

VOL. 79*.

79* ART OF PHOTOGRAPHY ;

INSTRUCTIONS IN THE
ART OF PRODUCING PHOTOGRAPHIC
PICTURES

IN ANY COLOR, AND ON ANY MATERIAL.

BY
DR. G. C. HERMANN HALLEUR.

Price One Shilling.

LONDON: JOHN WEALE.

THE
ART OF PHOTOGRAPHY.

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INSTRUCTIONS IN

THE ART OF PRODUCING PHOTOGRAPHIC PICTURES
IN ANY COLOR, AND ON ANY MATERIAL,

FOR THE USE OF BEGINNERS;

AND ALSO OF PERSONS WHO HAVE ALREADY ATTAINED SOME PROFICIENCY
IN THE ART;

AND OF ENGRAVERS ON COPPER, STONE, WOOD, ETC.

BY DR. G. C. HERMANN HALLEUR,

Late Director of the Royal Technical School at Bochum.

WITH PRACTICAL HINTS

ON THE LOCALS BEST SUITED FOR PHOTOGRAPHIC OPERATIONS, AND ON THE
PROPER POSTURE, ATTITUDE, AND DRESS, FOR PORTRAITURE.

BY F. SCHUBERT, PAINTER.

AND AN APPENDIX

CONTAINING BRIEF EXPLANATIONS OF SOME OF THE CHEMICAL TERMS WHICH
OCCASIONALLY OCCUR IN THE WORK.

TRANSLATED FROM THE GERMAN

BY G. L. STRAUSS, PH. DR.

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PREFACE.

I HAVE been engaged for several years in experiments and researches on the chemical alterations and modifications produced in various bodies by the action of light. The object which I had more immediately in view was to ascertain whether other metallic compounds, besides those of silver, might be used in photography.

In addition to this, I had also proposed to myself to try whether the purely conjectural and random way of mixing together the salts used in photographic processes, might not be reduced to something like a law of definite mixing proportions. It affords me sincere gratification to be able to state that I have attained both objects.

The results of the experiments which I made to ascertain whether other metals besides silver might not be employed in photography, fully established the fact that all metallic compounds suffer alteration under the influence of light. In many of them this alteration takes place in a very short time, as in the case of iron for instance; others require a more protracted exposure to the action of the light. By combinations of different metallic salts the most interesting variations may be produced. Next to silver, the salts of iron, and the compounds of chromium appear to me the most important. Thus, for instance, the blue or green images produced with a salt of iron and ferricyanide of potassium (commonly termed *red prussiate of potash* or *potassa*), look remarkably fine, and are well adapted for light-screens and lithophanies; to protect them effectually from injury, they need simply be enclosed between two glass-plates set in a frame. The alteration suffered by many metallic salts under the influence

of light is in most cases not immediately visible, but it speedily makes its appearance upon the application of the proper re-agent.

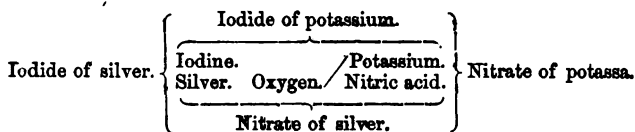
For the benefit of those who may wish to engage in photographic experiments, but do not possess the requisite chemical knowledge, I have added to the present work a Table (III), giving the deportment of the metallic salts with the most important re-agents. Guided by the information contained in that table, it will always be easy to select the proper reagent, and in many cases also to obtain divers variations in the tints of the pictures. This table will serve, moreover, to enable persons unskilled in chemistry to test the substances, which they are about to use, and thus to make sure of their identity and purity.

In reference to the proper mixing proportions of the substances employed, I think I have found a definite rule in the laws of equivalents or combining proportions; I have therefore added Tables I and II. An example will show the way in which these tables are to be used.

Suppose you want to prepare iodised paper (silver iodide paper) for the taking of negative images, and you wish to know in what proportions you ought to mix the iodide of potassium and the nitrate of silver, to obtain a highly sensitive preparation; you need simply look out in the first column of Table II., iodide of potassium, and there you will find in the third column, the number 166, which is the combining or mixing weight of the iodide; then look out nitrate of silver, where you will find the number 170, the combining weight of the nitrate of silver. You will accordingly have to mix the two salts in the respective proportions of 166 of the one (the iodide), and 170 of the other (the nitrate). It does not matter what denomination of weight you use, whether grains, or grammes, or any other kind; but of course the weights must correspond for the several substances. Thus, for instance, if you have weighed off 166 grains of the iodide of potassium, you must weigh off, on the other hand, 170 grains of the nitrate of silver. You may also use a less number of grains or grammes, &c., the one-half, or the one-third, for instance, of the number given in the table; but you must keep

rigorously to the proportions indicated. Thus, for instance, to 83 of iodide of potassium you would have to use 85 of nitrate of silver. Now, supposing you have weighed off 166 grains of the iodide, and 170 grains of the nitrate, dissolve the two salts separately, each in an equal volume of water, viz., 8 ounces; then imbue the paper which you want to iodise with the two solutions in the usual way (see Talbotype).

When the two solutions come in contact on the paper, there ensues a double decomposition as follows :—



Iodide of silver has accordingly been formed on the paper; but, besides this, also nitrate of potassa or nitre, which must be removed from it. This is effected most readily by laying the prepared side of the paper on water, in which the nitre will speedily dissolve, and, from its greater specific gravity, subside to the bottom, whilst the iodide of silver, being insoluble in water, will firmly adhere to the paper. The paper so prepared is very insensible, and may, if carefully kept, be preserved a long time (for years even), without losing its properties. When you want to make use of it for photographic purposes, you must imbue it once more with the silver solution, or with one of equal strength, but in which a portion of the water is replaced by acetic acid. Your paper will thus receive the requisite excess of silver, and be rendered thereby highly sensitive.

If you wish to add bromine to your preparation, you need simply calculate from the table the amount of bromide of potassium to be added, and take a corresponding weight of iodide of potassium less. Thus, for instance, if you wish to add one-tenth of bromine, you will have to take 11.92 grains of bromide of potassium, and, to make room for this, 16.6 grains less of iodide of potassium.

These examples will suffice, I hope, to point out the proper way of proceeding in all other cases.

The substances enumerated in the table, have all been used in my own experiments. I have added the chemical formulæ, because I know from personal experience that chemists and druggists will often serve you with a very different article from what you want. To adduce an example, I got at a druggist's, instead of *iodide of ammonium* (NH_4I), iodate of ammonia ($\text{NH}_4\text{O}, \text{IO}_5$)—a preparation altogether useless for the purpose for which I intended it, viz., for the preparation of iodised collodion. This is one of the most fertile sources of failure in photographic experiments. Now, if you simply demand the article by name, mistakes of the kind may occur without any great blame being imputable on that account to the druggist; but if you add the chemical formula of the substance demanded, the substitution of another article would be quite inexcusable.

I am now on the point of completing another work on the art and science of photography, which embraces all my experiments and researches in the domain of that most interesting of modern inventions. This work which I hope will appear next spring, under the title “Manual of Photogenetic Chemistry and Photography;” will contain plain instructions on the easiest and safest way of preparing all the materials required in photography.

If this little work should contribute to impart a little more certainty and regularity into the various manipulations of the photographic art, I shall deem myself amply rewarded for my labors in that interesting branch of the natural sciences.

THE AUTHOR.

BERLIN, May, 1853.

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THE

ART OF PHOTOGRAPHY.

INTRODUCTION.

LIGHT,—that essential condition to the existence of the whole vegetable kingdom, with a few rare exceptions, and which, in so many classes of animals, exercises also so great and beneficent an influence over animal life,—is likewise one of the most energetic causes of chemical action; and there are many chemical combinations and decompositions which can only take place under the influence of light.

Photography presents us, in this respect, with a number of the most interesting phenomena, which even now have acquired considerable practical value, but promise still greater and more important results for the future. The discoveries made in this new field of science, have naturally called the attention of chemists to the problem of the true nature and essence of light, and have engaged them to make researches with a view to a possible solution of that problem. As the domains of optics and of chemistry may be said to touch and combine in photography, every successful attempt in that direction may reasonably be expected to lead also to some new progress or discovery in optics, which, on its part again, may serve to bring the philosopher nearer the elucidation of the phenomena of light.

The action which light exercises upon fused chloride of silver (hornsilver), viz., that it imparts a black tint to the originally white salt, was known as early as the sixteenth century (to the alchymists); still it was only in the eighteenth century that this phenomenon was more closely examined. It would appear, also, that about the same

period the influence of light upon the crystallisation of various salts was first observed. Petit published his observations on this latter subject in 1722, and Chaptat and Diez  their about sixty-six years after : the former in 1788, the latter in 1789.

Scheele studied the phenomenon of the nigrescence of chloride of silver under the influence of light ; he occupied himself more particularly with those alterations which the chloride of silver suffers under the influence of the prismatic rays. In 1777, he published the results of his observations. He had discovered that chloride of silver, minutely divided and spread on paper, turned black much sooner under the influence of the *violet* ray than under that of any of the other colors. Sennebier found, in 1790, that fifteen minutes' exposure to the *violet* ray sufficed to impart to chloride of silver the same black tint which it was seen to acquire in the *red* ray only after twenty minutes' exposure. In 1801, Ritter discovered that the chemical action of light extends beyond the colored rays of the spectrum, manifesting itself still through invisible rays. About the same time, Wollaston was engaged in similar researches. The results of these investigations led Wedgewood to further experiments ; and to him unquestionably is due the honor of having been the first photographer ; the allegation that the Indian jugglers had known the art for centuries, and had thereby maintained their influence, being more than doubtful.

We find in the "Journal of the Royal Institution," of 1803, a paper by Wedgewood, with observations by Sir Humphrey Davy. The paper is entitled "An Account of a Method of Copying Paintings upon Glass, and of making Profiles by the Agency of Light upon Nitrate of Silver."

White paper, or white leather, saturated with a solution of nitrate of silver, served as the impressionable surface. Wedgewood says in his article, "The alteration of the colors commences the more speedily in proportion to the degree of intensity of the light. In bright sunshine, from two to three minutes suffice to produce the full effect, whereas, in the shade, several hours are required to arrive at the same end. Through differently-colored glasses the light acts with different degrees of intensity. When the shadow of a figure is thrown upon the prepared surface, the parts covered by the shadow remain white, whilst the other parts speedily turn black. To copy paintings on glass, the

negative images should be taken on leather, because the action is more rapid with this material than if paper were used.

“When the color is once fixed on paper or leather, it proves fast to a degree; water, and even soap-water, failing to remove it. Besides the method of copying just given, there are several others; it will be useful to make copies of all such objects as are partly transparent and partly opaque. The woody fibres of the leaves of plants, and the wings of insects, may be very accurately copied in this manner; all that is needed to this end is, to transmit the direct light through the object to be portrayed, and to receive the shadow on prepared paper, or prepared leather.” To this statement, Davy adds: “It has been observed that the image of the camera obscura is too feeble to make an impression upon the nitrate of silver within a reasonable space of time. To copy these images, was Wedgwood’s chief object. I followed up his experiments, and found that the images of small objects, produced by the solar microscope, may be copied without difficulty on prepared paper. A comparison of the effects produced by the action of light upon chloride of silver, with those produced on nitrate of silver, fully and clearly showed that the chloride is the more sensitive compound of the two. All that is required now to render these experiments as useful as they are interesting is, to find a way of preventing the subsequent coloring of the white parts upon exposure to daylight.”

It would appear that no further experiments were made for several years. Wedgwood and Davy’s failure was owing solely to the circumstance that at that time those agents were unknown which are now used with such success to fix the images. Hyposulphite of soda, its properties and its deportment with salts of silver, were only discovered in 1819, by Sir John Herschel; iodine also was unknown in 1812; and without these agents photography could not advance beyond the point where Wedgwood and Davy had left it.

In the year 1814, Niepce directed his attention to the chemical effects of light; his object was, to fix the images of the camera-obscura. He discovered the peculiar property of the solar rays to alter the solubility of various resinous substances. He spread a thin layer of asphalt on a glass or metal-plate, and placed this in the camera-obscura; after waiting from five to six hours, he found on the plate a

latent image, which became visible upon treating the surface of the plate with a solvent. The development of the invisible image was afterwards made by Mr. Fox Talbot the subject of an English patent for a new invention, although the process had been known and applied twenty years before.

In the year 1827, Niepce made photographic experiments at Kew. His friends preserve still some of the pictures obtained by him in these experiments. These pictures bear some resemblance to the Daguerreotypes, although they are greatly inferior to them. Daguerre commenced his experiments in the year 1824, and employed, as Wedgewood had done, both nitrate and chloride of silver. In 1826, Daguerre and Niepce became acquainted, and from that time forward, they pursued their experiments jointly. In 1829, Niepce communicated his method to Daguerre in a letter, in which he says :

“ The discovery which I have made, and to which I have given the name *Heliography*, consists in this, that I produce instantaneously, by the action of light, the image of the camera-obscura, in all gradations from white to black.” He then goes on to describe his method, and continues : “ The plate so prepared can be exposed to the action of the light in the camera-obscura ; however, when it is withdrawn from the camera, after sufficient exposure, no alteration is perceptible in it ; the lines of the image remain still invisible. The next operation is to develop the latent image, which is effected by means of a solvent.”

In 1829, Daguerre and Niepce employed, for the first time, iodine ‘to blacken the plate which contained the heliographic impression.’ However, Daguerre would seem to have observed some peculiarities in the action of light upon silver plates treated in this manner, for in one of his letters to Daguerre, Niepce speaks of a decoction of cassweed (*Phlaspi arvense*), of phosphor fumes (phosphorous acid), and more especially of sulphur, as acting on silver in the same manner as iodine ; and he observes also, that heat produces the same effect by the oxidation of the metal, and maintains that it is from this cause (the oxidation) that proceeds in all these cases the extraordinary sensitiveness to light.

Niepce died in 1833, and in January 1839, Daguerre announced his great invention. In the month of July following, the Chamber of Deputies voted an annual pension of 6000 francs to Daguerre, and one

of 4000 francs to Isidore Niepce, the son of the late photographer (as purchase-money for the secret of the daguerreotype), for the honor of "having presented the scientific and artistic world with one of the most surprising discoveries that adorns their country." France has adopted this discovery, and is proud to present it—"as a gift to the whole world." These are Arago's words, and Duchâtel adds: "This discovery cannot be secured by patents; when it is made known, everybody may profit by it." Although these expressions were undoubtedly meant most sincerely, yet, notwithstanding, we find Daguerre soon after in the English patent market; and on the 15th July, 1839, Mr. Miles Berry obtained—"for a foreigner residing in France"—a patent for this invention, which had been so munificently rewarded in France, and had been declared in that country not to admit of being secured by patent.

On the 31st January, 1839, Fox Talbot published "Some remarks on the art of Photographic Painting." On the 21st February of the same year, he gave the methods of preparing the paper used in his photographic processes. Among these methods we find also the one to cover the paper with a thin layer of chloride of silver, made sensitive for exposure in the camera-obscura, by repeated washing. Here we see the same substances employed which Davy recommended Wedgewood to use in his experiments, and with nearly the same manipulations which he himself employed. Mr. Talbot recommended to fix the images obtained in a brine bath (solution of chloride of sodium, or common salt), which process, however, succeeded only very indifferently, since the light parts turned bluish the moment they were exposed to daylight.

The next communication of importance was that of Sir John Herschel to the Royal Society, on the 14th March, 1839, followed on the 20th February, 1840, by a paper on "the chemical effects of light in the solar spectrum." In the former of these two papers, Herschel recommended the use of hyposulphite of soda as a fixing agent, and in the latter he recommended to use the solution of the hyposulphite hot in the case of iodide of silver, as this latter salt is less readily soluble in the cold solution of the hyposulphite than is the case with chloride of silver. Herschel recommended also the employment of iodide of potassium, to convert the nitrate of silver on the paper into

iodide of silver, and gave moreover the peculiar properties of the "iodised paper." He says: "The papers so prepared (with iodide of potassium and nitrate of silver) vary considerably in sensitiveness, according to the strength of the solutions used. A concentrated solution of iodide of potassium gives a paper nearly or altogether insensible; with a weak solution the result is the reverse."

At the meeting of the British Association at Plymouth, in July 1841, Mr. Robert Hunt read a paper "On the influence of the yellow ferrocyanide of potassium (a compound of equivalents of cyanide of potassium with one of protocyanide of iron, and three of water) upon iodide of silver, and on the high sensitiveness of the same as a photographic preparation." He gave also instructions how to prepare the "iodised paper," viz., as follows: "Select good smooth letter paper, wash it on one side with a solution of one drachm of nitrate of silver in one ounce of distilled water; let it dry quickly, and then wash it once more with the same solution. As soon as it is dry again, saturate it with a solution of two drachms of iodide of potassium in six ounces of distilled water; wash it afterwards cautiously in distilled water, and then let it dry in the dark, at the common temperature."

Iodised paper was used likewise by Ryan, Lassaigne, and others; and it seems moreover pretty certain that this paper, as prepared according to the instructions given by Herschel, Hunt, and others, was an article of commerce, before the patent for the *Calotype* had been obtained.

In Sir John Herschel's paper above alluded to, we find also mentioned already the use of "gallic acid" as an accelerative agent. In that paper, Sir John Herschel states, that he "failed to obtain satisfactory results (in the way of accelerating the process) by any of the agents tried, with the somewhat problematical exception of gallic acid and its compounds."

The direct production in the camera-obscura of positive pictures on paper, was the next point which attracted the attention of the friends of the photographic art. Prepared paper blackened by the action of light was saturated with a solution of iodide of potassium, and placed in the camera, where it was bleached by the luminous rays, and an image thereby produced, in which the distribution of light and shade was found to be the same as in nature. The most successful

experimenters in this line were, Dr. Fyfe and Robert Hunt. The latter published in September and October 1840, in the "Philosophical Magazine," a paper on the use of iodide of potassium as a photographic agent. Several pictures obtained in this manner, and paper prepared for the process, were sold in London, at Ackermann and Co.'s. Herschel states also in his communication to the Royal Society, which we have repeatedly mentioned already, that positive paper, prepared after R. Hunt's method, was manufactured for sale. These facts prove that iodised paper was in use before the time the calotype patent was obtained. This patent was granted in 1841, and includes the use of the iodised paper, the gallic acid, and, more especially, the development of the latent image. There can be no question but that Talbot is the inventor of the beautiful calotype process; and every one who takes an interest in the photographic art, must feel grateful to that gentleman for his recent generous abandonment of his patent, whereby he has in a measure presented his process as a free gift to the world. Talbot's invention appears to be one of those which are usually termed *accidental*. But in scientific discoveries the term *accidental* is certainly misapplied, since the observer must in a measure be prepared for the phenomenon observed, in order that it shall not elude his attention, and, still more, that he may improve upon the results of his observations.

