optical lantern, or directly upon the retina, taking care that each photograph has transmitted through it the light so coloured that it will stimulate only the proper nerves, and excite them to just the right proportional intensity, then the colours of the original will be exactly imitated so far as the eye is concerned. Mr. F. E. Ives has elaborated this process and brought it to a highly successful issue in his photochromoscope system. The photochromoscope cameras take the three-colour records, each through its appropriate colour screen (or colour filter), and the photochromoscope itself, by means of mirrors and colour screens, serves to transmit to the eye the suitably coloured image from each record, superimposed to form the complete picture. The lantern photochromoscope superimposes the three coloured images upon a screen.

By a similar method it is possible to prepare three low gelatine reliefs representing the three colour sensations, to stain each with the complementary colour to the sensation that it represents, and by superimposing the three to get a transparency or lantern slide "in natural colours." This method of work has been successfully elaborated by Mr. Sanger Shepherd, whose firm has put upon the market every requisite for working it. The necessity for using the complementary colours instead of the colours themselves will be obvious on considering that in the photochromoscope system the three coloured lights are produced separately and added on the screen or on the retina; but when the coloured films are superimposed,

each robs the same light of some of its constituents. In the photochromoscope system the three colours added give white, but by superposition, the three colours used in the other method give black.

The three films may be mounted on paper if that is preferred. Or by preparing three half-tone printing blocks or other printing surfaces, three-colour prints may be made by ordinary typographic or lithographic printing processes by superimposing the three impressions. The difficulty of finding suitably coloured inks has been largely overcome, and in spite of the impossibility of ensuring that each colour shall be printed with its requisite intensity upon every impression, some very fine work has been done by these methods.

"Photography in natural colours" is almost beyond the intended limits of this volume. Those who wish to pursue the subject further will find a useful bibliography by Mr. T. Bolas in the *Journal of the Society of Arts* for 23rd April, 1897 (or *Photography Annual*, 1897, page 58), and supplementary notes by Mr. P. E. B. Jourdain in *Photography*, June 22nd, 1899.

CHAPTER XXXVIII.

PHOTOGRAPHIC MEASUREMENTS.

THE one function of a photographic negative or transparency is to control the light that passes through it; its one fundamental property, therefore, is its opacity. In a similar manner the one function of a print is to control the light reflected from it, and its fundamental property is its absorption of the light that falls upon it. In many scientific applications of photography, as well as in investigations of photographic procedure, it is necessary to measure the opacity of plates and the blackness of prints.

For almost all practical purposes it is most convenient to express these measurements as opacity logarithms or the equivalent, and the relationship that exists between the light transmitted (or transparency), opacity, and opacity logarithms, will be obvious from the following table—

Light transmitted.	Opacities.	Opacity logarithms
$\frac{1}{10}$	10	1
$\frac{1}{100}$	100	2
$\frac{1}{1000}$	1000	3

The superior usefulness of opacity logarithms was first pointed out by Messrs. Hurter and Driffield. They called these figures "densities," and showed that they were generally proportional to the amount of silver or other equivalent matter in the plate.

Methods of measuring opacity. In arranging apparatus for measuring opacity it must be borne in mind that when light passes through a photographic plate a not inconsiderable part of that which emerges is scattered, behaves, that is, as if the plate itself were a source of light,

instead of pursuing a path in line with the incident light. If, therefore, the transmitted light is measured at a distance from the plate, a considerable and uncertain proportion of this scattered light is not measured, and the plate appears to be more opaque than it really is. The author has estimated this scattered light in a number of cases, and the figures in the following table are the multipliers necessary to convert the higher apparent opacity logarithm into the opacity logarithm obtained when no light is lost, each figure being the average result of the measurement of a series of different densities :

An ordinary plate developed with ferrous oxalate	.71
Another ,, ,, ,, ,, ,,	.73
An old rapid plate developed with metol ..	.70
A new plate of medium rapidity	.82
An isochromatic plate of medium rapidity ..	.79
After intensification with mercury and ammonia	.73
Another ,, ,, ,,	.71
Another ,, ,, ,,	.75
Bleached with mercuric chloride	.245

There is no doubt that the character of the deposit has a large influence on the amount of scattered light. Bleaching the image makes an enormous difference, for the loss of light is then so great that, speaking approximately, the amount of the deposit would have to be increased to four times to reduce the total light transmitted to the apparent light transmitted when the scattered light is left out of consideration. Or in other words, the bleaching of the deposit, while it really permits more light to be transmitted, appears very much to reduce the light when the scattered light is excluded from the measurement.