Mr. Talbot, in the course of a series of experiments, tried various chemical preparations, and among others, also gallic acid. He put by in the dark some silver iodide papers which he had treated with this acid, and which showed no alteration; when he took them out again after some time, he found very distinct impressions on them.

Fresh experiments confirmed the great importance of gallic acid in the photographic process; the manipulations of the method of employing gallic acid as an agent in photography are unquestionably Talbot's own. The first pictures produced in this manner created no inconsiderable sensation in the scientific world, although they did not possess by far the degree of perfection that has since been attained.

Still this method of Talbot's, notwithstanding its undoubted excellency, could only with difficulty be employed for the portraying of living objects, as the prepared paper was wanting the requisite degree of sensitiveness, which was imparted to it subsequently by Gundell as

stated by that gentleman in the "Philosophical Magazine," of May, 1844. At the time when Daguerre presented his invention to the French government, twenty minutes were required to obtain an impression. It was only subsequently, in 1840, that Dr. Draper, of New York, succeeded in producing the first daguerreotype portrait, by acting upon Towson's suggestion to employ larger lenses, and to place the prepared plate or paper in the rightly-adjusted focus.

In the same year the art of photography was essentially advanced by Goddard and Claudet's discovery that chlorine and bromine, in conjunction with iodine, considerably increase the sensitiveness of the prepared surface. The employment of accelerative agents, such as chlorine and bromine, may be looked upon as a consequence necessarily resulting from the introduction of the scientific element into the study of the photographic art; since the analogy of iodine, chlorine, and bromine, in their effects and properties was at the time already well known to chemists. The manner of employing these agents underwent numerous modifications, and a variety of mixtures were recommended.

In 1844, Hunt communicated to the meeting of the British Association at York, his experiments with sulphate of protoxide of iron, as a liberating or developing agent, to bring to light the latent images on paper. At the same meeting, Dr. Woods made public *his* method, which he called *catalysotype*, and in which sesqui-iodide of iron plays an important part. As Talbot was also present at the meeting, the new methods were amply discussed, and Talbot fully acknowledged their importance. Still, notwithstanding these several progresses in the photographic art, the time required to obtain a picture was much too long to admit of the portraying of living objects; and, although some enthusiastic admirers of the art had the rare courage to sit nearly half an hour with open eyes and immovable features (as far as they could command them), in the dazzling sunshine, yet the lineaments impressed on the plates were of a nature that it could not well be expected they should be acknowledged as faithful likenesses.

It was soon seen that this serious obstacle was in a great measure to be attributed to the camera-obscura, and that this instrument could no longer be retained in its simple construction; nor did Towson's improvements in it go far enough to remedy the imperfections complained of. A lens had hitherto been used, of three inches aperture, and sixteen or

eighteen inches focal distance ; this was covered to one inch aperture, by means of a screen placed before it at a certain distance. Now, this contrivance indeed excluded those rays which, from the form of the lens, could not be brought to converge, and must, therefore, necessarily tend to disturb the distinctness of the image. A pretty uniformly distinct impression was thus obtained ; but to achieve this result, an equally great sacrifice was imposed, on the other hand, viz., that of a considerable amount of light, excluded by the smallness of the reduced aperture. All attempts to dispense with the screen, by modifications and improvements in the construction of the lens, failed for a time. Many fruitless experiments were made by practical opticians ; many equally unproductive calculations and computations by theorists. To a combination of both it was reserved to gain the victory.

Professor Petzval, of Vienna, at the request of Professor von Ettinghausen, who was engaged at the time in a variety of experiments on the new invention, submitted the question of the construction of an object-glass that might answer the purpose of photography, to a long and searching examination, and made extensive calculations and computations on the subject. In 1843 he published the result of his labors,* which then ultimately led to the combination of glasses in the lens, on which rests the construction of the object-glasses, universally known as Voigtländer's. This was indeed a considerable step in advance towards the attainment of the desired end, but it was not yet all that was required. For, as it was desired to employ photography more especially for the portraying of living objects, and as the slightest movements of the person sitting for the portrait would necessarily tend to efface the clear outlines of the image, the great desideratum was to devise means to heighten the sensitiveness of the prepared surface to such a degree that half a minute's sitting should suffice to obtain a clear impression. And this problem chemistry has gloriously solved, by a judicious combination of the iodine with bromine and chlorine. The opticians, on their part, continued to devise and apply improvements in the construction of the object-glasses ; and it may be affirmed that Breton, Buron, Chevalier, and others, of Paris, Waible, of Vienna, and Busch, of Rathe-

* "Bericht über die Ergebnisse einiger dioptrischer Untersuchungen." Pesth, 1843.

now, supply object-glasses at present, which are in no way inferior to those by Voigtländer, and may even be said to excel them. This applies more especially to Busch's, which are from one-third to one-half cheaper than Voigtländer's glasses, and combine with the greatest accuracy and correctness of delineation, a comparatively high degree of luminousness. *I have tried and most carefully examined lenses of every kind and description, procured from a number of different shops, and I can most conscientiously say that the object-glasses made by Busch of Rathenow are positively the best that can be procured at present.*

The apparatus, No. 1, of the annexed price-list (see Appendix) is suited more especially for medallion pictures; Nos. 2, 3, and 4, are suited principally for daguerreotypes. Nos. 6 and 8 are the very best that can possibly be procured for talbotypes and vitrotypes.*

The high price of the silver plates, on the one hand, and the circumstance on the other, that the daguerreotypes can only be seen with equal distinctness in all parts in a certain position to the light, and also the unequal texture of paper, naturally induced a desire to devise means for remedying these drawbacks; and this led to the application of glass covered with a thin coating of matter sensitive to the action of light.

The first who made experiments in this direction was Sir John Herschel. As early as 1840, he attempted, by the precipitation of iodide, bromide and chloride of silver, to fix a thin coating of these compounds on glass plates, which he then exposed in the camera. In this manner he obtained very distinct negative images, which could be converted, by a simple process, into positive impressions. For this method, which is unquestionably Herschel's property, a patent has recently been granted to some other person. Herschel describes his process as follows: "the glass plates, so prepared, receive in the camera a distinct negative image, which appears either in the natural position, or reversed, as you look at it in front or from behind. If a solution of hyposulphite of soda is spread cautiously over the surface, and the latter is afterwards rinsed with water, the picture vanishes, but as soon as the plate is dry it comes again to light, when it looks very similar in appearance

* These apparatus may be had of the publisher, Mr. John Weale, 59, High Holborn.

to a daguerreotype, more especially if it is placed on a dark ground, or blackened over the lamp, whereby, indeed, the negative image is made positive."

The next improvement, which was made by Niepce de Saint Victor, and published by him in the "Technologist," of 1848, consisted materially in this, that he covered glass plates with a thin coating of albumen (white of egg), containing iodine. This coating, although the pictures taken on it are truly beautiful, is too little sensitive to serve for the taking of portraits.

Talbot used various other substances to take photographic pictures on, and took out patents for the whole of them. Among these, porcelain plates are mentioned as giving most gratifying results; however, the difficulties of preparing porcelain plates suitable for the purpose are so great, that there appears little chance of their ever being much used in photography. The same remark applies equally to the other substances recommended by Talbot.

Talbot's latest patent includes the use of sulphate of protoxide of iron, and of sesqui-iodide of iron. Talbot published his method of employing these salts in a letter to the "Athenæum," bearing date the 6th December, 1851, and in which he states that he has determined the right proportions in which these two compounds may be used most advantageously.

Talbot's eagerness to secure for himself by patent every new process and every trifling improvement in photography, served to discourage further attempts at improvements on the part of the best English experimenters—a result which is deeply to be regretted. However, Talbot has now relinquished his patents, and has thereby removed the bar which he had opposed to further researches on the part of his countrymen.

Le Gray was the first to suggest the saturation of the paper intended for the reception of negative images with white wax. This process gives highly gratifying results, and is excelled only by the collodion method.

As, from the unequal texture of paper, the positive impressions obtained are always defective, the original defect of the negative image being transferred also to the positive; and as it would be difficult to procure a paper less open to this objection, I attempted to

dissolve paper, and to spread it in a thin coating on glass ; however, after many troublesome experiments, which led to no satisfactory results, I desisted. I then tried some other substances, but also with very indifferent success, until the spring of 1850, when M. Simon, apothecary, of Berlin, called my attention to collodion and its properties.* I immediately made experiments with this substance, but with no great success at first. It was only in the spring of 1851, that I succeeded in producing pictures which, though still imperfect, would bear inspection.

Messrs. Archer, Fry, and Diamond, of London, had, about the same time, also made experiments with collodion ; and the method of applying this substance in photographic processes is so greatly improved now that it leaves little to be desired.

True, that little is of the vastest importance, concerning no less a point than the natural colors of the objects portrayed. Whether this highest aim of the photographer's aspirations will ever be attained, is a question which time alone can solve. This much is certain, however, that the achievements in this direction accomplished up to this time by Niepce de Saint Victor, and others (with the exception of the North-American Hill), warrant a hope that the photographic art may ultimately reach even this highest goal of perfection.

Not only with a view to this final glorious achievement, but also on account of certain beautiful changes of color produced by them, various metallic salts have been employed by different experimenters, and with brilliant results, as will be shown hereafter.

The entire domain of the photographic art may properly be divided into the following chief provinces or sections.

- I. DAGUERRETYPE, or *Photography on metallic plates.*
- II. TALBOTYPE, or *Photography on paper.*
- III. VITROTYPE, or *Photography on glass.*
- IV. ANTHOTYPE, or *Photography with vegetable juices.*
- V. PHOTO-LITHOGRAPHY, or *Photography on stone.*

We will now pass on to the description of the photographic apparatus, commencing with the most important of them, the *Camera-obscura.*

* I had at the time been several years absent from Europe, and had therefore not yet heard of collodion.

THE APPARATUS.

The simple camera-obscura, invented by Porta in the year 1650, served for photographic experiments as long as the art remained in its infancy ; but as the art progressed, it was soon found that this instrument was too imperfect to satisfy the increasing demands made upon it. We have already seen in the Introduction, how a most material improvement was made in the camera by the combined exertions of Petzval and Voigtländer. But even this improved camera is by no means everything that could be desired. The demands that may be justly made upon an apparatus truly deserving the epithet *perfect*, are as follows : it must give a large-sized picture, correctly drawn, and equally distinct in all parts ; it must command a most intense light ; and it must be adapted equally for portraying, and for taking views of architectural objects. Now, up to the present time, the problem of fulfilling all these conditions *equally*, has not yet found its solution ; indeed, one excludes the other. If the picture is to be large, of equal clearness and distinctness in all parts, even to the border, and equally so for near objects as for those farther off, the focal distance must be proportionately longer, and the aperture, through which the luminous rays enter, must be smaller ; the necessary consequence of this mode of construction is, that the apparatus does not command a sufficiently intense light to answer the purpose of taking portraits with it. On the other hand, if the focal distance is lessened, and the aperture enlarged (with a lens suited to the purpose), the apparatus will indeed command a greater amount of light, and will accordingly be better adapted for the taking of portraits—but it will be found that this has been achieved only at the expense of the size of the picture, and of the desired correct delineation, and equal clearness and distinctness in all parts.

An apparatus so constructed is, therefore, but imperfectly adapted for taking views of landscapes and of architectural objects ; and although small views may, if need be, be taken with it, by placing screens before it to reduce the aperture, the productions so obtained are very inferior to the views taken with an apparatus of greater focal distance and smaller aperture. This applies more especially to pictures

taken on paper ; since, from the unequal texture of that material, the minute details of an object delineated on it will necessarily grow indistinct and confused, or even vanish altogether, if the surface acted upon is too restricted to reflect these details on a sufficiently large scale.

The task of the optician consequently is, to construct and combine the apparatus in a manner to produce the best total effect in every individual case ; which, of course, requires, in the first place, due attention to the choice of suitable curvatures in the lenses, as it is principally upon this that depends the accuracy of the impression. A proper achromatisation of the glasses will obviate the occurrence of colored edges in the images taken. The glass for the lens ought to be as white as possible, and pure and even throughout—requirements which it is not always easy to fulfil. Perfect whiteness, however, is not *absolutely* necessary ; on the contrary, a violet tint of the glass is rather desirable than otherwise—provided always the coloration be not too intense, since this would tend to lessen the luminousness of the apparatus, more particularly with larger lenses, on account of the greater thickness of the glass. There are not unfrequently little bubbles and small black spots in the vitreous mass ; however, if there are not too many of them, nor over large ones, their presence matters little, as may be readily proved by a simple experiment : cut out a small round of paper, and paste it with gum on the object-glass in the centre ; a picture taken with this glass will show no difference from another taken with a clean glass ; at the most, the time of exposure may require to be prolonged a little, that is, if the piece of paper pasted on the object-glass is of rather large size in proportion to the aperture. But the glass must be free from tears ; and indeed no conscientious optician will make use of glass having tears, which, however, it requires a practised eye to detect. Still, even with glasses of the kind, an apparatus, otherwise properly constructed, is preferable to one with faultless glasses but with a defective combination of the lenses ; the defect caused by tears being, after all, imperceptible in the miniature picture of the camera, or, at all events, scarcely visible to the naked eye. To be enabled to pronounce a correct opinion on the quality of a photographic apparatus, the one thing needful is, to take a picture with it ; of two apparatus of the same construction, that one is

the best which produces the larger pictures of the two, of equal or superior distinctness, and in the shortest time.

Besides the quality of the object-glass, and the proper fixing of the chemical focus, of which we shall treat in the next section, the accurate adjustment of the apparatus also forms an essential condition for the good success of photographic operations. The prepared side of the plate or paper, on which the image is to be produced, must be placed exactly in the spot previously occupied by the roughened side of the ground glass plate, or focussing glass (the side turned towards the object-glass). If it is not made to occupy that exact position, the clearness of the impression produced will suffer in proportion to the extent of the deviation from it.

The construction that has been given to the camera-obscura, and to the frame for the reception of the plate or paper, varies greatly; however, all the modifications introduced have essentially one and the same object in view, viz., the facilitation of certain manipulations.

In Voigtländer's apparatus the camera consists of a large cylindrical brass tube; in others it is a square wooden box; the latter again varies greatly in size and in the arrangement of the details of construction. But they all agree in this point, that they have the object-glass set in the anterior part, the roughened or depolished glass plate, or focussing glass (for which is substituted the frame carrying the plate or paper), being placed in the posterior part.

Fig. 1.

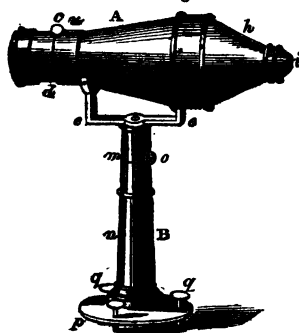
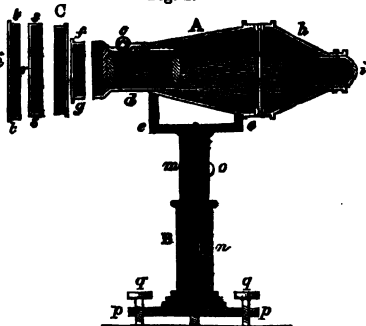


Fig. 2.



Figs. 1 and 2 may serve to illustrate the construction of Voigtländer's apparatus. Fig. 1 presents a full, fig. 2 a sectional view of it.

A is the camera-obscura ; *a b*, the object-glass, which may be moved forwards and backwards towards the focussing glass *e*, by means of the rack-work adjustment *c*. The compound lens consists of two achromatic glasses ; the one nearest the object having an available aperture of eighteen lines, the other, an available aperture of nineteen lines ; the focal length of the two is five-and-a-half inches. The size and the focal length of the glasses differ of course with the size of the apparatus.

f is a tube screwed on before the object-glass, to exclude the lateral light ; *g*, the plate cover to it, which serves to close the aperture of the object-glass.

h is the conical tube with the focussing glass ; this tube screws into the camera.

i is the peep-glass in the tube *h*, which tube is movable, for the better adjustment of the focus.

B is the pedestal or stand of the camera, consisting of the supporters *e e* ; the two sliding tubes, *m* and *n*, which serve to raise or lower the camera ; the thumb-screw *o*, which serves to fix the tubes at the proper height ; and the plate *p*, with the three adjusting-screws *q*, which serve to place the camera in the proper horizontal position.

C is a frame intended to receive the prepared plate *r* ; this plate is placed in the ring *s s*, which screws on to the frame ; *t t* is the cover of the frame, to screen the iodized plate from the light.

The camera-obscura, together with the stand and all the accessories, is made of metal. The stand B screws on to the plate *p*, and may accordingly be unscrewed, to make it more convenient for transport.

When it is intended to use this apparatus, the plate *p* is put on a table, the stand B is screwed in, and the camera laid on the supporter *e*, in such a manner that the projecting ring *u* lies close to the smaller bracket of the supporter ; which will ensure the same position of the camera in every operation.

One of the great advantages of this apparatus of Voigtländer is, that when taken to pieces and packed in a box, it occupies only a small space, and may therefore be readily carried about, which makes it very convenient for travelling. Moreover, the material of the apparatus being metal, there is no fear of absorption of iodine and bromine, or of aqueous vapors. On the other hand, this apparatus has also its drawbacks ; the plates at present in use being square, the edges of them

must be cut off to fit them for the round frame; moreover, the apparatus requires repeated moving in the course of every operation; and the naturally low temperature of the metal demands a longer exposure of the plate.

The old construction of the camera, and which is even at present most generally used, differs from the preceding principally in this, that the large brass cylinder is replaced by a square wooden box. See fig. 3, representing a so-called *expanding* camera.

The tube B, carrying the object-glass, is fastened to the front side of the camera, by means of the annular plate *a*, and by screws. The outer box, A, the size of which is regulated by the size of the plates, encloses a smaller sliding box, C C C, which is open at both ends, and may be moved backwards and forwards on the lengthened ground-board, E D, by means of the rack-work, F. A piece is cut out at G, to admit into the grooves formed inside the box on both sides by the ledges *cc*, *cc*, the frame with the focussing glass, or the sliding board which holds the frame, carrying the plate.

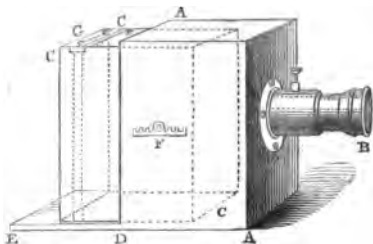
The sliding box C serves to lengthen the camera, which is necessary, more particularly when it is intended to take very small pictures, or to make reduced copies of larger landscapes or portraits; the rack-work F is not sufficient for this purpose.

This power of lengthening, or expanding the camera is an advantage which Voigtländer's apparatus does not possess; if it is intended to take very small pictures with the latter, the camera must be removed to a great distance from the object to be portrayed; and this is in many cases difficult, and in others even altogether impracticable.

Fig. 4 represents a camera of a different construction, which combines all the advantages of the two preceding ones.

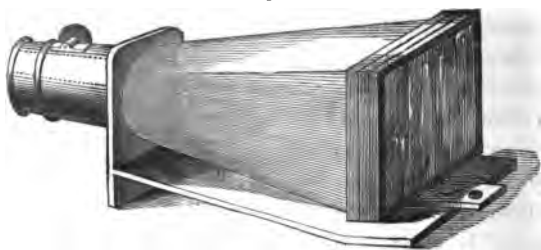
The principal advantage of this camera consists in the stretching bag of cloth or caoutchouc, and in the simple way in which the paper or the plate may be adjusted to any angle, which may be thought adapted

Fig. 3.



to obtain a good focus. Another advantage is the vertical mobility of the object-glass, whereby the object to be portrayed may readily be brought into the centre of the field of vision. The posterior part of

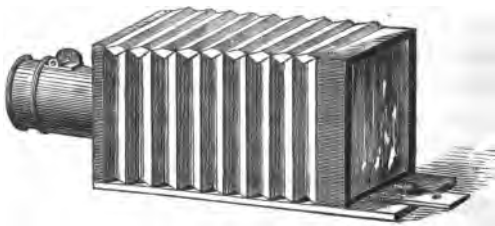
Fig. 4.



the apparatus is fastened to a movable plate, which may be screwed fast on the ground-board, at a longer or shorter distance from the object-glass ; by which means the operator is enabled to employ, if need be, object-glasses of different focal lengths. The whole apparatus is so arranged, that it may be readily folded and packed. It weighs only half as much as a common camera, and when packed up, occupies only about half the space taken up by the latter.

Instead of, and even in preference to, the cloth or caoutchouc-bag camera, one of pasteboard may also be used, made in the same shape as the bellows of an accordion. See Fig. 5.

Fig. 5.



As this camera may be lengthened, without the intervention of a sliding box, it is particularly suited for copying pictures in enlarged or reduced sizes. To do the former, and more especially to copy enlarged

positive pictures from small negative pictures on glass or paper, another camera of the same size and construction is required, which is fastened light-tight to the object-glass of the first camera, so as to place the object-glass between the two. The negative picture to be copied is put into the frame in the back of the second camera, which is then so placed that the direct light falls through the negative picture ; in the frame of the first camera is placed the plate or paper intended to receive the positive impression. Of course, the length of both cameras must be adjusted to the desired size of the picture. In this way small, but accurate and perfect portraits may be copied life-size. This apparatus is admirably suited for travellers, to take views of landscapes and architectural objects ; negative impressions of small size, and fitting accordingly in a limited compass, may be taken on the journey, and may then at leisure be transferred in larger size to positive plates or positive paper. The operation of copying is conducted exactly the same way as the original taking of the negative impression ; the development of the positive picture is effected in the usual way.

There is still another camera of different construction, used more particularly in England and France, for taking views of landscapes, and to which the name "*traversing camera*" has been given. The peculiar feature of this camera consists essentially in this, that with a comparatively small and indifferent object-glass, it produces pictures of considerable size, accuracy, and clearness. Thus, with an object-glass of common quality, views are obtained, fourteen inches long, by four-and-a-half inches wide, and which are perfectly clear and distinct throughout, and embrace a field of vision (horizon), of more than 150 degrees.

The arrangement, by means of which this result is obtained, consists in the main :—first, in an horizontal motion imparted to the object-glass by rack-work, and which causes it to traverse successively all the points of the horizon ;—secondly, in the cylindrical incurvation which the paper or plate is made to assume by means of a groove in the camera ; as the paper by itself would not retain the curved position given to it, it is placed moist on a metal plate, to which it readily adheres, and its incurvation is thus ensured during the operation ; by this contrivance objects at however unequal distances from each other are transferred to the plate or paper, at the same focal distance, and

without displacing the camera ;—thirdly, in a small vertical aperture in the bottom of a kind of box, which accompanies the object-glass in its motion. This aperture, which supplies the place of a diaphragm that would occupy a position in the rear, brings to bear upon the excitable surface only the rays in the centre, *i. e.*, those rays only which have no sensible aberration. This tends, of course, materially to increase the distinctness and accuracy of the impression.

The position of the turning axis of the object-glass must be fixed with the greatest precision, otherwise the images of the objects towards which the apparatus is successively turned, would, ere they become extinct and give place to the succeeding ones, move on the depolished glass, and accordingly also on the plate or paper, which of course would destroy the clearness of the image.

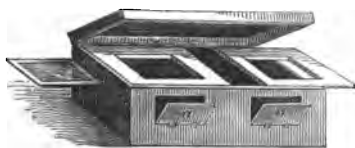
To hit the proper position of the axis to the object-glass, the tube of the latter need simply be pushed in more or less, until perfect immobility of the images is attained.

The next apparatus in importance is the *Iodine apparatus*.

This consists of a wooden box lined with glass ; or of a porcelain or glass* dish ; or cup about two inches deep, and of a size corresponding to that of the plates to be acted on ; the rim of the dish or cup is ground perfectly even ; the cover consists of a strong yellow glass plate, also ground perfectly even.

Fig. 6 represents an apparatus in which the iodine dish, and the

Fig. 6.



bromine dish are in the same box. This apparatus, which is much used by English photographers, affords this advantage, that the progressive coloring of the plate may be watched in the two mirrors

in front ; and that the frame carrying the plate may be readily shifted from the iodine to the bromine.

The *Mercurial apparatus* (fig 7) consists of a square box, resting on four legs, and for the sake of greater convenience, with the top slanting

* Yellow glass dishes are preferable to all others ; the porcelain dishes are strongly affected by the iodine, and after a time the glazing comes off. Phials of yellow glass are also suited best to keep photographic preparations in. Solutions of silver, for instance, never turn black in them.

at an angle of 45 degrees; at the bottom of the box there is a small iron cup for the mercury.

In front, and at one side, there are two apertures, closed with panes of *yellow* window-glass, through which the image may safely be examined by daylight, to note its progress. If panes of *white* glass are used, the image can be examined without injury only by the light of a small taper.

Fig. 7.

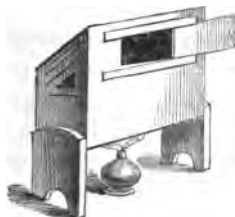


Fig. 8.

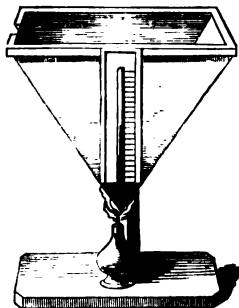


Fig. 8 shows a mercurial apparatus of a different construction, which is used in North America.

This apparatus affords the advantage of a saving of mercury, as in the first place less of that substance is required with it; and in the second place, the fumes evolved condense on the sloping sides of the hopper-shaped box, and roll back into the iron cup at the bottom. Moreover, this apparatus does not require so high a temperature as others of different construction.

Besides these apparatus, the operator requires also a small stand to lay the silver plates on, in the process of gilding; and some porcelain or glass cups and dishes to hold distilled water, solution of hyposulphite of soda, of nitrate of silver, of iodide of potassium, &c. &c.

There are several other little contrivances and implements, serving to facilitate certain manipulations, but which every one may devise and construct for himself, as they may seem best suited to the purpose for which they are intended.

THE FOCUS.

It is a remarkable fact, and one which must never be lost sight of in photographic operations, *that the rays which possess the greatest luminousness, do not likewise exercise the greatest chemical action.* Therefore, even with an adjustment of the apparatus giving a perfectly clear and distinct image of the object, and with the most rigorously exact placing of the photographic plate or paper, there are still certain accessory conditions required to obtain a correct impression.

The rainbow colors of the white ray refracted through the prisma, are seen side by side on the surface on which they are thrown ; now in the camera-obscura, these colors or rays lie, properly speaking, behind one another, and cover each other, so that they appear to the eye as one—coinciding all of them in the *yellow ray as the most intense of them*; it is accordingly to this ray that the *optical focus* of the camera-obscura is adjusted. But the yellow ray is not the one possessed of the most energetic *chemical action* ; it is the *violet ray* in which the chemical force and influence of light chiefly resides ; the plate or paper intended for the reception of the image, must accordingly be placed in the focus of this latter ray. Now, as the length of each ray depends partly on the radius of the curvature of the lenses, partly on the refractive power of the vitreous mass, and partly also on the distance of the object from the object-glass, it follows that every object-glass must be specifically tried and tested, to determine the difference between the *optical* and *chemical focus*.

In non-achromatic lenses, the point of convergence of the *violet rays*, and accordingly the *chemical focus*, lies usually *nearer* to the object than the *optical focus*, which difference decreases, however, in proportion to the distance of the object from the apparatus. In this case, therefore, the camera must be shortened, which is effected most simply by moving the object-glass backwards.

But the case is different with achromatic lenses ; here no general rule can be laid down, but every object-glass must be submitted to a separate, careful trial. Various apparatus and contrivances have been devised to determine the chemical focus of an object-glass, but the

simplest and easiest way of all is the following, recommended by Professor Dr. Varrentrap.

Place nine books, with printed title on the back, perpendicularly side by side at a certain distance from the object-glass, in such a manner that the second stands an inch further back than the first, the third than the second, the fourth than the third, and so on for the rest.

Place and adjust the apparatus so that you see the titles on the backs of the books reflected in the glass plate, with the printing on the back of the *fifth* in the row appearing the most distinct of the nine, which may be readily and accurately discerned. Now, take a picture with the apparatus so adjusted, and without displacing it. The degree of accuracy and distinctness possessed by the picture will enable you to fix upon the proper adjustment of the apparatus.

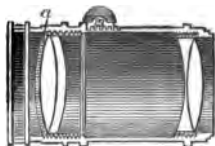
Opticians have indeed endeavored to supply object-glasses, through which all the rays should converge in one point : in this they have, however, succeeded only for certain distances.

There is another way of arranging the matter, viz., by employing glasses that intercept those rays of which the chemical action is but little energetic, or, in other terms, those rays which counteract the chemical effects of the violet ray ; the principal among these rays is the yellow. True, this means involves a certain loss of light, which, however, is amply compensated by the increased energy of the chemical action, and the greater certainty in the performance of the process.

As it is, however, rather difficult to procure glasses of the kind, another way still may be recommended, viz., to place before the object-glass a very thin violet-colored glass, ground to exactly the same curvature as the object-glass, as may be seen in Fig. 9, where *a* denotes the violet-colored glass.

This contrivance, which fully answers the purpose, may be readily applied to object-glasses of all kinds.

Fig. 9.



I.—DAGUERREOTYPE ;

OR,

PHOTOGRAPHY ON METALLIC PLATES, WOOD, AND IVORY.



STRONGLY-SILVERED copper plates are now almost exclusively employed in Daguerre's method of producing pictures on metallic plates by the influence of light. However, the light does not affect the compounds of silver alone, but almost all metallic oxides, though in very different degrees and spaces of time, as will be seen hereafter.

The so-called "silver plates" used for photographic purposes are manufactured in two different ways, of which one, however, is greatly preferable to the other. The silvered copper plates generally sold in the early days of photography, had a thin coating of silver hammered or rolled down on them ; the same method is still pursued at the present time in England and France. Now, these plates have their good points, which are outweighed, however, by certain defects inherent in the mode of their manufacture, as will be shown immediately. The other, and better method of plating the copper, is by the *galvanic process*. The great advantage of this latter process is this, that the silver spread over the surface of the copper is purer, and more uniformly and evenly distributed, than is the case with the plates prepared by the hammering or rolling process ; and, what is of greater importance still, that the silver coating is of *equal density throughout*, which cannot well be the case with the hammered or rolled plates. Now a disparity in the density of the silver of the coating is a serious drawback ; since not only are the softer and looser parts more strongly affected and wasted in the processes of cleaning and polishing than the harder and denser parts, but the formation of iodide of silver, in the process of iodising, extends also more deeply into the softer parts, which, of course, cannot but impair the beauty of the picture subsequently taken on the plate.

Another defect which the *French* plates more particularly labor under must not be passed over here : it is this, that the silver coating

on them is so extremely thin (which explains their cheapness), that they can hardly bear one cleaning with pumice powder or Venetian tripoli and oil, and can accordingly, in most cases, be used only once; which is a serious consideration for beginners, who are so liable to failure in their experiments. Whereas the galvanic-plated article, with its thicker coating of silver, will bear cleaning repeatedly, and may, therefore, be used several times. The best plates as yet offered to the trade are those manufactured by F. Schneider, 9, Link's Strasse, Berlin.

To render a silvered copper plate sensitive to light, it must be subjected, in the first place, to the processes of cleaning and polishing.

CLEANING THE PLATE.

The plates sold in the shops are seldom so free from scratches, &c., that the operation of cleaning can be dispensed with; however, they need not be rubbed so long as plates that have already been used.

To clean the plate properly, it should be fixed on a small board or block. The best cleaning material is Venetian tripoli, ground to an impalpable powder upon a porphyry slab, with water, and dried. This powder is dusted over the plate out of a muslin bag, and the surface so dusted over is then rubbed with cotton fleece,* imbued with a little *olive oil*, or, better still, with *ethereal oil*, which does not waste the plate so much as olive oil. The hand of the operator should be moved round in circles of various dimensions, until all superficial scratches, spots, or cracks are rubbed out, and the plate presents a uniform white lustre.

POLISHING THE PLATE.

The plate cleaned by the preceding operation is then polished. To this end, the particles of fat which may still adhere to it are removed, which is effected in the most simple way by the application of some polishing agent, and best of most *finely levigated and elutriated colcothar* (rouge, or jeweller's red rouge), which is dusted over the surface, and moistened with a few drops of *slightly acidulated distilled*

* The cotton fleece had always better be washed first in spirits of wine, and dried again before using it.

water (one drop of sulphuric acid, and two drops of nitric acid, to an ounce of water); a dossil of clean cotton is then rubbed about on the surface in circles of various dimensions, until the plate is perfectly dry, presents a clean polish, and shows no colored spots or streaks when breathed upon. If it happens to show spots or streaks, the operation must be repeated to get rid of them. The final deep-black lustre is usually given by means of a polishing lathe, mounted with circular velvet buffs. The plate, still attached to the board or block, is dusted over with most finely pulverised *colcothar* or *bone-dust*, and is then gently pressed against the buffs, the wheel being kept rapidly revolving, until the desired deep-black lustre is given to the plate. It is by no means a matter of indifference in which direction the polishing stroke or touch is carried; for it is upon this that depends in a great measure the distinctness of the picture subsequently taken on the plate. The touch must be carried so that it intersects at a right angle the perpendicular lines of the object to be portrayed. In default of a polishing-lathe, buffs to work with the hand may be used instead, in which case the operation will, however, consume more time; the buffs consist simply of narrow slips of board, covered with prepared velvet or doe-skin leather.

The polishing of the plate is an operation which requires particular care, as upon its proper execution depends the distinctness of the picture. The polishing material has a great deal to do with the proper success of the operation. An astonishing variety of substances and mixtures have accordingly been suggested for the purpose. One of the best of these is the so-called *American plate powder*, which is composed of two parts (by weight) of *colcothar*; one part of ivory-black, two of graphites, and one of binocide of tin; these substances are most finely levigated and elutriated, and most intimately mixed together.

The plate being thus prepared for the subsequent processes, the operator has now to impart to it the requisite sensitiveness to light. Various agents are employed to effect this. Almost every photographic artist has some pet mixture of his own.

Among the agents employed in photography, the compounds of silver with iodine, bromine, and chlorine, used either separately or jointly, are the most highly valued, on account of their ready decomposition by light.

The compounds of fluorine, cyanogen, sulphur, selenium, phosphorus, play likewise an important part, and in many cases also ammonia. Iodine is unquestionably the most important body used in photography, as its compounds with the metals are so very readily decomposed by light. The sensitiveness to light of a plate prepared with iodine, is still heightened by the additional application of chlorine and of bromine, or of both united.

IODISING THE PLATE.

As iodine has a tendency, even at the common temperature of the air, to assume the gaseous state, and as it combines in that state with the metals, upon simple contact with them, it is an easy task to generate on the polished silver plate the coat of iodide of silver, requisite for the production of a picture on it. For this purpose we use the so-called iodine-box.

Dry iodine, in a state of minute division, is uniformly spread over the bottom of the box, which is then covered with the yellow glass plate. The simplest way of reducing the iodine to a state of minute division, is to dissolve it in alcohol, precipitate it again with water (a menstruum in which it is only very sparingly soluble), filter off the fluid, and dry the pulverulent precipitate.

The polished plate is now put into the iodising frame, the glass plate lifted off the box, and the frame carrying the plate substituted for it. The iodine fumes in the box combine forthwith with the silver on the plate, whereupon the surface of the latter acquires first a straw-colored hue, then a golden tint, which changes to rose, then to violet, and finally to blue. Each of these different degrees of iodation is possessed also of a different degree of sensitiveness to light. For the taking of inanimate objects, where the time of exposure is a matter of secondary importance, the blue coloration answers the purpose best; but the case is different in reference to living objects, as we shall see hereafter. If the blue-colored plate is still left exposed to the iodine fumes, it commences to turn green, in which state it is almost entirely insensible; upon a further continuation of the process, the color of the plate changes again to yellow, and then passes once more through the various shades, until the surface ultimately presents again the blue tint, which it exhibited at the end of the first iodation; this repetition

of the process seems to heighten the sensitiveness of the plate. Upon a further continuation of the process, the colors change again, passing through all the various shades indicated, from yellow to blue; but the plate loses thereby in sensitiveness, and is finally rendered quite insensible. One of the principal points to be attended to, is uniformity of coloration, as stains on the plate always necessitate a fresh polish. An unequal distribution of the iodine powder over the bottom of the box is a frequent cause of stains on the plate; but this defect is often occasioned also by the use of plates that have been kept ready-polished a long time before their iodation is proceeded with. This is a practice to be disapproved of altogether, since the impressions taken on such plates are never quite clear and distinct; which may be owing to the condensation of atmospheric air or other gaseous bodies on the surface of the plate, where they subsequently tend to impede the combination of the iodine fumes with the silver.

The plate so prepared may now be exposed to the light in the camera obscura; the time of exposure varies according to the luminousness of the apparatus, and to the illumination of the object to be portrayed; from one to two minutes are, however, generally sufficient to produce a clear impression, unless the luminousness of the apparatus is too feeble, and the object not properly illumined.

By the joint application of bromine or chlorine, or of both together, with the iodine, the time of exposure is shortened to a few seconds. The proper proportions in which these substances ought to be mixed, must be left to personal experience and practice; this much may be said, however, that the success of the process is greatly dependent upon the proportions used. There are numbers of recipes for the preparation of such mixtures, many of them rather complex, but not the better for that than others that are more simple. The easiest way (if you operate with fluid substances) is to use brome water. One part of bromine requiring thirty-eight parts of water for its solution, all that is necessary to prepare a solution of bromine of accurately known and constant strength, is to pour over a given quantity of bromine, in a glass phial, an amount of water sufficient only to dissolve the greater part of the bromine, so that some undissolved bromine is left at the bottom of the phial.