It should be remarked that the numbers just given show in the majority of cases an unmistakable tendency

to increase as the density of the plate increases, varying, say, from .68 to .77 with opacity logarithms varying from .57 to 1.5. This is doubtless due to the posterior portion of a high density being unable to produce its full proportion of scattering, because of the scattering already produced by the anterior portion.

Although it may be possible to reduce this error in the use of apparatus that measures the light at a distance from the plate, it is preferable to avoid it altogether. This may be done by employing an "Abney screen," which consists of two small white squares in juxtaposition, one translucent and illuminated from behind and the other opaque and illuminated from the front. To prevent the front light from shining on the translucent square, a rod or plate is supported a little distance in front of it and casts its shadow upon it, after the manner of the shadow rod in a Rumford's photometer. When both squares are made equally bright by adjusting the illumination, the plate to be measured is brought behind the translucent square. The light in front must now be drawn back or the other light brought nearer to restore the equality of the illumination of the two squares. The movement of the light to make this adjustment gives the measure of the opacity of the plate.

An opacity meter. The author has designed a convenient apparatus for making such measurements. His "opacity meter" as made by Messrs. Baird and Tatlock is shown in fig. 75. It has the advantages of being only two feet long and of requiring only one light, preferably an incandescent gas light, variations in the intensity of which do not affect the readings. This shines directly upon one side of the Abney screen, and by means of three mirrors and

a velvet-lined tube with diaphragms, a beam is brought round to the other side. The screen is supported on the movable carrier, to which the plate to be measured is held by clips. The scale over which the carrier moves gives at once the estimation required in opacity logarithms,

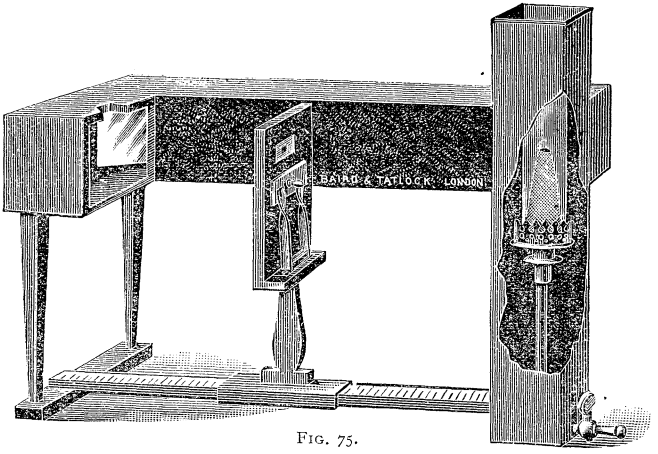

FIG. 75.

or any other terms (transparency, opacity, etc.) that may be marked upon it. The Abney screen is of a more permanent character than those employed by Sir William Abney, being made with opal glass instead of white paper. For opacity logarithms above 2.0, the reflected beam is reduced by a diaphragm.

An opacity balance. The author's " opacity balance " does not give absolute measurements as the meter does, but serves to compare opacities. The opacities can be estimated on any convenient empirical scale, such as a circular graduated screen. A diagrammatic section of the apparatus is shown in fig. 76.

COMPARING OPACITIES.

One source of light is used, generally a Welsbach burner, and two mirrors reflect pencils from this, as shown by the dotted lines, through apertures in a velvet-lined dark box to a prism of small angle (one pencil falling on each face of the prism) which reflects the pencils and renders them parallel. The pencils of light then fall upon the object glass of the telescope, which gives sharp images of the apertures in the field of the eyepiece. For low densities the images are not viewed directly, but are received on a white surface which is looked at through an eyepiece set at an angle by the aid of a small sloping

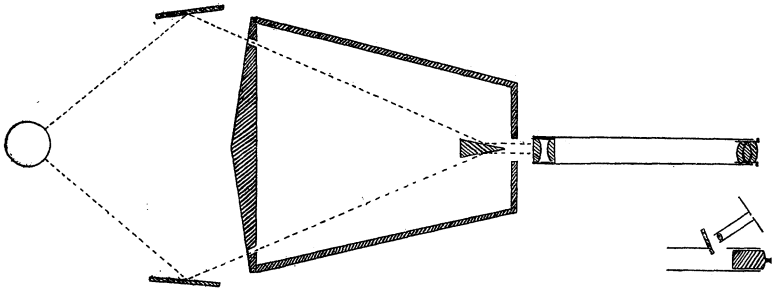

FIG. 76.

mirror, as shown in the lower drawing. The two apertures in the box are provided with adjustable slits, and diaphragms may be used to reduce the effective length of the slits if that is desired. The plates that have to be compared are fixed, one against each slit.