This brome water is poured out into a glass or porcelain dish

covered with an air-tight fitting glass plate, and the silver plate, iodised to the violet tint, is then exposed to the action of the brome vapor rising from the solution, until it has acquired a blue color. To keep the solution of bromine of constant strength, it is advisable to pour the brome-water back into the phial each time after using it, taking care, of course, that there shall always remain some bromine undissolved in the flask.

Or the plate, iodised to the rose tint, is placed over chloride of lime, until it reaches the violet hue ; it is then exposed to the bromine vapor until it changes to blue.

Easy and simple though this method unquestionably is, yet the brome water has this great disadvantage, that aqueous vapors will often, and more particularly at a somewhat high temperature, escape along with the bromine, and condensing again on the cold plate, diminish or even altogether destroy the sensitiveness of the latter. Moreover the impressions on plates that have had a touch of aqueous vapor, are always defective, and often look as if a veil or film were spread over them. It may therefore be preferable to substitute for the brome water, lime impregnated with bromine, which may be readily procured by putting bromine into a small vessel, placing this in a larger vessel, containing recently burned lime, slacked in the air, and inverting a glass-bell over the whole. The volatilising bromine is at once absorbed by the lime, until the latter is completely saturated with it, which may be known by the cinnamon color which it exhibits.

Equal sensitiveness, together with a finer tint, is given to the plate by a combination of chlorine with iodine, usually called chloriodine (chloride of iodine), and which is most probably a compound of the protochloride and terchloride of iodine. With this compound, there is no need of a previous iodation of the plate ; the latter may at once be exposed to the fumes of the chloride of iodine, until the blue color appears. A little bromine may be added to the chloriodine ; this addition would seem to impart greater sensitiveness to the plate.

In default of chloride of iodine, the plate may first be exposed in the iodine-box until it shows the violet tint, and then placed over chloride of lime, until the blue color appears. The result is the same. Bromide of iodine and iodide of bromine are also frequently used in the same way.

Of all the mixtures hitherto used, that recommended by Graff, of Berlin has been found to answer best. This consists of—

. 1 ounce of *protochloride of iodine*.

1 „ *brome water*.

$\frac{1}{2}$ „ *tincture of iodine*.

10 ounces of *distilled water*.

Mix the iodine tincture with the water, add the protochloride of iodine to the mixture, and then as much water as will impart to the whole fluid the color of Madeira wine. Add the brome water, and shake the mixture. Upon the addition of the water to the mixture of iodine tincture and protochloride of iodine, the fluid turns turbid, owing to the separation of iodine; however, this turbidity disappears again, upon the addition of the brome water.

The mixture must be allowed to stand at rest for several days before using it.

The American photographers, whose productions enjoy such universal reputation, use almost exclusively dry substances, to render the plates sensitive to light. The one most generally used is sold in the shops as *Thompson's Dry-quick*; this is prepared as follows:—

A large lump of quick lime is soaked two hours in spirits of wine, and then let slake in the open air to a fine powder. To one pound of this powder are added one and a half ounce of bromine, and one and a half ounce of pulverised alum. The process of iodation is first conducted over the dry iodine in the box, and afterwards over the powder. When this powder has lost some of its strength, the addition of a few drops of bromine suffices to restore it to the proper standard.

The American photographers use also a fluid composition, sold in the shops under the name of *Thompson's Accelerator*. This is prepared in the following manner:—

Make a strong solution of lime in a quart of water, add to this half an ounce of chloriodine, and then drop bromine into the mixture, until the chloriodine is dissolved.* Then add one drachm of nitrate of silver, shake the mixture well, and add thirty drops of aqua regia (nitrohydrochloric acid). When you want to use this mixture, put first

* Some recommend as an improvement to add at once a drachm of bromine, and then every day a few drops of that substance, until the desired end is attained. The great point, however, is to avoid the addition of an excess of bromine.

a table spoonful of pulverised alum into the dish, and then one part of the mixture, diluted with six parts of water. Expose the plate first in the iodine-box, until it has acquired a lemon color, then place it over the mixture in the dish, until a dark orange tint is produced, and ultimately expose it again to the dry iodine fumes one fourth of the time which it took to impart the orange tint to the plate.

The following method may be resorted to to prevent the unequal distribution of iodine fumes over the surface of the plate. Spread the iodine as evenly as can be over the bottom of the box, cover it over with two or three pieces of flannel of the size of the box, lay over the last piece a leaf of very smooth paper, and over this a small board fitting closely into the box. This little board will absorb the iodine fumes equally all over its surface ; upon this board is subsequently laid the frame carrying the plate, and left there until the required tint is imparted to the latter.

Besides the "accelerating agents," which we have described here, there are, as has already been stated, various other compositions recommended for the same purpose ; but they all of them contain the same substances as those mentioned here, and differ from them only in reference to the respective mixing proportions of the several ingredients. The time of exposure in the camera, required to produce a correct impression on a properly prepared plate, depends on various circumstances, and cannot be accurately fixed therefore. As a general rule, it may be assumed that, with a good apparatus and a properly prepared plate, from thirty seconds to one minute's exposure to sun light, will always suffice to obtain a clear and vigorous impression.

The plate removed from the camera, after adequate exposure to the luminous rays, must present no trace as yet of the picture. If the latter can be discerned on it, the exposure has been too long ; in which case the best way is to clean and polish the plate again, as the picture may be looked upon as irremediably spoiled.

To develop the latent image on the plate, the latter is exposed in the mercurial apparatus to the fumes of mercury, which, condensing on the parts acted on by the luminous rays, render the tracings of the image visible. The plate is attentively watched through the yellow peep-glass in front of the box, and the exposure to the mercurial fumes is stopped the moment the picture has become distinctly visible in all

parts. Persons unskilled in photographic operations, should watch the thermometer of the apparatus; when this indicates a temperature of from 122 to 140 degrees Fahrenheit, the spirit or oil lamp should be removed to let the mercury cool again. In no case should the heat be permitted to exceed 167°. An eye, practised by experience is, however, always the safest guide in this operation.

The picture is now indeed finished, but it has still to undergo an additional process before it can be safely exposed to the light of day; this process concerns the removal of the iodide of silver from the plate. The best and most reliable agent for this purpose is, a solution of one ounce of hyposulphite of soda ($\text{NaO}, \text{S}_2 \text{O}_3 + 5\text{HO}$), in a quart of distilled water; in this solution the plate is immersed, until the whole of the iodide of silver is dissolved, which is clearly indicated by the change of color (the removal of the yellow tint of the iodine). With this solution of hyposulphite of soda, the desired end is readily and expeditiously achieved. A hot concentrated solution of common salt (chloride of sodium) may also be used as a fixing agent, but it does not answer the purpose half so well as solution of hyposulphite of soda. Iodide of potassium and bromide of potassium, might indeed also be used to remove the iodide of silver from the plate; however, as their action in this respect is by no means superior to that of the hyposulphite of soda, whilst, on the other hand, they are much more expensive than that salt, their substitution for it would offer no advantage.

As soon as the whole of the iodide of silver has been removed, the plate must be washed, first in common water, then in distilled water, and afterwards quickly dried over a spirit lamp. In this latter operation the plate should be held in a very inclined position, and the action of the flame let proceed from the upper to the lower edge, taking care to move the plate incessantly to and fro all the while, and to take away the lamp as soon as the surface is fairly drying. The last few drops of water, which remain adhering to the lower edge of the plate, may be readily removed with some blotting paper. The operation of washing requires great care and attention, to guard against staining the image, an accident to which the plate is but too liable, more especially if the distilled water used for the last washing is not absolutely pure, since in that case the matters which it holds in solution, are, upon

its evaporation, left on the plate, and it is difficult to remove them again.

It is only now that it can be fairly ascertained to what extent the process has been successful, as it is only now that the imperfections and blemishes of the picture are brought fully to light.

As the latent image produced on the plate by the action of light, has only been developed by the condensed mercurial fumes, and as the mercury has not entered into chemical combination with the silver, but simply adheres to it mechanically, it is evident that the image must be exceedingly liable to be effaced, unless protected from contact; this protection is best afforded by a thin coating of gold, which is put on by pouring solution of chloride of gold over the surface of the plate, and applying the flame of the spirit-lamp to the bottom. This puts the finishing touch to the picture, which is only now seen to full advantage. After gilding, the plate is washed once more in distilled water, and quickly dried.

As has already been intimated, pictures may be produced also on other metallic plates besides silver; however, the process must be modified in certain points, according to the nature of the metal used. Copper plates are cleaned and polished in the same way as silvered plates; but the surface on which the impression is to be taken, must not on any account be touched with the fingers, before it has been thoroughly cleaned, since that would produce stains upon it, which it would be found impossible to remove afterwards, even by heating the plate to redness.

The cleaned and polished copper plate is then iodised, and the impression taken on it in the camera, in the same way as in the case of silvered plates; but, instead of employing mercurial fumes to develop the latent image, the impression is exposed to the vapor of sulphuretted hydrogen, which speedily renders it visible, the several parts of the image appearing differently colored, according to the intensity of the illumination of the object. Unfortunately, copper plates are not sensitive enough to serve for the portraying of living objects, but they answer very well indeed for landscapes.

Iron, steel, brass, and German silver may also be used: I have employed these different metallic substances, preparing them in the same way as silver and copper plates, and have obtained very promising

results with them; still not yet of so positive and definite a kind as would justify my recommending their general application in the Daguerreotype process. The ultimate decision as to their fitness or unfitness for the purpose, must be left to a series of systematic experiments; I hope I may at some future time have something more to say upon this point.

The method recommended by Talbot and Malone to produce photographic pictures on steel, should more appropriately be termed a method to produce images on iodised albumen, the steel serving simply as the material over which the layer of the latter substance is spread. This method is said to be applied advantageously in steel engraving, to get the drawing on the plate. However, I cannot say that I have been successful in it.

But there are two non-metallic substances which, impregnated with silver, give truly beautiful results, viz., wood and ivory. To prepare the former of these materials for photographic purposes, I select a piece of veneer of hard and fine-grained wood, and which is susceptible of a high polish, and endeavour to make it as even and smooth as possible, by rubbing with pumice-stone and water. I proceed in the same manner with an ivory plate. When the wood or ivory plate is perfectly dry again, I rub it once more vigorously with a clean piece of strong leather. I then immerse the plate in a solution of nitrate of silver (one drachm of silver to an ounce of water), in order to impregnate it with that salt. The ivory plate is left in the solution until it has acquired a yellow color; the coloration of the wood plate, which marks the proper degree of metallic impregnation, depends upon the nature of the wood; however a little practice will suffice to enable the operator to hit upon the right point in this respect. As soon as the plates are properly impregnated with silver, I expose them under water to the direct light of the sun, until they have acquired a black tint; I then take them out of the water, and let them dry. The dry plates I clean, polish and iodise, and treat in every other respect exactly as the silvered copper plates.

The so-called artificial ivory also is well suited for photographic purposes, as it is susceptible of a high polish. This material may, moreover, after it has been prepared for the process, be kept a long time, without suffering alteration.

To prepare a plate of artificial ivory for photographic impressions, it must in the first place be cleaned with finely-ground pumicestone, to remove any trace of fatty matter, and to facilitate thus its impregnation with fluids. It is then polished in the usual way, with Venetian tripoli, but without using oil. The polished plate is immersed for about a minute in a solution of twenty parts by weight of sal-ammoniac (chloride of ammonium), in two hundred parts by weight of water. After its removal from this solution, it is suspended by one of the corners, to let the liquid drip off; when no more fluid remains on the surface, the plate is immersed in the dark, in a solution of forty parts by weight of nitrate of silver in two hundred parts by weight of distilled water; this immersion also should last about a minute. The plate is left in the camera until a more vigorous impression is obtained than is ultimately desired. The plate is then removed, washed in water, and the image fixed on it, with either a cold or hot solution of twenty parts by weight of hyposulphite of soda in one hundred parts by weight of water. As soon as the image has acquired the proper tone, the plate is taken out of the fluid, and washed copiously with water, to remove every trace of the soda salt; it is then suspended to let the greater portion of the water evaporate, but, before it is quite dry, it is pressed between two plates of soft wood, by which means not only the last traces of moisture are removed, but the warping of the plate also is effectively guarded against.

If it is intended to take impressions on wood for technical purposes, *e.g.* to obtain the tracing for an engraving, the process must be conducted in a different manner from the one given above. In my own practice, I either produce the impression on the wood directly in the camera, or I transfer the impression to it from another plate; in the former case I obtain a negative, in the latter, a positive image. Both ways answer equally well; still, upon the whole, I prefer the latter, though the process is a little more tedious.

In the first method, a piece of boxwood is selected, since this is found to answer better than other sorts, and fitted accurately into the frame which usually carries the plate in the common Daguerreotype process; the piece must be fitted so that the larger surface, and which is intended to receive the impression, is *endwood* or *grainwood*. This surface must previously have been rough-polished with pumicestone,

since, were this operation postponed till the wood has been fitted to the frame, it might be difficult to obtain an even surface. The wood so prepared and fitted, is once more polished with pumicestone and water, and subsequently washed and dried; when dry, it is again polished, but this time with dry pumicestone. It is then carefully cleaned, and the polished surface is imbued with a solution of one equivalent of iodide of potassium, (KI , see table ii.), in four ounces of water. When it has dried again, it is dipped for about one minute into a solution of one equivalent of nitrate of silver (AgO,NO_5), in four ounces of distilled water; the nitrate of potassa (KO,NO_5) formed is then cautiously washed away with water, and the plate dried, and laid by in a dark place, until it is required for use. Immediately before its exposure in the camera, the prepared surface is imbued once more with a solution of one equivalent of nitrate of silver in four ounces of distilled water, to which are added two equivalents of crystallisable acetic acid ($\bar{A} = C_4H_3O_5 + HO$), since this acid promotes the decomposition of the iodide of silver, and keeps the parts not acted upon by the luminous rays, of a beautiful white. The time of exposure varies with the greater or less intensity of the illumination; however, as a general rule, one or two minutes are sufficient. To develop the latent image, the prepared surface is bathed with a saturated solution of gallic acid ($\bar{G} = C_7H_3O_5 + HO$); a small addition of nitrate of lead (PbO,NO_5) promotes the action of the gallic acid, and imparts a darker tint to the image. Pyrogallic acid, &c., may be substituted for the gallic acid, to develop the image—see the chapter on the *Vitrotype*. The image is fixed with solution of hyposulphite of soda.

In the second method, the negative image, taken on a glass plate covered with a layer of iodised collodion (see *Vitrotype*), is placed right on the wood prepared with iodide or chloride of silver, and is then, in that position, exposed to the solar rays. If the impressionable surface has been prepared with iodide of silver, the latent image must be developed by means of a saturated solution of gallic acid, in the same way as in the first method. The image is ultimately fixed with solution of hyposulphite of soda.

The negative image may also be transferred to the wood, in an enlarged size, by means of the apparatus illustrated by Fig. 5.

II.—TALBOTYPE;

OR,

PHOTOGRAPHY ON PAPER.



COMPOUNDS OF SILVER.

IF OXIDE OF SILVER (Ag_2O) precipitated from a solution of the nitrate, is exposed for several hours to the solar rays, the parts exposed to the light acquire a deeper olive tint than the covered parts. If the exposure is continued a week or longer, it is found that the deep olive color turns lighter again, and that the covered parts are much darker than the exposed parts. I have frequently had occasion to observe that oxide of silver spread on paper, acquired a much lighter tint after a few days' exposure to light.*

NITRATE OF SILVER, (AgNO_3).—This salt, if absolutely pure, is not perceptibly affected by light, neither in the solid state nor in solution; but in nitrate of silver containing the least admixture of organic matter, the influence of light speedily produces an alteration. This property induced Sir John Herschel, in his first photographic experiments, to put organic substances on the paper which he intended to operate upon, and to imbue it then with solution of nitrate of silver; however, he did not obtain the desired result. But since that time it has been found that the joint application of organic substances with the silver salt, serves to promote and heighten to an extraordinary degree the alteration which the latter suffers under the influence of light. Count Rumford found that nitrate of silver, mixed with charcoal or with a carbonated earth, suffered reduction to the metallic state under the influence of the solar rays.

Prismatic Analysis.—The color which the prismatic spectrum produces on paper prepared with nitrate of silver, is first a light brown, which changes slowly to a deeper tint; the part under the blue ray acquires a bluish brown color, that under the violet ray a peculiar

* This accounts for the fading of the pictures.

rose color. The minimum of the chemical action is under the yellow ray, extending to about the middle of it ; the maximum of the chemical action seems to extend to the middle of the blue ray, though up to the edge of the violet ray the effect is only slight—beyond this it is very feeble.

Photographic Application.—Although nitrate of silver by itself is not sufficiently sensitive to light to find application in the photographic process (except in a few cases), still it is the most important salt of silver in a photographic point of view, since all other compounds of silver may be prepared from it.

If well-sized paper is imbued on one side with a solution of 120 grains of nitrate of silver in an ounce of distilled water, and dried in a warm place ; it may very well be used for the copying of feathers, lace, embroidery, and generally such objects as require simply sharp outlines. If the paper, before the application of the nitrate of silver, is first imbued with a solution of isinglass, or parchment, or gum arabic, or some other similar substance, or is coated over with albumen, the nigrescence under the influence of light proceeds with much greater speed, and it acquires ultimately a tolerably dark tint. The ground of the images taken on such paper may be agreeably varied, by the application of divers organic substances to the paper ; experiments of this kind succeed all the better if the organic substances are thrown down on the paper from their solutions by solution of lead ; the precipitate on the paper must be allowed to dry before the application of the nitrate of silver solution is proceeded with. Some remarks on the property of lead to accelerate the decomposition of the salts of silver, under the influence of light, will be found in the section on lead and its compounds. The pictures produced on the paper so prepared may be fixed by immersion, first in cold then in warm water, and a final careful ablution.

CHLORIDE OF SILVER (AgCl).—This salt, no matter whether precipitated from solutions, or existing in the form of hornsilver, speedily changes color under the influence of the solar rays ; indeed, diffused light suffices to produce this effect, nay, even in a totally dark place, the white color of chloride of silver changes to a darker tint, and after some time, turns bluish black. Upon exposure to the solar rays, the color changes first to a reddish hue, then to violet, afterwards to

bluish grey, and ultimately to dark blue. A trifling excess of the nitrate greatly promotes the migrescence, the chloride turning first of a dark-brown tint, which gradually changes to a fine olive color; after an exposure of several weeks, the metallic silver is seen to make its appearance. The great variety of tints produced by the combination of silver with different chlorides is very remarkable. However, it is only during the first stages of exposure to light that this variety exists; after a time all the different compounds acquire the olive tint.

With chloride of ammonium (sal-ammoniac NH_4, Cl), and chloride of sodium (common salt, NaCl), the tint produced is red; with chloride of strontium ($\text{SrCl} + 6\text{HO}$), brown; with chloride of barium ($\text{BaCl} + 2\text{HO}$), brownish purple; with chloride of calcium ($\text{CaCl} + 6\text{HO}$), brick-colored; with chloride of potassium (KCl), the tint varies from a fine brown to a bluish steel color; with sesqui-chloride of iron ($\text{Fe}_2\text{Cl}_3 + 6\text{HO}$), from deep brown to black. With hydrochloric acid ($\text{ClH} + \times \text{aq.}$), the color is red, changing to black; with chlorwater ($\text{Cl} + \times \text{aq.}$), red; with chloric ether ($\text{C}_2\text{H}_5\text{Cl}$), dissolved in alcohol, black. Other combinations will be mentioned in the sequel. As far as my own experience enables me to judge, these differences in the tints obtained seem to proceed from the presence of the alkalies, earths, or metals, and not from that of organic substances; though the latter, in combination with nitrate of silver, produce similar variations.

Prismatic Analysis.—The paper prepared with chloride of silver often acquires beautiful tints in the solar spectrum, which differ, however, according to the chloride used. Paper that had been imbued with a solution of chloride of ammonium (NH_4, Cl), or chloride of barium ($\text{BaCl} + 2\text{HO}$), dried, and then dipped into a solution of nitrate of silver, gave a series of colors nearly approaching the natural colors of the spectrum. Under favorable circumstances, the middle red ray leaves a red impression, which under the yellow ray changes to green; above this a lead color is seen, and under the blue ray, in the part where the chemical action was strongest, a brown coloration changing subsequently to black; a bluish brown tint is seen to extend under the most strongly refracted rays up to the latent rays. The opposite effect is observed at the least refracted end of the spectrum, where the paper remains white. This may be distinctly observed, if the rays are

collected through a good achromatic lens, and more distinctly still, if the spectrum is thrown right on the paper.

Photographic Application.—It has been already mentioned that Wedgewood, Davy, Daguerre, and others employed chloride of silver in their photographic experiments, though with indifferent success. But in the hands of Mr. Fox Talbot, this salt became a very important photographic agent. The following is the way of procedure adopted by that gentleman:—

He selects glazed paper of equal texture ; he dips this into a weak solution of common salt (chloride of sodium), and dries it afterwards between folds of blotting-paper, by which means he endeavours to ensure the equal distribution of the salt through the substance of the paper. He then lays the paper on one side upon a solution of nitrate of silver, and dries it again near the fire. The solution of nitrate of silver which he uses, is diluted with from six to eight parts of distilled water. The dried paper is ready for use. If properly prepared, Mr. Talbot considers it suited for all photographic purposes. He states that it gave, for instance, beautiful impressions of leaves, flowers, &c., more especially under the rays of a summer sun ; the light passes through the leaves, and copies even the most delicate veins.

Mr. Talbot found by experiments that there exists a certain definite proportion between the quantity of the salt, and that of the nitrate of silver in solution ; and that the chief effect of the operation fails, if this proportion is departed from. The use of an over-large quantity of salt tends to impair the sensitiveness of the paper to a greater or less extent.

If we wash a paper prepared by this process, in a saturated solution of common salt, and dry it again, we find that it has almost completely lost its sensitiveness to light, more especially, if an interval of several weeks had elapsed between the two processes. But, upon washing it now again with the silver solution, it re-acquires its sensitiveness, and even in a higher degree than after the first process. I have succeeded in this way, by repeated alternate washing with the salt solution, and the silver solution, and drying after each operation, to heighten the sensitiveness of the paper sufficiently to produce a picture on it in the camera.

The results obtained in these experiments are influenced by trifling differences in the respective proportions used of the salt and the nitrate of silver. Sometimes the chloride of silver on the paper will turn black even in the dark, which is a sign that an *excessive* degree of sensitiveness had been imparted to it. The operator must endeavour to hit the proper point, imparting to the paper exactly that degree of sensitiveness which, whilst leaving the color unchanged in the dark, brings about a change in it upon the least exposure even to the dullest daylight. In my own experiments I prepared a number of papers, all of them differing in the chemical proportions of the agent used ; I cut off a small piece of each, putting corresponding numbers on the papers and the samples cut off, and placed the latter in a faint diffused light ; I then selected the papers for use the samples of which had suffered the greatest change of color.

A simple experiment will suffice to explain this different sensitiveness to light in paper prepared with the same agent, but used in different proportions. Let a thin layer of chloride of silver be precipitated on a piece of clean glass, which may most appropriately be effected in the following manner : lay a piece of clean glass flat on the bottom of a rather deep vessel, fill the latter with a weak solution of common salt, and add a few drops of solution of nitrate of silver, just sufficient to impart a milky appearance to the fluid ; the chloride of silver formed will speedily subside, and settle on the glass plate ; as soon as this has taken place, remove the supernatant liquid by means of a small glass syphon ; take off the last traces of moisture from the plate with a common spun cotton wick. In this way a thin coating of pure chloride of silver is obtained on the glass. After drying, expose the plate to light in a somewhat slanting position, and let a few drops of solution of nitrate of silver fall upon it at the upper edge ; you will see that the chloride of silver turns black most speedily and most intensely at the borders of the little channels made in the coating by the solution of the nitrate of silver—which clearly shows that a slight excess of silver increases the sensitiveness of the chloride of that metal.

I would recommend the following proportions of chloride of sodium and nitrate of silver, to prepare a paper suited to receive impressions in the camera.

Dissolve fifty grains of chloride of sodium (common salt, Na Cl), in an ounce of water, imbibe the paper with this solution, and then dry it, first between folds of blotting paper, and finally near the fire.

Brush the paper now on one side with a solution of 120 grains of nitrate of silver in one ounce of water, and dry it again near the fire; repeat the application of the nitrate of silver, and dry again near the fire. For the chloride of sodium, you will often have occasion to substitute chloride of ammonium (NH_4Cl) or chloride of barium ($\text{BaCl} + 2\text{HO}$); in such cases you ought to use of the former salt thirty grains, of the latter forty grains, to one ounce of water. Of course, if you do not require a highly sensitive paper, you may use a less proportion of silver. All photographic operations demand care and attention. Indifference to the purity of the materials used, or inaccuracies in weighing and measuring, will always prove serious obstacles to the attainment of satisfactory results. The selection of the paper also requires the greatest care. Paper intended for photographic purposes should always be of equal and uniform texture throughout, and perfectly free from spots; it should combine with the highest possible degree of transparency sufficient thickness to intercept the light more or less completely in the dark parts of the picture. The excitable coating, to be properly sensitive, must be on the surface, not in the substance of the paper, as a few experiments will suffice to show.

Talbot observed, in his earliest photographic experiments, that however carefully he had prepared his paper with the same agents and in the same proportions, still it often proved almost entirely void of sensitiveness in some parts. All other photographers have since made the same observation. Upon exposure to light, a paper of the kind shows sharply-defined white spots, whilst the other parts turn black with the greatest readiness. Occasionally the spots are of a bluish color, with perfectly white borders. The only cause to which this imperfection can be attributed, seems to be the following: the chemical compound used is present in two distinct different proportions in the dark and in the light parts. If we examine the matter more closely, we find that the same paper absorbs the fluid more copiously in some parts than in others; accordingly, the quantity of the salt absorbed is also greater in some parts than in others. Now, upon brushing subse-

quently the solution of nitrate of silver over the paper, some parts of it will get fairly coated with the requisite quantity of chloride of silver, and the proper excess of the nitrate; whilst other parts receive only a coating of pure chloride of silver, or, worse still, of a double chloride of silver and sodium. These imperfections in the prepared paper may to some extent be guarded against by spreading the solution of salt uniformly over the paper with a sponge, instead of immersing the sheet in the brine.

Fixing the Picture.

To make the picture produced by the light permanent, it must be fixed; otherwise the light parts will also turn dark under the continued influence of light. Various fixing agents have been proposed. Talbot used first, and with tolerable success, a saturated solution of common salt (brine). This combines with the undecomposed chloride of silver on the paper, forming a double chloride of silver and sodium, which is less liable to be acted upon by light than the simple chloride of silver. However, the pictures fixed in this way acquire, after a time, an unpleasant bluish tone, which in a great measure destroys the original beauty and accuracy of the image; moreover, it would appear that pictures of the kind get bleached in the course of time. Iodide of potassium (KI) has also been recommended; but this salt acts, under the combined influence of light and moisture, much more strongly upon the dark parts of the picture than the chloride of sodium; besides, it converts the white chloride of silver into yellow iodide of silver, a circumstance which is very adverse to the taking of positive copies from negative pictures so prepared, as the yellow color impedes the action of the rays which blacken the salt of silver. The more desirable way is to remove the unreduced chloride of silver entirely from the paper; however, this has its difficulties, since most of the agents which dissolve chloride of silver act also strongly upon the oxide. This is the case more particularly with ammonia. Bromide of potassium (KBr), which has also been recommended as a fixing agent, gives indeed very accurate images, but it imparts the same yellow tint to the paper as the iodide of potassium; moreover, the high price of the iodide and bromide of potassium is a bar to their general application as fixing agents. Hyposulphite of soda ($NaO, S_2O_3, + 5HO$),

which was first recommended by Sir John Herschel, is unquestionably, of all the salts proposed, the best suited for the purpose. The best and safest way of proceeding is as follows: put the picture first in clean water, to dissolve and remove the free nitrate of silver, as completely as is practicable; after this, immerse the picture in water, holding in solution a few grains of chloride of sodium, which will serve to convert into chloride the free nitrate of silver that may still remain adhering to the paper; if you neglect this precaution, the hyposulphite of soda will convert the remaining nitrate into sulphide of silver, which will impair the beauty of the image by its brown color, and will, moreover, in the course of time, tend to destroy it altogether. Now immerse the picture completely in a solution of hyposulphite of soda; after some time, take it out, and dip it in pure water; lay it on a glass plate, and float it over with pure water, until the water running off tastes no longer sweetish; which is a safe sign that the chloride has been removed, as the compound formed with it by the hyposulphite of soda has a very sweet taste, by which it may readily be detected. It is a peculiarity of this method of fixing that all the delicate parts of the picture which seem to have suffered in the process, reappear with the most perfect distinctness after drying.

The picture may be fixed also by washing it with a solution of chloride of mercury (corrosive sublimate, Hg Cl), rinsing it subsequently in water, and letting it dry. This operation renders the picture perfectly invisible, and leaves, in the case of silver chloride paper, a white, in that of iodide paper, a yellowish surface. But the invisible picture may be brought to light at any time, by washing with a solution of hyposulphite of soda, rinsing in water, and drying. It may be mentioned here, that there is a vast difference in fixing pictures taken in bright sunlight, and such as have been taken in common daylight: the former lose little or nothing of their beauty and distinctness by the process of fixing, whereas the latter lose considerably.

IODIDE OF SILVER (Ag I).—Perfectly pure iodide of silver may be exposed a long time to the action of light, without suffering any perceptible alteration, except in some cases, where a slight increase in the intensity of the yellow tint is observed, which is to be attributed, perhaps, to the calorific rays, as the application of heat to the iodide of silver produces the same effect. But in presence of a little free

nitrate of silver, the iodide of that metal is much more sensitive to light than the chloride.

Prismatic Analysis.—The change which the prismatic spectrum produces on paper prepared with a weak solution of iodide of potassium (KI) and nitrate of silver, presents certain interesting peculiarities. The maximum of intensity is formed at, or a little beyond, the edge of the most refracted ray (the violet ray); however, it varies a little with different papers, and also with the quantity of the free nitrate of silver present. The effect begins almost in the middle of the red ray, where the paper assumes a lead or ash-color, whilst under the most refracted rays it acquires a reddish-yellow color; the change produced under the blue ray, or rather towards the end of the blue and beginning of the violet ray, appears rather suddenly; beyond the border of the violet ray, the effect decreases very rapidly; still the nigrescence produced by the invisible rays is more strongly marked than in the case of chloride of silver.

Photographic Application.—Paper prepared with iodide of silver deserves the preference before all others. The best proportions to use the iodide of potassium and nitrate of silver in, are twenty grains of the former, and forty grains of the latter, dissolved each respectively in one ounce of water. The paper is carefully brushed over with the nitrate of silver solution, and dried; it is then washed over on one side with the iodide of potassium solution, and dried near the fire, taking care, however, not to expose it to a strong heat, since this would change the fine straw color to a rusty tint, and would nearly altogether destroy the sensitiveness of the paper.

By combination with certain agents, iodide of silver acquires an extraordinary degree of sensitiveness. This is the case more particularly as regards the combination with gallic acid ($\bar{G} = C_7 H_3 O_5 + HO$), or that with the yellow ferrocyanide of potassium ($2KCy, FeCy + 3HO$), whereby the most beautiful results may be attained.

We will now proceed to give a description of the several processes of using the iodide of silver in conjunction with these agents, commencing with the one to which the inventor, Mr. Talbot, has given the name *Calotype*.

Preparation of the Paper.—Dissolve 100 grains of crystallized nitrate of silver in six ounces of distilled water, and brush over the

paper with this solution on one side only ; mark the side and let the paper dry, either near a fire, or in a dark room. As soon as it is dry, dip it for two or three minutes with the prepared side in a solution of 500 grains of iodide of potassium in sixteen ounces of water, wash it now in distilled water, and dry it either near the fire, or in a dark room. It is always advisable to perform all these operations in a dark room by candle or lamp-light. The paper so prepared has a beautiful straw color (from the iodide of silver), and is scarcely sensitive to light ; it must nevertheless be kept carefully secluded from light until it is required for use ; but in this way it may be kept for a long time without suffering alteration. When the time has come to use it, it is treated as follows :

Dissolve 100 grains of crystallized nitrate of silver in two ounces of water, and add to the solution a half-ounce of strong acetic acid.

Make a saturated solution of crystallized gallic acid in distilled water. When you want to make a calotype picture, mix these two solutions in equal proportions, but only so much of them as is needed for the operation, as the mixture speedily undergoes decomposition. With this solution of gallo-nitrate of silver the silver iodide paper is washed over upon the marked side with a soft brush. After half a minute the paper is dipped in water, and dried lightly by pressure between folds of blotting-paper. The operation must be performed by candle-light.

Although the paper so prepared may be kept several days, nay even several months, without losing its sensitiveness to light, still the better way is to use it at once, as it is apt to acquire a black tint even in perfect darkness.

Paper prepared in this way is exceedingly sensitive to light ; an exposure of one second's duration to common daylight, suffices to bring on an incipient change of color. If a piece of this paper is half covered over, leaving the other half exposed to the light of day, the least possible space of time suffices to bring about an alteration in the exposed part ; this alteration, however, is not visible, but latent. If the paper is laid by in the dark, the alteration becomes visible after a time ; or it may be brought out at once, by washing the paper again with the gallo-nitrate of silver, and holding it near a fire, whereupon

the parts acted upon by the light will acquire a dark-brown tint, whilst the other parts will retain their original color.

If you have taken an impression on the paper so prepared, and have developed it in the manner just now indicated, you must proceed to fix it, which is done by washing it first in water, and then dipping it in a solution of 100 grains of bromide of potassium in ten ounces of water, removing it after a few minutes, washing with water, and drying. In default of bromide of potassium, you may have recourse to common salt, or to hyposulphite of soda, which latter answers the purpose better than salt.

The discovery of the extraordinary property of gallic acid to heighten the sensitiveness of iodide of silver so greatly, is one of the most beautiful that Mr. Talbot has made in the domain of photography. The calotype process gives pictures of the greatest beauty, which not only most faithfully render the outlines of the object, but copy it even in the minutest details; leaving in fact nothing to be desired except the natural colors; and even this defect is in a great measure compensated by the marvellous harmony of the *ensemble*.

The picture produced in the camera is negative. When it has been properly fixed, any given numbers of positive copies may be taken from it. The process of reproduction is conducted as follows:—Lay the negative picture upon a leaf of positive paper prepared in the manner indicated, and put under the latter a smooth and even board, with a few sheets of soft paper on it; place above the negative an even, clean glass plate, so that the prepared paper and the negative lie between the board and the glass; press them closely together, to secure the contact of the papers. The frame of reproduction, or reversing frame, will be found to answer the purpose best for this operation. The time of exposure depends, of course, upon the transparency of the negative picture, and the intensity of the solar light. I need hardly mention that all the imperfections of the negative are necessarily transferred to the positive picture; it is therefore always advisable to select for the negative impression an absolutely equal and uniform paper, or a thoroughly transparent mass, such as glass, for instance (see *VITROTYPE*).

The share which the gallic acid has in the alterations produced will be easily understood if we remember that this acid precipitates the

metallic silver from the solutions of the salts of that metal. If the solutions of the gallic acid and the nitrate of silver be mixed in very feeble diffuse light, a precipitate will almost immediately form, although in the dark the same mixture remains clear for hours. Now if this clear mixture is put on a paper prepared with salt of silver, and which is sufficiently sensitive, or has been exposed already to light long enough to produce an alteration, the black precipitate of metallic silver forms almost instantaneously on the parts acted upon by the light, and indeed in exact proportion to the alteration suffered; the parts which have not been touched by the light, remaining white and unaltered. To keep these parts white, it is advisable to promote the decomposition by the application of heat, or by hot aqueous vapor. It requires some practice to obtain satisfactory results; for if the action of the gall-nitrate of silver upon the silver salt on the paper, and which has been changed by the agency of light, is not stopped at the proper time, the negative image produced will not answer the purpose of reproducing positive copies from it, the whole surface of the paper being liable to turn black.

This method may, however, be considerably simplified; but before we proceed to speak of this, we will here briefly glance at the alterations which gallic acid produces in various compounds of silver that have been exposed to light.—Paper simply imbibed with a solution of nitrate of silver, gave, after two minutes' exposure in the camera, only a faint image, upon being washed with gallic acid. Paper prepared with chloride of silver gave under the same circumstances a tolerable picture, but deficient in force and clearness. Bromide of silver gave a very beautiful picture, after one minute's exposure. Tartrate of silver, after ten minutes' exposure in the camera, appeared to remain unaffected by the gallic acid. Oxalate of silver, after ten minutes' exposure, gave only a very feeble image. With phosphate of silver, the result was not quite satisfactory. Carbonate of silver gave, after five minutes' exposure, a tolerably good picture. Benzoate of silver, and formiate of silver, gave very satisfactory results. Benzo-formiate of ammonia, in combination with nitrate of silver, gave results similar to those obtained with the iodide; this preparation is remarkably well suited for taking architectural views. Cyanide of silver, and cyanide of silver and iron, after ten minutes' exposure in the camera, showed

no alteration upon washing with gallic acid, nor with gallo-nitrate of silver. I have also tried several other compounds of silver. The general results of my experiments have shown that gallic acid, though unquestionably a most important photographic agent, is not sufficiently powerful in all cases to bring out the alteration suffered. The action may indeed be considerably strengthened by an addition of nitrate of lead (PbO, NO_3): still, even with this addition, it falls short of the energetic action of pyrogallic acid ($\text{p}\bar{\text{G}} = \text{C}_6\text{H}_3\text{O}_3$); which ought therefore always to be used in preference. In many preparations of silver, the reaction of the gallic acid becomes manifest only after the paper has lain for some time in the dark, or after the application of heat. Hyposulphite and hyponitrate of protoxide of iron may be employed in photography for the same purpose as the gallic acid, and with the same success; the former of these two salts has even a much more energetic action than the acid.