One advantage of this apparatus is that the two light patches have sharp edges that are brought exactly into contact, with no penumbra as when an Abney screen is used, and therefore there is no gain in using a portion of the photographic plate under examination greater than a millimetre in width, and this may certainly be halved

without inconvenience. The strip may be shortened to a square if that is preferred, and there would not be any special difficulty in measuring a patch only one-hundredth of an inch square. This type of instrument is especially suitable when experimental results have to be compared with a density scale on the same plate, because as the former is wanted in terms of the latter there is no gain in making absolute measurements of the opacities. A density scale is a series of small patches each of a known exposure, developed with the experimental exposures for the purpose of getting their equivalents in light intensities or exposure periods. In this apparatus the scattered light is lost, but this does not matter at all in such work as the apparatus is designed for, because the parts compared on any plate are equally affected.

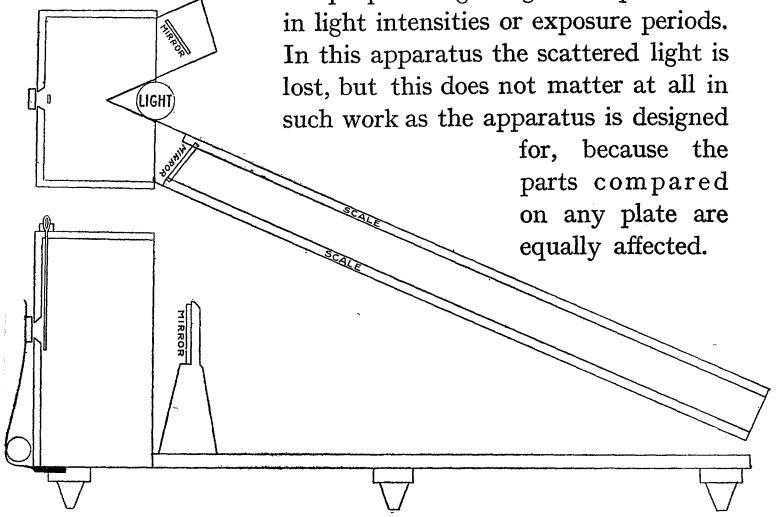

FIG. 77.

A print measurer. The kind of apparatus suitable for measuring the light reflected from prints is illustrated in fig. 77, which shows one designed and used by the author, in plan and elevation. The source of light is as before, a

Welsbach burner, and two mirrors, one on each side of it, give two beams of light which pass through two openings into a velvet-lined box and illuminate the patch of paper to be tested and a comparison patch. A shadow-rod is used as in Rumford's method of photometry, so that each beam illuminates only one of the patches. The illumination of the lighter patch is reduced by drawing the mirror back until the two are of equal brightness. Thus the apparatus does not measure the absolute proportion of light reflected, but the proportion is compared with that reflected from the white paper or whatever may be taken as the standard. For this purpose clean Rives paper may be used. A small blackened card slips into place at the back of the chamber, and in this card an oblong hole is cut, one half of which is covered with the standard selected, and the other half is left open that the print to be tested may be brought up against it.

There are two springs working together to hold the print in position, but they can be readily separated and turned on one side to gain access to the aperture in the chamber. If necessary, the springs can be entirely removed, so that the apparatus offers no restriction whatever to the size of the print that can be brought into position for testing. The brass shield that prevents the light from shining directly upon the surfaces being compared is separated from the woodwork by two or three thicknesses of asbestos cloth and felt, so that its heating does no damage. The front of the dark chamber is easily removed. The movable mirror can be turned on a vertical axis, and this is necessary so that the reflected beam may come in the same direction whatever the position of the mirror on the baseboard. This adjustment might at first sight appear

troublesome, but in reality it is not so, because the character of the edge of the shadow of the rod (the penumbra) is a safe and ready guide to the correct position of the mirror. Moreover, the proper angle of the mirror is marked for a few positions so that it can easily be checked. There is a small mark on each of the mirror carriers, and when at the proper angle the reflection of the rod that supports the mantle of the burner (that is, the centre of the light) is seen vertically below these marks when an eye is brought to the centre of the hole in the back wall of the chamber. The fixed mirror and the shadow rod are both adjustable through a small distance.

CHAPTER XXXIX.

THE MORE EXACT TESTING OF SENSITIVE PLATES, ETC.

THE estimation of the general sensitiveness of plates has already been considered. But there are several other matters connected with them about which it is often desirable to gain some information. The first of these is their sensitiveness to various colours, and the effects of coloured screens when used with them.

The Abney colour sensitometer is one of the most important instruments in this connection. It consists of a series of three or four small squares of coloured and one of colourless glass arranged so that a plate can be conveniently exposed beneath them. But the visual intensity of light from some source that is constant as to character, such as a gas flame, that is transmitted by all the glasses, has to be made uniform. This is accomplished by backing up every square, except that which appears the darkest, with a piece of exposed and developed celluloid film of suitable density. As these coloured squares are all of equal darkness to the eye, any combination of plate and screen that gives perfectly orthochromatic results will give an equal effect through each of them when illuminated with the light to which the sensitometer was adjusted.

With regard to the most suitable colours, Sir William Abney says that the best red appears to be what is called stained red, or a glass flashed on one side orange and the other ruby. For the blue glass, signal green with a film stained with a blue dye, or signal green and cobalt blue glass together. For green, a combination of signal

green and chromium green is to be recommended. For yellow, a plate may be coated with gelatine dyed with brilliant yellow. The final square should be of plain colourless glass. Sometimes a square coloured with methyl-violet in gelatine is useful in addition to the above.

A medium exposure should be given with such a sensitometer, because, as the author has shown, the steepness of gradation generally increases, other things being equal, as the refrangibility diminishes. That is, by increasing the exposure the density of the part exposed beneath the red will increase at a greater rate than the part beneath the green, and the latter at a greater rate than the part under the blue and uncoloured squares.

The Chapman Jones plate tester was devised by the author in 1900, and issued commercially by Messrs. Sanger Shepherd and Co. in the following year. The idea was to provide a rapid and simple method of testing sensitive plates that should give all the information concerning them that is generally needed, and provide without further work, except the measurement of the plate resulting from the test, for exact quantitative estimations so far as these are possible. It is only necessary to expose and develop one quarter-plate in the apparatus to see by a mere inspection of the result, (1) general sensitiveness, (2) general character and range of gradation and therefore range of exposure without obtaining notable under or over-exposure, (3) behaviour with regard to halation, (4) the character of the colour sensitiveness of the plate, and (5) the most suitable kind of dark room light to use for it. By spending a few moments a quantitative expression for its colour sensitiveness can be found. Examination with a pocket lens shows the character of the grain. By measurement

of the plate, as in an opacity meter, the gradation or density curve can be drawn, and a more exact estimation of colour sensitiveness made. By other exposures, the adjustment of colour screens or light filters to the plate, and the effect of backings, can be tested, and it is a convenient apparatus also for ascertaining the effect of any treatment whatever of the plate, such as variations in development, exposure, etc.

The use of a simple graduated screen (numbered 1 to 25, fig. 78) will give many of the results wanted, but it tells nothing about colour sensitiveness. The Abney colour sensitometer is a simple instrument for this purpose, and

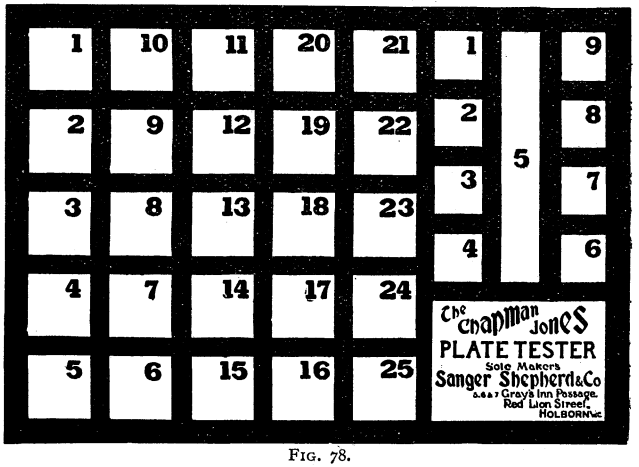

FIG. 78.