IODIDE OF SILVER AND FERROCYANIDE OF POTASSIUM. If paper prepared with iodide of silver in the usual way, is washed with solution of ferrocyanide of potassium ($2\text{KCy} + \text{Fe Cy}$), it acquires upon exposure to light instantaneously a greenish-black color, and turns afterwards still darker. This alteration is most speedy with iodide of silver perfectly pure and free from all foreign admixture. Although the same effect is produced irrespective of the proportion in which the salts are mixed, still it is better that there should be a minimum of alkali.

The best results are obtained with paper prepared in the following way:—

Brush the paper over on one side with a solution of two drachms of nitrate of silver in an ounce of distilled water, and dry it as quickly as possible; then brush the paper over on the same side with a solution of a drachm of iodide of potassium in an ounce of distilled water, lay it with the non-prepared side on a glass plate, and wash the whole of the soluble salt carefully away by floating the prepared side over with water. The paper may now either be used at once, or kept for future experiments. When you wish to use it, you need simply imbue it with a saturated solution of ferrocyanide of potassium, and place it in the camera.

The fixing of the pictures produced on paper so prepared is still in some degree uncertain. It often occurs that of several pictures which

have been fixed in one and the same way, some will speedily fade, whilst others will show no alteration. This fading of the pictures would seem to be owing to part of the protocyanide of iron having remained in the paper, which tends to destroy the image. The following is the best way of fixing pictures on paper prepared with iodide of silver and ferrocyanide of potassium: immerse the picture for some time in hot water, which should be repeatedly renewed; dip it afterwards in a weak solution of iodide of potassium, wash it thoroughly in cold water, and dry.

The high degree of sensitiveness of this paper is evidently owing to a mutual decomposition of the ferrocyanide of potassium and the iodide of silver under the influence of light.

Ferrocyanide of potassium may be used advantageously also with other compounds of silver, more especially with bromide and chloride of silver, whose sensitiveness it heightens considerably.

Production of Positive Pictures in the Camera, by means of Hydriodates.

When photographic paper, blackened by light, is washed with a solution of an hydriodate, the dark parts are bleached again upon subsequent exposure to light.

This property has been turned to account to effect the production of positive pictures by direct exposure in the camera.

The paper may be prepared with any of the sensitive salts of silver: however, chloride of silver has been found to answer best. Chloride of ammonium and chloride of barium are the salts best suited to prepare the silver chloride paper with, as the light acts most readily upon a surface prepared with these salts, producing impressions of great accuracy and fineness of delineation. The paper is prepared as follows:—

Dip the paper for from five to ten minutes in a solution of forty grains of either chloride of ammonium, or chloride of barium, in four ounces of water, and let the paper dry. Make a solution of 120 grains of nitrate of silver in twelve ounces of water, and add four ounces of alcohol, which will render the solution slightly turbid; let the mixture stand a few hours, and then filter off the fluid from the slight precipitate which has subsided in it. Imbue the paper with the filtrate, and expose it still wet to the sunbeams, when it will speedily

turn black. The nigrescence is not uniform, however, owing to unequal absorption of the fluids ; you must, therefore, imbue the paper once more with the solution of nitrate of silver, and expose it again to the light until it has acquired all over a uniform chocolate color, when you may dry it and keep it ready for use.

It is indispensable to perform this operation in the unclouded light of the sun ; since, strange though it may appear, it is no less true, that the clouds which may happen to obscure that luminary are faithfully, though very faintly, reproduced on the paper, and make their appearance in the next operation.

When you want to make use of the paper so prepared, you must imbue it with a solution of iodide of potassium, and expose it wet in the camera. The proper proportion in which the iodide of potassium should be used has not yet been definitely settled, though thirty grains of pure salt to an ounce of water would appear to answer best ; this is a question of great nicety, however, as a few grains more or less make a considerable difference in the results. For my own part, I should prefer iodide of barium to iodide of potassium, taking care to remove previously some of the barium by precipitation with one or two drops of diluted sulphuric acid or sulphate of baryta.

To fix the pictures obtained by this process, they should be washed with cold water, and then treated in the usual way with solution of hyposulphite of soda.

From the length of the time of exposure required (fifteen to thirty minutes), this method is adapted only for taking impressions of architectural objects.

BROMIDE OF SILVER (Ag Br).—Though light produces no visible effect upon perfectly pure bromide of silver, there can be no doubt but that this salt, even in the pure state, suffers alteration from the influence of that agent, as may indeed be readily demonstrated by the application of the proper reagents.

But when a trifling proportion of nitrate of silver is admixed to the bromide, nigrescence ensues instantaneously upon exposure to light.

Bromide of silver is a most important photographic agent. It is often added to the iodide to increase the sensitiveness of the latter. But it may also be used alone, in the following manner :—

Imbue paper with a solution of 100 grains of nitrate of silver in an

ounce of distilled water, and let it dry; imbue it now with a solution of twenty grains of bromide of potassium (KBr) in four ounces of water, and place it finally again in the silver bath. The paper so prepared is exceedingly sensitive; but it cannot be kept long, as it suffers alteration even in the dark. If the paper is intended to be preserved for use at some future time, a less proportion of nitrate of silver must be used.

To take an impression on the paper so prepared, it is imbued with a solution of 120 grains of nitrate of silver in an ounce of water, and exposed wet in the camera; after a few seconds' exposure it is removed from the camera, and let dry in the dark. When dry, it is placed in the mercurial apparatus, and the mercurial fumes are evolved slowly by the application of a gentle heat; the image developed often looks quite clouded or veiled over with a film; but in the course of a few hours this goes off, and a very accurate and vigorous impression appears on the paper. The best way to fix this is to wash the paper in brine, and to treat it afterwards in the usual way with hyposulphite of soda. The image may be developed also by means of an aqueous solution of gallic acid or of pyrogallic acid.

FLUORIDE OF SILVER (AgF) suffers about as little alteration under the influence of light as nitrate of silver, though it turns much darker in the course of time than the latter. Used in conjunction with bromide of silver, it considerably heightens the sensitiveness of the latter, more especially if fluoride of sodium (NaF) is employed in the operation. Although the proper proportions in which the two salts (the bromide of potassium and the fluoride of sodium) ought to be mixed are not yet quite settled, still I think the following proportions will be found to answer the purpose: twenty grains of bromide of potassium, and five grains of fluoride of sodium, dissolved each in one ounce of water. To save time, the two solutions may be poured together, and the paper imbued with the mixture; when the paper is dry again, it is imbued with a solution of sixty grains of nitrate of silver in an ounce of water, and subsequently washed carefully in water, to remove the nitrate of potassa formed. Paper so prepared will keep unaltered for several weeks, and may be exposed in the camera in the dry state. After its removal from the camera, it is drawn through water, and then floated over with a weak

solution of sulphate of protoxide of iron (green vitriol, Fe O , $\text{SO}_3 + 7\text{HO}$), whereupon the impression will at once make its appearance. As soon as this is deemed sufficiently distinct, the paper is washed in water, and the picture is then finally fixed with hyposulphite of soda.

PHOSPHATE OF SILVER (AgO, PO_3) is only suited to copy positives from negatives, as it is too little sensitive for exposure in the camera. Phosphate of silver paper is prepared as follows: imbue the paper with a solution of phosphate of soda, and let it dry; imbue it now with a solution of nitrate of silver, let it dry again, and imbue it once more with solution of phosphate of soda. The paper so prepared is well suited for copying positives from negatives, and affords this advantage, that the impressions on it may be easily fixed with a weak solution of ammonia, which readily dissolves the undecomposed yellow salt of silver, leaving the decomposed parts quite unaltered. Phosphate of silver paper, blackened by the influence of light, may be bleached again in the manner described at page 50, and may then be used for the direct production of positive impressions in the camera.

TARTRATE OF SILVER (AgO, Tr).—To make tartrate of silver paper, imbue the paper with tartaric acid ($\text{Tr} = \text{H}_2\text{C}_4\text{O}_6$), or with a solution of a tartrate, and treat it then in the usual way with solution of nitrate of silver. Tartrate of silver seems at first only feebly affected by light, but after a time it grows darker under the influence of that agent than any other salt of silver; for which reason it is admirably adapted for positive pictures. Its want of sensitiveness, on the other hand, is a bar to its use for negative images. The sensitiveness may, however, be somewhat increased by an addition of iodide of potassium or of yellow ferrocyanide of potassium.

To mention all the silver salts which I have tried would lead us too far here, and would, besides, be of but little practical utility, as some of them are too dear for general use, and others of too dangerous a nature, as *e.g.*, arseniate of silver. Still I may remark here, that agreeable variations in the color of the picture may be produced by means of some of them, such as the chromide, benzoate, formiate, and others.

The combination of nitrate of silver with ammonia is particularly well suited for positive images, to which it imparts a remarkably warm and pleasant tone. The mode of preparing the paper with nitrate of silver and ammonia is very simple. It is well known that upon

addition of ammonia to a solution of nitrate of silver, a whitish precipitate forms, which redissolves in an excess of ammonia. Now, paper need simply be imbued with this fluid (solution of nitrate of silver to which ammonia in excess has been added), and dried, to be at once ready for use. The pictures on this paper are fixed in the usual way.

Let it be borne in mind that, wherever hyposulphite of soda is employed as the fixing agent, the greatest care must be taken to wash from the paper every trace of soda; since, if the least particle of that substance be left behind, the picture will after a time show spots, or will even be altogether destroyed. Simple immersion in water will not suffice; the paper must be moved about in the bath, and the water must be repeatedly renewed.

COMPOUNDS OF GOLD.

It is a well known fact that an ethereal solution of gold is decomposed by light, the metallic gold separating at the side of the vessel turned to the light. Most of the salts of gold present a similar deportment under the influence of light; and they would accordingly find frequent application in photographic processes, if they were not rather too expensive.

If paper imbued with a solution of neutral chloride of gold ($\text{AuCl}_3 + 6\text{HO}$), is exposed to the sunbeams, its color changes at first to a lighter hue, but after a time it grows gradually darker, and acquires finally a purple tint. Though the chloride be now removed out of the influence of light and placed in the dark, the decomposition will continue, until the gold is completely reduced to the metallic state. The decomposition is greatly promoted by dipping the chloride in cold water. Employed in conjunction with nitrate of silver, the chloride of gold is acted upon more rapidly, and gives very fine positive pictures.

A most sensitive gold paper, which very speedily acquires a purple tint in the light of the sun, may be prepared as follows:—imbue the paper with a solution of thirty grains of oxalate of ammonia (NH_4O , $\text{C}_2\text{O}_3 + \text{HO}$) in an ounce of water, dry it, and then imbue it with a saturated solution of chloride of gold. To fix the picture produced on this paper, it is dipped, first in cold water, afterwards in a solution of ferrocyanide of potassium, and finally washed in water.

Paper prepared with acetate of lead ($\text{PbO}, \bar{\text{A}} + 3\text{HO}$) and chloride of gold, is less sensitive than the preceding; it presents, however, certain interesting peculiarities. When this paper is exposed to light, the yellowish brown color turns at first of a paler hue; subsequently it changes to a light grey, and acquires finally a slate color. If the action of the light is interrupted, ere the coloration has proceeded so far, and the paper is held in hot steam, or dipped in hot water, the parts acted upon by the luminous rays acquire immediately a deep purple tint; cold water produces the same effect, but only very slowly. Dry heat has no perceptible influence.

The compounds of gold with cyanide of potassium and nitrate of silver, and various other salts, give very satisfactory results; still the impressions are inferior to those obtained with silver; moreover, the high price of gold forbids its general application in this branch of photography. It is often used, however, to impart a deeper and more pleasant tone to the positive pictures produced on silver paper; this is done simply by dipping the picture, after fixing it with hyposulphite of soda, in a feeble solution of chloride of gold, and washing it afterwards in water.

COMPOUNDS OF PLATINUM.

The compounds of platinum also may find application in the photographic art; however, the pictures produced with them are of little value, as they speedily fade, and are, after a short time, completely effaced.

Paper prepared first with cyanide of potassium, then with bichloride of platinum ($\text{PtCl}_2 + 8\text{HO}$), and finally with nitrate of silver, is speedily acted upon by light, giving a very beautiful deep lilac-colored positive picture. If the nitrate of silver is placed on the paper first, or if it is present in excess, the picture produced appears as distinct on the left as on the right side. Iodide of potassium seems to be the best fixing agent for platinum pictures; however, as has already been intimated, no precaution, not even absolute seclusion from light, can prevent the gradual fading and final effacement of the picture; after a few months nothing is left of it but a piece of white paper. The compounds of platinum with iodine or bromine give the same ephemeral results.

If the paper prepared with cyanide of potassium, bichloride of platinum, and nitrate of silver, is imbued with a solution of chloride of mercury (Hg Cl), and exposed in the camera for about fifteen minutes, there is hardly a perceptible alteration in it; however, upon application of ammonia to the prepared surface, a deep black positive picture appears on an iron-grey ground. If this is dipped in a solution of chloride of mercury, a negative picture is produced by the solution of the dark parts. Application of dry heat destroys the whole picture.

COMPOUNDS OF IRON.

Almost all the salts of iron suffer a very perceptible alteration under the influence of sunlight; some of them sooner, others later. The change is most easily observable in the salts of the sesquioxide with organic acids. Some of these salts, and more especially the double salts which they form with ammonia or with potassa, are so readily decomposed by light, that they may be used for the production of negative pictures in the camera; still, they are better suited for positive pictures.

But what imparts to the salts of iron a peculiar value in a photographic point of view, is the property which they possess to produce with different reagents a variety of colors.

This property, and the facility with which they are decomposed by light, make them, under circumstances, fit substitutes for the salts of silver, to which they are even preferred in certain cases.

The most important of these salts are,—the oxalate of sesquioxide of iron and ammonia, the citrate of sesquioxide of iron and ammonia, and the tartrate of sesquioxide of iron and ammonia. The compounds of the oxalate, citrate, and tartrate of sesquioxide of iron, with potassa or soda, and the double sulphate of sesquioxide of iron and ammonia ($\text{NH}_4\text{O}, \text{SO}_3 + \text{Fe}_2\text{O}_3, 3\text{SO}_3 + 24\text{HO}$) are also very sensitive to light.

Photographic paper may be prepared with any one of these salts in the following simple manner:—

Dissolve one part by weight of the salt in ten parts by weight of distilled water; brush the solution over the paper on one side, and let it dry in the dark. The paper is now ready for use. It may be kept

for years without the slightest loss or diminution of sensitiveness. The best suited for exposure in the camera is the oxalate of sesquioxide of iron and ammonia. The paper prepared with this compound is exposed in the usual way for a longer or shorter space of time, according to the intensity of the light and the illumination of the object; when removed from the camera, no sign of the picture is perceptible, or, at all events, only a very faint trace of it; but it becomes visible at once upon the application of one of the reagents which we shall immediately proceed to name. However, as has been intimated already, these salts are more advantageously used to reproduce positive from negative pictures; for this purpose, they may be said to answer each of them almost equally well. The negative picture intended to be reproduced, is applied on one of the iron-papers, and affixed to it at two ends with glue, gum, or paste; it is then put in the frame of reproduction, and exposed to light (to the solar rays, if possible). The overlapping parts of the paper speedily show a brown tint; the frame is examined from time to time, to see whether the picture is done. The time of exposure depends upon the degree of intensity of the light; in bright sunshine, from three to five minutes are generally sufficient. Though the impression should only be faintly visible, or even nearly invisible, the application of the proper reagent will speedily bring it out.

The picture is then taken out of the frame and brushed over with a solution of red ferricyanide of potassium (3KCy , Fe_2Cys) in water (no matter the proportion, provided always the solution be not too highly dilute), which will immediately bring the picture out with a very intense blue color; the solution should be applied with a broad flat brush. Simple washing in water suffices to fix the image. Potassa (KO) destroys the blue color, and with this the picture itself; bisulphate of potassa ($\text{KO}, 2\text{SO}_3 + \text{HO}$), on the contrary, heightens the intensity of the color, and makes it permanent; sulphate of copper (blue vitriol, $\text{CuO}, \text{SO}_3 + 5\text{HO}$), changes the blue color to a pale greenish blue tint.

A green picture is obtained by adding solution of gum-arabic to the ferricyanide of potassium solution. These pictures require no additional fixing; washing in water would change the green color to blue.

Solution of nitrate of silver imparts a deep blackish-brown tint to the picture; simple washing in water suffices to fix it.

Solution of ammonio-nitrate of silver ($\text{AgO}, \text{NO}_3 + 2\text{NH}_3$) imparts a greyish-black tint to the picture; simple washing in water suffices to fix it. It is not advisable to use a brush to apply the solution of nitrate or ammonio-nitrate of silver to the picture, as these substances would injuriously affect the material of that implement. The better way is to pour the solution into a glass or porcelain dish, or over a glass plate laid down horizontally, and to apply the paper with the latent image to the liquid, taking care to leave no air-bubbles under it, since this would give rise to spots, which it would afterwards be found impossible to remove. If a brush be used, however, care must be taken to wash it thoroughly in water immediately after; if this is neglected, the implement is of no further use in operations of the kind, as the silver retained in it would spoil the pictures to which it might happen to be applied.

With ammonia ($\text{NH}_3 + \text{aq.}$) an ash-colored picture is obtained, which is equally distinct on both sides of the paper.

Solution of terchloride of gold ($\text{AuCl}_3 + \text{aq.}$) gives a purple-colored picture, which continues to deepen as long as there remains a trace of undecomposed chloride in the paper.

Arseniate of potassa ($\text{KO}, \text{AsO}_3 + \text{HO}$); gives a yellowish-brown picture, of lighter or darker hue, according to the strength of the solution. Simple washing in water suffices to fix the pictures obtained by the application of this and of the preceding substance.

The use of the arseniate of potassa requires of course great caution, on account of the poisonous nature of the material.

Some very interesting results, and such as no other metallic salts afford, may be obtained with the salts of iron before mentioned, and more especially with the citrate of iron and ammonia.

A paper prepared with the latter salt in the manner indicated, is imbued with a solution of ferricyanide of potassium, and dried in the dark. This paper does not keep long, and should therefore be used soon after its preparation. If a picture has been reproduced on this paper, it need simply be dipped in water, to render it instantaneously visible in blue. If the paper is now imbued with a solution of nitrate of suboxide of mercury ($\text{Hg}_2\text{O}, \text{NO}_3 + 2\text{HO}$), the picture imme-

diately vanishes. The paper must then be well washed in water, that no free mercurial salt may be left in it. The picture may now be rendered visible again with brown color, by the simple application of heat (holding it near the fire, or passing a hot smoothing iron over it); it disappears again upon cooling, but may always be brought out anew by the same process. In some cases, it will not at once disappear upon cooling, but will remain visible for weeks.