therefore there is added to the graduated screen patches of four colours, red, yellow, green, and blue (1, 2, 3, and 4), and a strip of uncoloured space (5), all adjusted to approximately equal luminosity. The combination of these two is worth a great deal more than just the two

tests added together, although it requires only one exposure for both, because the graduated screen gives a quantitative character to the indications of the other. Using an Abney colour sensitometer alone, it is possible to underexpose and get no result under a yellow tint, although the plate has considerable sensitiveness to yellow light; or with over exposure, the effects under the colours may approximate to each other although the sensitiveness to the various colours is really very different indeed. By comparing the densities produced under the different colours with the graduated series, their proportional values are indicated at once. In under exposure a maximum limit to the special colour sensitiveness can be set, and in over exposure the large range of possible interpretations, and therefore perhaps their uselessness, is obvious at a glance.

But this combination is not sufficient. It is not possible to locate exactly the want of sensitiveness, or indeed often to discover it, by the use of mixed colours. Therefore another set of colour patches is added (6, 7, 8, 9), dividing up the spectrum into distinct portions, and just those portions into which it is practically divided by the plates at present available. "Ordinary" plates are practically sensitive to the ultra-violet, violet, blue, and green up to about the Fraunhofer line *b* or E, so the first patch is a blue that transmits this light, cutting off the rest of the green, the yellow, and the red. Isochromatic plates have an added range of sensitiveness extending from about E to D. The next patch is therefore a green that transmits this light. With the usual range of exposures an "ordinary" plate will show an effect under the blue patch only or a very slight effect under the green,

while isochromatic plates give marked effects under both the blue and green patches. Then follows a red patch that transmits light from D upwards, which distinguishes red sensitiveness. And a further red patch distinguishes between the red from D to C, and that less refrangible than C by transmitting only the light less refrangible than C. This division of the spectrum is shown in fig. 79.

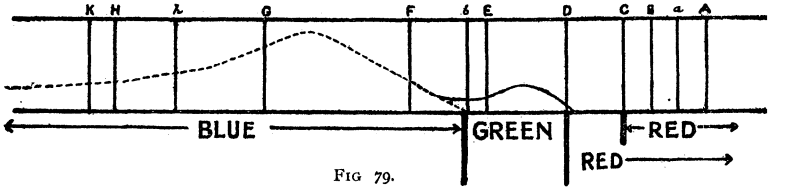

FIG 79.

This series of definite colours, being on the same screen with the graduated tints, can also be treated quantitatively by comparing the densities given under each with the graduated tints, and there is exactly the same safeguard against over or under exposure as explained in connection with the Abney colour sensitometer. That portion of the screen that bears the name has also on it a piece of negative from a plaster cast, and gives a general idea of the rendering of half-tone.

The exposure behind this screen can be made by any light, but a standard candle is the source of illumination selected as the most convenient. The complete apparatus is shown in fig. 80. The candle is surrounded on three sides by a black screen to keep draughts from the flame; and the frame that carries the compound screen with the plate behind it is attached to the stand for the exposure at a distance of one foot.

In order to compare one density with another on

the trial plate with any approach to accuracy, it is necessary to isolate the two patches that are under observation. The thick black paper supplied to protect sensitive films on spools in an excellent material for this purpose. Convenient sized pieces are used, each with a hole about three-sixteenths of an inch in diameter. One is placed

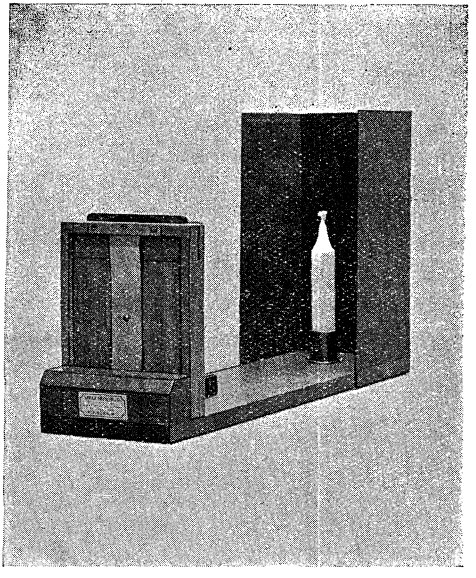

FIG. 80.

over the square to be valued, and another passed along the graduated series until a match is made. A piece of white card or paper forms a convenient background, but it is important that it should be evenly illuminated.

In determining the proportional colour sensitiveness,

although extremes of under and over exposure must be avoided, there is a very considerable range of exposure that will give satisfactory results, and it makes no difference what the exposure is so long as it falls within these limits. Nor does the duration of development or the density of the plate as a whole affect the result so long as there is sufficient density to enable one to distinguish between the adjacent squares of the graduated series, because whatever affects the density of the deposit under the colour patch also affects the graduated series with which it is compared.

The table given below illustrates the methods of determining the comparative sensitiveness of various plates to different colours. Ten plates are dealt with, numbers 3, 4, 5, 6, and 7 are from the same box, and numbers 4, 5, 6, and 7 were developed together. Numbers 8, 9, and 10 are from the same box, and numbers 8 and 9 are parts of the same plate and developed together. The simultaneous development is not necessary, and it was done for other purposes than the results here given. All the exposures were to candlelight. Obviously there is no absolute significance in the exposures required for the different colours, as if the light used had been more blue, like daylight, the porportional values for blue would have gone up, that is, the figures indicating the exposures necessary would have been less. But such a change would affect the results of all the plates alike—if the exposure required for the blue were halved in one case it would be halved in all, so that the value of one plate as compared with another would remain unaffected. In the series 3 to 7 the effect of varying exposure is well shown. The least exposure (4) shows an effect only under the blue,

the next (3) shows a slight effect under the green, but its value is uncertain, because the 12 square of the graduated series is just on the limit of the developable effect. Number 5 gives the green dense enough to measure it, number 6 gives the red, and the last (7) gives the red well, but the blue is getting towards the over exposure portion of the graduated tints.

Plates.		General sensitiveness to candle-light. Proportional figures.			Sensitiveness to different colours. The number of the graduated tint that matches the effect produced through each colour.				Previous section expressed as *proportional exposures* necessary for uniform results on *each plate*.				Previous sections multiplied by the exposure required for the individual plates, giving *proportional exposures* required, *comparable throughout*.			
		Exposures.	Effects of exposures.	Exposures for same effect.	Blue.	Green.	Red (1).	Red (2).	Blue.	Green.	Red (1).	Red (2).	Blue.	Green.	Red (1).	Red (2).
A.	1	4	6	$\frac{3}{32}$	8	14	7	12	1'5	12	1	6	1	8	'7	4
B.	2	4	6	$\frac{3}{32}$	9	11	15	0	2	4	16	—	1'3	2'7	11	—
C.	3	2	2	1	7	12 ?	0	0	1	—	—	—	—	—	—	—
	4	1	1	1	7	0	0	0	—	—	—	—	—	—	—	—
	5	4	4	1	7	12'5	0	0	1	7	—	—	1	7	—	—
	6	16	16	1	7	12	17	0	1	6	32	—	1	6	32	—
	7	32?	—	—	7 ?	12	17	0	1	6	32	—	1	6	32	—
D.	8	16	4	4	8	11	13	0	1'5	4	8	—	6	16	32	—
	9	64	16	4	8	11	13	17	1'5	4	8	32	6	16	32	128
	10	512	128	4	8 to 11	8 to 11	8 to 11	17	—	—	—	32	—	—	—	—

Where the number of the graduated tint matching the effect produced through each colour is marked as O, it indicates that the exposure has been insufficient to give enough range to produce an effect under that colour. In number 10 considerable over exposure is shown, for the densities under the blue, green, and first red may be equal to anything in the graduated series

from 8 to 11; but the fact that the deposits under the colours are, perhaps, levelled up by over exposure and not by an equal colour sensitiveness of the plate, is plainly obvious by the fact that so much difference in exposure produced no obvious difference in density in the graduated tints mentioned—that is, no difference detectable by the simple method of comparison above described. Differences can be found and measured by more exact methods, but all the results given in the table were obtained by simple comparison of the densities, using nothing more than pieces of black paper with a hole in each to isolate the parts to be compared.