The following is another interesting experiment. Dissolve one part by weight of citrate of sesquioxide of iron and ammonia in eleven parts by weight of water, and add an equal volume of a saturated cold solution of chloride of mercury; imbue the paper with this mixture, before a precipitate has had time to form, and dry the paper. The color should be yellowish, without the least tinge of blue. Expose the paper now in the frame of reproduction, until a faint but clearly visible image is produced on it. Pass over it with one stroke of a broad brush, a saturated solution of cyanide of potassium, mixed with three times its own volume of a solution of gum-arabic of moderate consistence. The picture will immediately make its appearance; after a few days you may freely expose it to light; it will even bear the light at once, without any great injury. This picture improves with time, parts which at first were half visible, coming gradually out with the greatest distinctness. Another interesting experiment is the following: If a solution of nitrate of silver is added to a solution of bitartrate of sesquioxide of iron, a precipitate is immediately formed, which is almost entirely re-dissolved upon the application of a gentle heat; a further addition of silver solution leaves the fluid clear. The solution of silver should be added in the proportion of one volume to two. The yellowish mixture is filtered; the filtrate may be kept unaltered in the dark. If a paper imbued with this filtrate is exposed *wet* in the camera, no picture appears on it, unless the exposure should have been too long protracted; but after a time it makes its appearance spontaneously. The result is different if the paper is employed in the *dry* state to reproduce positive pictures. For this purpose it suffices to apply the paper on the negative picture, and to expose for from thirty seconds to one minute to the solar rays. The exposure must not be continued until the impression commences to make its appearance, since in that

case it would soon come out spontaneously ; there should be no sign of the picture on the paper. Still the picture is there, and to render it visible, you need simply breathe upon it, or hold it over steam, when it will at once appear with great accuracy and distinctness of delineation. It very often vanishes again as soon as the moisture of the breath or the steam is gone off ; but it may readily be called forth anew in the same way.

Considering the facility and safety with which the salts of iron may be employed, and the great variety of colors that may be produced with them, and also the moderate prices at which they may be procured, it would be very desirable indeed that a series of systematic experiments should be made with a view to ascertain in how far these salts may be suited for the purposes of the practical photographer, and whether they might not in some measure supersede the salts of silver.

COMPOUNDS OF COPPER.

As has already been stated in the chapter on the Daguerreotype, copper also may find application in photography.

The salts of copper, though of inferior sensitiveness, give yet very interesting results in conjunction with other metallic compounds. Among the salts which may be advantageously added to the salts of copper, we mention more particularly that of chromium, and especially the neutral chromate of potassa, and the bichromate of potassa. The latter salt gives in conjunction with sulphate of copper a highly sensitive preparation, with which pictures may be produced in a variety of colors.

A paper imbued with a mixture in equal proportions of a saturated solution of sulphate of copper (copper vitriol, blue vitriol, $\text{CuO}, \text{SO}_3 + 5\text{HO}$), and of a saturated solution of bichromate of potassa ($\text{KO}, 2\text{CrO}_3$), may be used immediately after drying, or it may be kept in the dark for any length of time, without suffering the least diminution of sensitiveness. This paper will, however, serve only to reproduce positives from positives, negatives from negatives. When it is exposed in the frame of reproduction to solar light, the uncovered parts acquire first a brown tint, if the paper is removed from the frame ; at this period the image is negative ; but if the exposure is

continued, the brown color turns to a brighter hue, and a positive picture is produced. If the copy, after its removal from the frame, is treated with solution of nitrate of silver (no matter of what strength), a positive, brick-colored picture is produced in both cases; however, in the latter case, the picture is of greater beauty and vigor than in the former. To fix these pictures, they need simply be quickly washed in perfectly pure water. If the water contains a chloride, or if chloride of sodium is added to it, even in a small proportion, the picture vanishes on the instant, and completely; but it may be brought out again by exposing it, still wet, to the solar rays, and letting it dry. The color however, is now changed, varying, according to the greater or less quantity of salt used, between rose and deep violet. A longer exposure to sunlight serves to improve the picture.

The neutral chromate of potassa may be substituted for the bichromate. If a solution of neutral chromate of potassa ($\text{KO}, \text{Cr O}_3$) is added to a solution of sulphate of copper, a precipitate is thrown down, which when filtered off and thoroughly washed with water, dissolves in water slightly acidulated with sulphuric acid. Paper imbued with this solution has a pure yellow color, which is completely bleached in sunlight. A picture produced on such paper is developed with a solution of carbonate of potassa ($\text{KO}, \text{CO}_3 + 2\text{HO}$), or carbonate of soda ($\text{NaO}, \text{CO}_3 + 10\text{HO}$), or also with a solution of nitrate of silver. It will occasionally happen, more especially if the light was only feeble, that the nitrate of silver bath will impart a uniform tint to the whole surface of the paper, leaving the picture altogether or nearly invisible; however, after the paper has lain by for some time, the picture makes its appearance, the lights being gradually bleached by the sulphuric acid in the paper, until they are perfectly white, which brings out the shadows the more boldly, yet without hardness.

If ammonia is used, instead of either carbonate of potassa or soda, or nitrate of silver, the picture, if it happens to be already visible, vanishes again, but it speedily makes its reappearance, with a faint blue color.

Very interesting pictures may be produced also with bichromate of potassa unmixed with copper. The mode of proceeding is as follows:—imbue paper with a weak solution of starch paste and let it dry:

imbue it now with a saturated solution of bichromate of potassa, and let it dry. It is now ready for use; but it may be kept for any length of time without suffering the least diminution of sensitiveness. To produce a positive copy on this paper, apply a positive original on it, and expose it in the usual way in the frame of reproduction, until you have a vigorous yellow impression on a brownish ground; wash this in water, which will dissolve the undecomposed salt; and then coat the right side over with an aqueous solution of iodine, which will impart a deep violet tint to the picture, leaving the brownish ground unaltered; simple washing in water will suffice to fix the picture.

SALTS OF MANGANESE, LEAD, NICKEL, &c. Of the *salts of manganese* the manganate of potassa (KO, Mn O_3), is the best suited for photographic purposes. A solution of this salt imparts to paper a brown tint, which exposure to the sunlight destroys again in the parts touched by the rays, restoring these parts to their original white color. Addition of nitrate of silver to the manganese salt heightens the brown tint of the paper; but upon subsequent exposure to light, the parts touched by the rays turn intensely black, instead of resuming their original white color. The impressions may be fixed by washing in water, and subsequent treatment with hyposulphite of soda.

The other salts of manganese, although they are also perceptibly altered by light, are not so well suited for photographic purposes.

The *salts of lead* are useful as photographic agents only under certain conditions. Papers imbued solely with them change color continually, which leads to the ultimate destruction of the pictures produced on them. Added in small proportion to other salts, more especially to those of silver, the compounds of lead tend to heighten the intensity of the color; but care must be taken not to add too much of them; since otherwise the picture is apt after a time to turn black all over.

The only compounds of lead with which I have obtained satisfactory results, are the iodide (PbI), used in conjunction with nitrate of silver, or with starch paste; and the nitrate (PbO, NO_3), used in conjunction with protiodide of iron and nitrate of silver. Recently precipitated and thoroughly washed iodide of lead dissolves readily and completely in solution of nitrate of silver. Paper prepared with a solution of

iodide of lead in nitrate of silver is highly sensitive to light. The copies produced on it are fixed by simple washing in water.

A very sensitive paper, and one well suited for taking pictures in the camera, may be prepared also as follows:—

Imbue the paper with a solution of fifteen grains of nitrate of lead (PbO, NO_5) in an ounce of water; dry the paper, and when dry, treat it with an aqueous solution of protiodide of iron ($\text{FeI} + 4\text{aq}$). The paper so prepared will keep a considerable time, if properly secluded from light. It is made sensitive for exposure in the camera, by a bath of one hundred grains of nitrate of silver dissolved in an ounce of water. Should the picture not yet be visible when the paper is removed from the camera, it will speedily make its appearance, without the application of any developing agent. Simple washing in water suffices to fix it.

Or the iodide of lead, recently precipitated, may be intimately mixed in the dark with starch paste, and the mixture spread uniformly over paper; upon exposure to light the paper so prepared will immediately acquire a black color; the pictures produced on it are fixed by dipping in solution of nitrate of silver, and subsequent washing in hyposulphite of soda, and in water.

Of the *salts of nickel*, the best suited for photographic purposes is the iodide (NiI), which is prepared by mixing solutions of iodide of potassium or iodide of potassium and iron, and nitrate of nickel ($\text{NiO}, \text{NO}_5 + 6\text{HO}$). Iodide of ammonium would not answer the purpose. If iodide of potassium and iron has been used, the light blue color of the compound changes to a light green upon exposure to the luminous rays.

There are still many other metallic salts, which suffer alteration under the influence of light, as for instance, nitrate of cobalt, hydrochlorate of cobalt, bichloride of tin, and tartrate of antimony. With these salts pictures may be produced in the usual way.

III.—VITROTYPE;

OR,

PHOTOGRAPHY ON GLASS.

PROPERLY speaking, the term "pictures on glass" is a misnomer, as the glass serves simply as the basis whereon the impressionable material is supported, and takes no part in the production of the image. In fact, were it not that the transparence of the basis forms an essential condition in the subsequent process of reproducing copies from the pictures taken, any other material would answer the purpose equally well as glass.

When Daguerre and Niepce's ingenious invention became known, it was very natural that the wish should arise to discover some means of multiplying in a direct way the pictures produced by the action of light. A great many experiments, and of the most varied nature, were accordingly made with a view to achieve the desired end, but with imperfect success only.

The negative pictures produced on paper, and from which a tolerably large number of copies may be taken, may certainly be looked upon as a considerable step in advance in that direction.

However, as has already been intimated in the introductory part, paper has the almost unavoidable defect of inequalities in its texture; and as all the imperfections and blemishes resulting therefrom are necessarily transferred also to the copies of the picture taken on this material, these copies always require retouching,—an operation which, more especially in unskilful hands, tends to impair the likeness of the picture, and, moreover, consumes much time.

Photographers were therefore naturally led to seek whether some other material, free from the defects inherent in paper, might not be substituted for the latter. Sir John Herschel was the first to try glass for this purpose.

The first difficulty which presented itself with this new material was

the fixing on it of the iodide of silver, or some other excitable substance. Niepce, who occupied himself much with this subject, tried various means to effect the purpose in view, such as albumen, glue, starch paste, &c. ; and, indeed, he obtained very good pictures with these materials, but always at the expense of the sensitiveness of the impressionable surface. These substances, therefore, however so well suited for landscapes, are not well adapted for portraits. In the case of albumen, there is besides some little difficulty in the manipulation which may become a source of defects, and which it requires some practice to overcome ; as the following instructions for *albumenising* glass plates will show :—

Mix the whites of a certain number of eggs with an equal volume of distilled water, and whip the mixture into a froth. When this has become perfectly liquid again, filter the clear portion off, and spread it smoothly and evenly over a well-polished glass plate. When you have succeeded in spreading the albumen evenly over the plate by tilting and inclining the latter in various directions, let the superfluous liquid run off at one of the corners, and put the plate to dry in a place perfectly free from dust, taking care to lay the plate down in an horizontal position : you may promote this process of drying by the application of heat. Although the plates so prepared will keep, yet it is not desirable to albumenise too many at a time, on account of the difficulty of removing the particles of dust which will always somehow settle on them if they are long kept lying by, and which subsequently cause spots in the picture. When you wish to take a photographic picture on one of the plates, expose the plate over dry iodine in the iodine box, until it has acquired a yellow tint ; and then plunge it suddenly, and with all parts simultaneously, into a solution of four drachms of nitrate of silver in ten ounces of distilled water, to which have been added two drachms of crystallisable acetic acid ; wash it now cautiously in water, and expose in the camera. The great point here is to effect the sudden and simultaneous immersion of all parts of the surface of the plate, since upon this depends, in a measure, the success of the operation—for this reason, that the albumen, upon coming into contact with the aceto-nitrate of silver solution, shrinks considerably, which tends to produce cracks in it, and this most in those parts where the immersion has been delayed for however so

short an instant. These cracks are subsequently transferred to the copy.

The picture produced on the plate in the camera is developed with gallic acid, and fixed afterwards with hyposulphite of soda. To save trouble, the albumen may also be iodised previously to its application on the surface of the plate; for which purpose you need simply add per each egg fifteen drops of a saturated solution of iodide of potassium, proceeding in all other respects as instructed above, with the exception, of course, of the iodine-box operation, which would now be superfluous.

Application of steam to the albumenised surface previous to its immersion in the silver bath, may also advantageously be resorted to, as it tends to soften the albuminous coating, and thus to facilitate its impenetration by the silver solution.

The common, or *joiner's glue*, which has been recommended as giving remarkably accurate negative pictures, is, nevertheless, unsuited for the purpose, since it dissolves in the aqueous solutions with which the plate has to be treated after the exposure in the camera; this happens more especially upon treating the plate with the gallic acid, to develop the image; the latter is indeed brought out most beautifully, but in the same instant it melts away again, owing to the ensuing liquefaction of the glue. The same remark applies also to isinglass.

Pure starch paste, made of wheaten flour, is much better suited for the purpose than glue or isinglass; but care must be taken to use only the very purest starch; the article which is sold in the shops being generally adulterated, and altogether useless for photographic purposes. The easiest and simplest way of producing pictures on starch paste is as follows:—

Blend one ounce of pure wheaten starch most thoroughly and intimately with two ounces of water in a levigating dish; add sixteen ounces of boiling water, rapidly stirring the mixture all the while, and then in the same way one drachm of iodide of potassium dissolved in an ounce of boiling water. Strain the liquid through silk to remove all remaining impurities, and spread it then evenly and smoothly over a well polished glass plate, in the same way as the albumen; dry it at a tolerably high temperature, and proceed in all other respects as with the albumenised plate.

Caseïne, dissolved in ammonia, has also been recommended ; this substance gives a very pure and clear coating.

But the best and most suitable of all substances recommended for vitrotpe purposes, is unquestionably *collodion* or *collodium*. Collodium is a solution of gun-cotton in ether, which had always best be procured ready-made from a respectable chemist's. The collodium of the shops is, however, generally much too thick to spread readily and evenly over the surface of the plate ; it must accordingly be diluted to the requisite point with sulphuric ether, perfectly free from the least admixture of acid ; on the other hand, care should be taken not to add too much ether, since over-tenuity of the collodium film would tend to impair the sensitiveness of the impressionable surface.

To the sufficiently dilute collodium is now added either simple tincture of iodine (which proceeding, however, gives a product of inferior sensitiveness), or iodide of ammonium ; or, and this is unquestionably the best way, iodide of silver at once. If you elect to use the second of those agents (iodide of ammonium), add to six ounces of collodium of the proper degree of dilution, one drachm of iodide of ammonium, and four grains of fluoride of potassium, moistened with from four to six drops of distilled water. There is no need that the iodide of ammonium and fluoride of potassium should be quite dissolved before being added to the collodium, as these substances readily dissolve in the latter ; the use of much water, would, moreover, be rather hurtful, as it would tend to impair the adhesion of the collodium to the surface of the plate, and might thus lead to the film becoming subsequently detached again in the silver bath. Shake the bottle two or three times, and let it then stand at rest, until the fluid is quite clear and transparent. The color ought to be a pale yellow. However, should the ether or the collodium have contained the least admixture of an acid, the iodide of ammonium will be decomposed by this, and the liberated iodine will impart a dark red tint to the fluid. Should this be the case, the acid must be neutralised, which is effected best by adding a little pulverised cyanide of potassium, and shaking the bottle, whereupon the liquid will speedily show the proper pale yellow tint.

It happens also sometimes that the iodised collodium turns acid from being kept too long ; this state, which impairs the sensitiveness of the preparation, is indicated by the rubescence of the color of the

liquid. Addition of a little pulverised cyanide of potassium will suffice to restore the fluid to its proper condition. But the best way, as already intimated, is to add at once iodide of silver to the collodium, which is done as follows :—

Put ten grains of recently precipitated and thoroughly washed iodide of silver into a bottle holding six ounces ; add some crystals of iodide of potassium, moistened with the least possible quantity of water, but no more of them (viz., crystals of iodide of potassium) than will suffice to effect the solution of the iodide of silver ; fill the bottle now with collodium of the proper consistence, shake the mixture vigorously, and let it stand until the fluid is perfectly clear and transparent ; the color ought to be nearly white, it is however generally a little yellowish.

Iodide of ammonium moistened with alcohol may be advantageously substituted for iodide of potassium, to effect the solution of the iodide of silver ; this substitution will tend to heighten the sensitiveness of the preparation.

The iodised collodium which I now exclusively use, and on which I can obtain impressions of objects in motion, as the time of exposure is less than a second in the open air, is mixed and prepared as follows :—Take an ounce of iodide of potassium, dissolved in the requisite quantity of hot water ; add ten ounces of collodium, eleven ounces of sulphuric ether, eleven ounces of alcohol of ninety degrees, six ounces of absolute alcohol ; mix all these ingredients properly together, shake the mixture, let it stand at rest a day or two, and then filter through felpaper. Should the preparation be still too thick, dilute it with sulphuric ether, alcohol of ninety degrees, and absolute alcohol mixed in the proportion of eleven of each of the two former to six of the latter. With this preparation I use a silver bath of one ounce of nitrate of silver, thirteen ounces of distilled water, and one ounce of crystallisable acetic acid.

As with the object-glasses at present in use, the several parts of a photographic picture lie in a curve, the so-called catacaustic curve, the image must necessarily appear a little distorted, more especially in the more prominent parts of the object depicted. That this must impair the likeness of the picture is self-evident. Nothing can be done to the object-glasses to remedy this evil ; but there is another means

which may be most successfully resorted to in vitrotyping operations, viz., the substitution of bowed instead of level glass plates. The English bowed window-glass answers the purpose admirably; plates of equal curvation are cut out of tables of this glass; the hollow or concave side is then prepared with the silver iodised collodium in the usual way, and turned in the camera towards the object to be depicted. I think it need hardly be observed here, that in the subsequent reproduction of the positive pictures, the glass must be laid with the convex or rounded side upon the paper or other material on which the copies are taken.

The plates of glass, used in vitrotypic processes, must be perfectly clear and free from striæ, as all the blemishes in them would be faithfully reproduced on the copies. The surface which is to receive the film of collodium must be thoroughly cleaned and polished, which is done best with hydrate of potassa (KO,HO), fine Venetian tripoli, and water; washing the plate subsequently in clean water, and letting it dry.

To obtain an even film of collodium hold the plate at one corner between the thumb and index of the left hand, in a perfectly horizontal position, or balance it on the tips of the fingers, and with the other hand pour the silver iodised collodium on the middle of the plate; tilt towards one corner (if you hold the plate between the thumb and index, towards the corner you hold by—taking care not to let the collodium touch the thumb), incline towards another corner, then towards the third, and finally pour off at the fourth corner, resting this on the neck of the collodium bottle. Incline the plate now repeatedly first to the right, and then to the left, until the ridges are removed.