The last section of the table shows a kind of result that is often useful. The plates C are four times as sensitive to candlelight as the plates D. But to pure red light (less refrangible than Fraunhofer's D) these plates are equally sensitive, the additional sensitiveness of C being wholly in the blue and green. Where pure red has to be dealt with, therefore, the slower plates D will be comparable to the more rapid plates C used in conjunction with a coloured screen to reduce the effects of the blue and green. For spectrum work, for example, if the red is wanted and must therefore be exposed for, the extra sensitiveness of the plates C is not only unnecessary but positively troublesome. Using both without a coloured screen, the plates D will require no longer exposure, and will give a more even and desirable result. But if red sensitiveness is wanted, the enormous advantage of plate number 1 (A) may be noticed, it is more than forty times as sensitive to red as the plates C and D, but is at the same time markedly deficient in green sensitiveness. There is no need to dwell on other results shown by the table, it is given only

to illustrate the possibilities of this method of work, without supplementing it with any other instrumental means.

Testing coloured screens. To test the suitability of coloured screens for use with any specific plate for ordinary work, the desire being to render correctly various colours as seen by daylight, the plate should be exposed in a camera behind the compound screen of the apparatus. Almost any dark slide will accommodate the two together. The lens and the coloured screen to be tested are attached to the camera as usual, and the exposure is made on a white surface, such as a piece of card or sheet of cartridge paper, arranged as if for illuminating a negative for enlargement. Any exposure within a considerable range will serve equally well, and it will be found convenient, instead of timing the exposure, to estimate it in units of light (tints) as determined by one or other of the exposure meters now so generally used. The exposure meter should be placed by the side of the white surface so that the light falls equally on it and on the sensitive paper of the meter. Watkins's "indoor meter" will be found particularly serviceable for this purpose.

If the screen is perfectly adapted to the plate, the four inner colours, blue, green, yellow, and red, and the grey strip, will give patches on the plate of practically equal density. If the plate is only slightly sensitive to red, or the screen is not intended to correct for this colour, then the blue, green, and yellow squares, and the grey strip should approximate to equality, and the screen that gives the most equal results will be the best. The cause of any inequality can be conveniently traced by reference to the effects produced under the four outer or pure colours, an inspection of which will show that part of the spectrum

to the rendering of which the error is due. In order to make sure that the exposure has been such that a notable variation would have caused an appreciable difference in the densities produced under the coloured squares, they should be roughly matched on the graduated series of tints, and if the equivalent density here is markedly different from the number on either side of it, and is not too low down on the scale to give a sufficient range, the exposure has been satisfactory. The remarks made on testing the colour sensitiveness of plates are, in general, also applicable in this case.

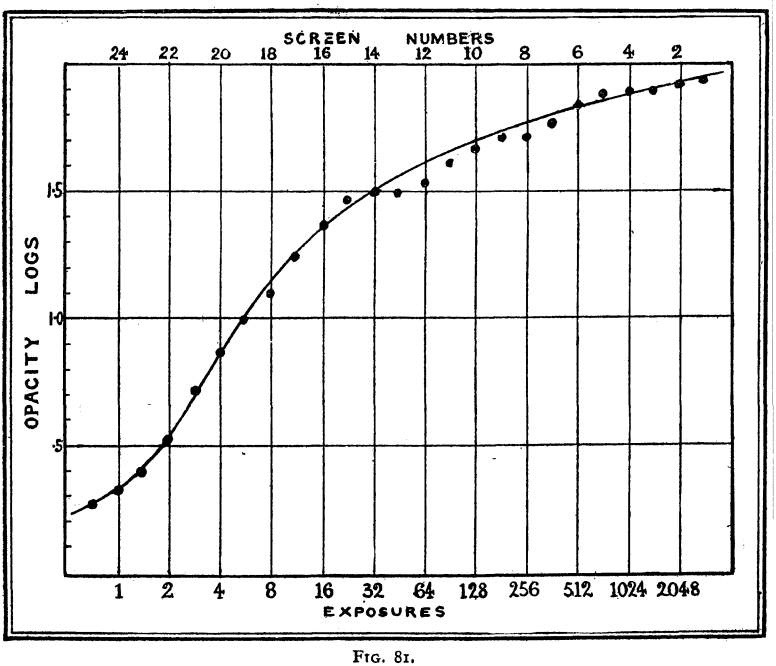

FIG. 81.

Density curve. Fig. 81 shows a density curve drawn from measurement in the opacity meter of a plate exposed in the plate tester. As will be seen the range of exposures is very great, and in the lower screen numbers there is the effect of much over exposure. The slight irregularity of the results in the higher densities is due to error in the screen itself. It will not of course be expected by the use of so simple an apparatus, and one that gives results so rapidly, to obtain data with the same exactness as if more elaborate means had been employed.

ENGLISH WEIGHTS AND MEASURES.

MEASURES OF BULK.

60	minims	=	1	fluid dram.
8	fluid drams	=	1	fluid ounce.
20	fluid ounces	=	1	pint.
2	pints	=	1	quart.
4	quarts	=	1	gallon.
1	minim	=	.91	grain of water.
1	fluid ounce	=	437.5	grains of water.
1	pint	=	1.25	lbs. of water.
1	gallon	=	10	lbs. of water.

MEASURES OF WEIGHT.

Avoirdupois Weight.

437½	grains	=	1	ounce.
7000	„	=	16 ounces	= 1 pound.

Troy Weight.

24	grains	=	1	dwt.
480	„	=	20 dwts.	= 1 ounce.
5760	„	=	12 ounces	= 1 pound.

COMPARISON OF THE ENGLISH WITH THE METRICAL SYSTEM.

MEASURES OF LENGTH.

1	millimetre	=	.03937	inch.
1	metre	=	39.37	inches or 3.28 feet.
1	inch	=	25.4	millimetres.

MEASURES OF BULK.

1	cubic centimetre (c.c.)	=	.0352	fluid ounce.
1	litre	=	35.2	fluid ounces or 1.76 pints.
1	fluid ounce	=	28.4	cubic centimetres.

MEASURES OF WEIGHT.

1	gram	=	15.43	grains.
1	grain	=	.0648	gram.
1	ounce avoir.	=	28.4	grams.
1	„ troy	=	31.1	„

COMPARISON OF FAHRENHEIT AND CENTIGRADE THERMOMETERS.

Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.	Cent.	Fahr.
100	212	75	167	50	122	25	77
99	210.2	74	165.2	49	120.2	24	75.2
98	208.4	73	163.4	48	118.4	23	73.4
97	206.6	72	161.6	47	116.6	22	71.6
96	204.8	71	159.8	46	114.8	21	69.8
95	203	70	158	45	113	20	68
94	201.2	69	156.2	44	111.2	19	66.2
93	199.4	68	154.4	43	109.4	18	64.4
92	197.6	67	152.6	42	107.6	17	62.6
91	195.8	66	150.8	41	105.8	16	60.8
90	194	65	149	40	104	15	59
89	192.2	64	147.2	39	102.2	14	57.2
88	190.4	63	145.4	38	100.4	13	55.4
87	188.6	62	143.6	37	98.6	12	53.6
86	186.8	61	141.8	36	96.8	11	51.8
85	185	60	140	35	95	10	50
84	183.2	59	138.2	34	93.2	9	48.2
83	181.4	58	136.4	33	91.4	8	46.4
82	179.6	57	134.6	32	89.6	7	44.6
81	177.8	56	132.8	31	87.8	6	42.8
80	176	55	131	30	86	5	41
79	174.2	54	129.2	29	84.2	4	39.2
78	172.4	53	127.4	28	82.4	3	37.4
77	170.6	52	125.6	27	80·6	2	35.6
76	168.8	51	123.8	26	78.8	1	33.8
						0	32

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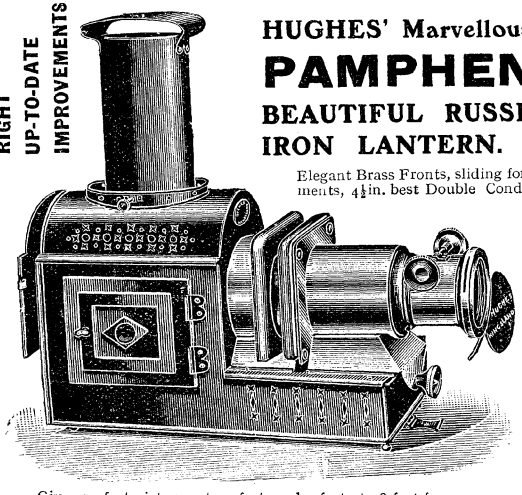

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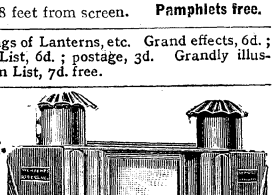

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