Before the collodium is quite dry, dip it evenly into a bath of nitrate of silver (forty grains of nitrate of silver dissolved in one ounce of distilled water, to which a little acetic acid may be added), lifting up and down to allow the evaporation of the ether, and facilitate the combination of the iodine with the silver. When the greasy appearance is gone, and the film presents a uniform bluish-white color, the plate is ready for the camera.

Some photographers would prescribe a certain fixed time to leave the plate in the silver bath; this is a mistake: a practised eye alone can determine the right point in every individual case, from the absence of

all greasy appearance, and from the bluish-white tint of the film. If the plate looks still greasy, and is exposed in that state in the camera, the picture produced will be spotted and cloudy, and cannot, of course, be expected to give good positive copies.

The time of exposure depends here also upon the power of the sun, and the nature of the subject, and must accordingly be left to individual judgment. The next step is the development of the latent picture; gallic acid is not sufficient here to bring the picture properly out; but pyrogallic acid ($C_6H_3O_3 = p\bar{G}$) gives the desired result. The mode of proceeding is as follows:—

Dissolve two grains of pyrogallic acid in one ounce of distilled water, and add to the solution half a drachm of crystallisable acetic acid ($\bar{A} + HO = C_4H_3O_3 + HO$). Pour the solution over the horizontally placed plate, whereupon the picture will at once make its appearance. Should there be any delay, owing to insufficient exposure in the camera, the development of the picture may be accelerated by addition of a few drops of solution of nitrate of silver. A positive picture is obtained by the addition of from two to three drops of nitric acid. Instead of pyrogallic acid, hyposulphate or hyponitrate of protoxide of iron may be used with the same result; gallic acid, in conjunction with acetate of lead, may also be used as developing agent, but the results are doubtful. The image is then ultimately fixed by pouring a saturated solution of hyposulphite of soda over it, and washing the plate afterwards in pure water; in these last operations, the plate should never be immersed in the fluids, but simply floated over with them; otherwise the film of collodium may become detached from the plate, which involves the risk of its being torn.

As the film of collodium on the plate has lost much of its firmness and solidity by the treatment with the solution of silver, &c., it may be advisable to protect it from damage by a thin coating of a hot solution of colorless gelatine or of isinglass. The solution must be free from all impurities, and must be spread uniformly over the picture and dried at the fire.

A more durable product is obtained by diluting the silver iodised collodium with an ethereal solution of gutta percha; or also by dissolving gutta percha in chloroform, adding to the solution one sixth of its volume of acetic ether, letting the fluid stand at rest for

some time, and finally mixing together equal volumes of this solution, and of the silver iodised collodium. This preparation is exceedingly sensitive, and very solid, and adheres firmly to the glass. A film of this substance is rendered strongly electric by friction, in which state it is liable to cracks.

IV.—ANTHOTYPE;

OR,

PHOTOGRAPHY WITH VEGETABLE JUICES.

BESIDES the metallic substances hitherto enumerated, other bodies of very different nature may also be used in photographic processes : unfortunately the pictures produced with them, though very beautiful, are not permanent, but fade away after a shorter or longer period of time.

Among other substances we mention here more particularly the alcoholic solutions of various resins, and the expressed juices of most young plants and flowers.

The least fugitive of the resin pictures are those prepared with guaiacum resin. If a paper is imbued with an alcoholic solution of guaiacum resin, and is then dipped in water slightly saturated with chlorine, it acquires a beautiful cerulean tint, which is bleached again in the light. A paper so prepared may be used to copy pictures : unfortunately, they are not permanent, but will soon fade away.

Exceedingly delicate and beautiful pictures are obtained also with the expressed juice of young plants, or the coloring matter of them, extracted with alcohol ; but they are still less permanent than the resin pictures.

If paper is imbued with the expressed green juice of the leaves of the young cereals, and used in the same way as chloride of silver paper, to copy pictures on, the uncovered parts are speedily bleached under the influence of the luminous rays, and a most delicate and

beautiful positive copy is produced from a positive original. These pictures need not be fixed.

The juice of the rose and of the violet, tincture of turmeric, and many other vegetable coloring-matters may be used in the same way.

Saw-dust and shavings of mahogany, when boiled in water, yield to that fluid their coloring matter; paper imbibed with this decoction is highly sensitive to light, and gives very pretty pictures; but they are not more permanent than the preceding anthotypes.

PHOTO-LITHOGRAPHY;

OR, PHOTOGRAPHY ON STONE.

To produce pictures on lithographic stones by the action of light in the camera, and to multiply them afterwards by the press in the usual way, is a task beset with considerable difficulties; and I believe that, though a great many photographers have tried their hand at it, no one has succeeded up to this time to solve the problem and to attain the desired end. I have been fortunate enough to find means of producing photographic pictures on stone in the camera, and have even succeeded to take portraits on stone; as early as two years ago I publicly exhibited pictures produced on that material. For certain reasons I cannot give here all the methods which I have found successful; I will however describe the two least difficult ones of them.

1. Select a stone of moderate weight, and fit it into the frame of exposure (if the stone is very heavy you will find it difficult to fix it properly); treat the stone in the usual way, to give it the grain required for a fine crayon tracing. Imbue it now repeatedly with a weak neutral solution of oxalate of sesquioxide of iron, taking care to make the solution as neutral as possible, and to make it penetrate into the stone as deep as can be. A stone so prepared may be kept a very long time without losing its sensitiveness, provided, of course, it be

properly secluded from light. The best way is to expose the stone still moist, but not wet; the time of exposure depends upon the power of the sun, and the nature of the object to be depicted. If the exposure has been sufficient, the image may already be seen in all parts in a brownish color. A solution of carbonate of ammonia is now poured over the stone, which will bring out the picture to the greatest advantage, and will at the same time serve to fix it. The stone is then floated over with water to wash away the soluble salts.

In order to multiply the picture by the press, the stone need simply be made to take the printer's ink on the drawing only, leaving the other parts perfectly clean; this is effected by etching with an acid in the usual way, and the acid best suited for the purpose is highly diluted oxalic acid. The remaining operations are conducted in the same way as is generally done in lithography. By means of this method, impressions may be taken of architectural objects, and multiplied by the press.

2. Prepare the stone in the same way as in No. 1, and coat it over with a solution of asphaltum in ethereal oil; place on it the object to be copied (a drawing, or a negative photographic picture on paper or glass), and press this closely against the prepared surface by means of a strong glass-plate; expose now to the light. The resinous coating loses its coherence in the parts corresponding to the lights of the negative picture. Upon blackening the stone now with lithographic ink, the saponaceous ink adheres to the stone in all these denuded parts, but not in those where the resinous coating remains intact; upon treating this surface afterwards with an acid, the decomposed soap leaves a fatty layer on the denuded parts and on the resinous coating; and on washing the stone now with alcohol or ether, the resinous coat, together with the layer of fatty matter covering it, is removed; whilst in the parts where the fatty layer adheres directly to the denuded stone, no change takes place. By means of this method, and the common etching with an acid, copies of drawings, &c., may be taken by the lithographic press in the usual way.

Gummi guaiacum and other resins may be used instead of asphaltum to coat over the stone.

THEORY OF THE PHOTOGRAPHIC PHENOMENA.

If we inquire the nature of the action of light in the production of the photographic phenomena, we find that the effects produced arise from the decomposing action which light exercises upon metallic compounds, tending to reduce them to the metallic state.

In the case of iodised silver plates, the following appears to me the rational explanation of the phenomena observed.

The iodide of silver formed on the plate in the iodine box, is reduced by the action of the luminous rays to subiodide, the liberated iodine being again absorbed by the plate; this reduction is most considerable in the most strongly illuminated parts; in the less illuminated parts it is much less marked, and in the darkest parts, the iodide of silver is hardly affected at all. Now, upon the subsequent contact of the mercurial fumes with the surface of the plate, the mercury combines with the iodine of the iodide of silver, forming subiodide of mercury, with a corresponding reduction of silver to the metallic state; the quantity of the subiodide of mercury so formed, is greatest in the shaded parts where the iodide of silver is left almost intact, less in the parts feebly affected by the luminous rays, and least in the parts where the action of the light, has been strongest. As regards the shaded parts, the chemical action stops here; but the case is different with the parts previously acted upon by the luminous rays; in these latter parts, the subiodide of mercury formed coming into contact with the subiodide of silver, a double decomposition ensues: the subiodide of mercury separates into two parts, of which one combines with the iodine of the subiodide of silver, and with the iodine of the other part, forming iodide of mercury; the reduced silver and the reduced mercury amalgamating and settling on the plate. The picture accordingly makes its appearance first in the lightest parts, since the quantity of mercury absorbed is the greater, the richer the parts are in subiodide of silver. In the most shaded parts, on the other hand, where iodide of silver alone is offered to the mercurial fumes, there can be formed only a more or less dark film of subiodide of mercury, mixed with metallic silver, which latter substance being in a state of most minute division, exhibits a black tint. But between these two extremes of the deepest shadow and the strongest light, are seen the semi-tints of the object depicted;

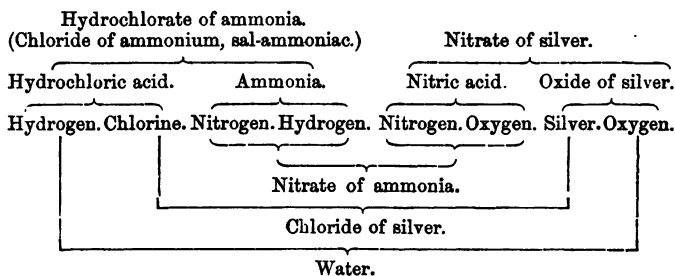
and these semi-tints again are lighter or darker in the different parts of the picture, in proportion to the depth of the film of subiodide of silver respectively covering the several parts, and accordingly in proportion as the iodide has been acted upon more or less vigorously by the luminous rays; and thus we find also after the exposure of the plate to the mercurial fumes, that the shaded parts, being covered with iodide of mercury and metallic silver, look black or greenish, whereas the lightest parts look reddish, from the presence on them of an alloy of silver and mercury in invisible particles, covered with a film of iodide of mercury. Upon washing the plate afterwards with a solution of hyposulphite of soda, the iodide of mercury is dissolved, the subiodide being decomposed at the same time, into iodide, which is then also dissolved, and metallic mercury, which remains on the plate.

The white parts of the picture are accordingly constituted by the alloy of mercury and silver deposited on the plate, and are the more vivid, the more copiously this alloy has been deposited; the dark parts on the other hand are formed by deposits of most minutely divided metallic silver. The production of photographic pictures on paper or glass, is likewise the result of the decomposition by the agency of light, of the metallic compounds forming the impressionable surface; of this fact anybody may convince himself by the following simple experiment:

Take a piece of paper prepared with chloride of ammonium and nitrate of silver, and put it, together with a little potassium, into a perfectly dry glass tube; seal this hermetically, and leave it about twenty-four hours in the dark, to give time for the oxygen of the air in the tube to combine with the potassium. Place the tube now in sunlight: after a few hours you will find that the paper has acquired a black tint; though not of the same intensity as another piece of the same paper, which has been exposed for a much shorter time in the open air.

If you now open the glass under a solution of ammonia, you will not indeed detect any free chloride in it; however, if you examine the potassa salt in the glass, you will find that it is the hydrochlorate, an evident proof that hydrochloric acid must have been liberated from the paper, and have combined with the alkali metal. The several

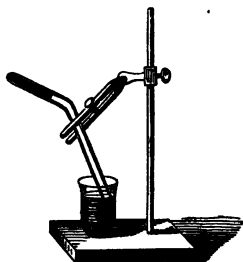
processes of decomposition and combination which have taken place may be briefly stated as follows:—The paper having been prepared with chloride of ammonium and nitrate of silver, we have in it—



There are accordingly contained in the paper, nitrate of ammonia, chloride of silver, and water, and besides these substances a little free nitrate of silver, as has been intimated already on a former occasion. Under the influence of the solar rays the chloride of silver is decomposed, the liberated chlorine probably combining with the hydrogen of the decomposed water, and forming hydrochloric acid with it, whilst the potassium combines with a portion of the liberated oxygen of the water, forming potassa, which again combines with the hydrochloric acid to hydrochlorate of potassa; the liberated silver of the chloride combines with the other portion of the oxygen to oxide of silver.

The liberation of the chlorine may be equally demonstrated by another very simple experiment. Put a little pure chloride of silver into a bent glass tube, closed at one end, and confine the other end under water (see figure 10); expose the chloride in the tube to light, taking care to shake the tube occasionally, in order that the whole of the chloride may be brought under the influence of that agent. As soon as the chloride of silver begins to acquire a black tint, the water will be seen to rise in the tube. When the whole of the chloride has become black, add a few drops of solution of nitrate of silver to the water, when

Fig. 10.



the formation of a precipitate of chloride of silver will at once demonstrate the presence of chlorine in the water.

This simple experiment sufficiently shows that the chloride of silver suffers decomposition under the influence of light, chlorine being set free, and the reduced silver combining with oxygen instead.

The same explanation of the process applies of course equally to the iodide and bromide, and other salts of silver. The use of gallic acid to develop the latent image rests upon the great affinity of that acid for oxygen, by virtue of which it decomposes the salts of silver; properly speaking, therefore, this acid simply serves to complete what the light has already begun. The action of the light has tended already to loosen the connection between the component elements of the silver-salt, in the parts touched by the luminous rays; in these parts, therefore, the gallic acid readily succeeds in reducing the silver to the metallic state; the minutely-divided reduced silver exhibiting a black tint. In the parts that have not been acted upon by the light, on the other hand, the silver salt has remained unaltered, and the gallic acid cannot, therefore, effect the separation of metallic silver here so speedily as in the parts impressed by the light. Now, upon treating these pictures afterwards with hyposulphite of soda, the unaltered salt readily dissolves in this agent, and is thus removed; whereas, the separated silver is but very little affected, and remains in the substance of the paper in a state of minute division; the picture appears accordingly negative (that is, if produced in the camera in the usual way). Instead of gallic acid, other substances, that have a strong affinity for oxygen, such as hyposulphate, sulphate, and hyponitrate of protoxide of iron, may be used with the same result; also the alcoholic solution of many ethereal oils, more especially of the oil of cloves (*oleum caryophyllorum*), and of cinnamon (*oleum cinnamomi*); these latter, however, act much more slowly than the other substances named.

In the case of the salts of iron, the impression produced by the decomposing action of the light is brought out most fully and clearly by subsequent treatment with ferricyanide of potassium.

A few practical hints on the proper selection and arrangement of the locale in which photographic operations may best be performed, and on the proper posture, attitude, and dress of persons who wish to have their portraits taken with the photographic apparatus.
By FRANCIS SCHUBERT, Painter.

PHOTOGRAPHIC portraits are, of course, always taken best in the open air; however, as it is not at all times feasible to do so, the photographic artist must select and suitably arrange an appropriate apartment for the purpose. It need hardly be remarked here that this apartment must be as light as can be; in fact, the most suitable is a glass house, standing in an open ground, or erected on the top of a building. But here again, everyone has not the means at his command to have a structure of the kind erected in an appropriate spot. Most photographic artists must content themselves with the choice of a well lighted apartment, if possible, with a sky-light. A room receiving the light from the north-west is preferable to others.

The walls should be painted of a light blue, which will tend to diffuse a mild, uniform light throughout the apartment; in the case of a glass house, the light may be regulated in the same manner by means of light-blue curtains. This contrivance has another beneficial effect; viz., it excludes those luminous rays which are least effective in a photographic point of view.

As regards the proper attitude of the person sitting for the portrait, this must of course be left in a measure to the individual judgment and taste of the artist. However, a few hints on this subject may not prove unwelcome.

The posture of the person sitting for the portrait should be easy and unconstrained; the feet and hands neither projecting too much, nor drawn too far back; the eyes should be directed a little sideways above the camera, and fixed upon some object there, but never upon the apparatus, since this would tend to impart to the face a dolorous, dissatisfied look. Stout persons should be placed at a certain distance from the apparatus, turning towards it a little sideways; whilst people of slender make should be made to sit full in front, and nearer the apparatus. Long arms and legs require drawing back a little. The hands should rest easy on the lap, neither too high nor too low; or

one hand may be placed on the table, the other holding a book or some other object. A thick hand should show the thumb in the foreground, with the fingers bent a little inward; a long hand had better show the back; a hand of handsome shape, neither too long nor too short, should show full two thirds, with the fingers easily and gracefully hanging down. A slight lateral inclination of the body forward will generally produce a good effect. In the case of ladies, a shawl or boa, or similar article of dress, thrown lightly over the shoulders, and arranged in a manner to hide some defect, and to properly distribute light and shadow, will mostly tend to produce a pleasant impression.

Of a full round face, with large mouth, small eyes, and small nose, the portrait should be taken in half profile, so as to show one side of the face in full, with very little of the other side.

A moderately full face, with, aquiline nose, and handsome mouth and eyes, should be taken in three-fourth profile; a countenance with strongly-marked features full in front.

The selection of a proper background for the picture is also a matter of some importance; in some cases, a landscape will give a most pleasing background, in others a simple wall will answer as well, or even better; the decision here must be left to the individual judgment and taste of the artist.

If two persons are to be portrayed in the same picture, the one should be made to lean lightly on the chair of the other, and the faces of both should be partly turned to each other, as in conversation. Or they may be placed at a table seated opposite each other, the one with the right, the other with the left arm laid on the table, and the bodies of both gently inclined forward and towards each other, as in conversation.

The arrangement of family groups again must be left entirely to the judgment of the artist; care should always be taken, however, to place the several persons constituting the group all at the same focal distance.

With respect to dress, colors and objects of intense illumination should always be avoided; this applies more particularly to yellow and scarlet. Plain-colored dresses, neither too light nor too dark give always the most pleasing pictures.

TABLE I.

THE MOST IMPORTANT CHEMICAL ELEMENTS, OR SIMPLE BODIES, WITH
THEIR RESPECTIVE SYMBOLS AND COMBINING PROPORTIONS.*

NAME.	SYMBOL.	EQUIVALENTS, OR COMBINING PROPORTIONS.	
		OXYGEN=100.	HYDROGEN=1.
Aluminium	Al.	170.5	13.6
Antimony (Stibium) . .	Sb.	1612.5	129.0
Arsenic	As.	937.5	75.0
Barium	Ba.	857.5	68.6
Bismuth	Bi.	2600.0	208.0
Boron	B.	136.2	10.9
Bromine	Br.	1000.0	80.0
Calcium	Ca.	250.0	20.0
Carbon	C.	75.0	6.0
Chlorine	Cl.	443.7	35.5
Chromium	Cr.	335.0	26.8
Cobalt	Co.	368.6	29.5
Copper (Cuprum) . .	Cu.	396.0	31.7
Fluorine	F.	237.5	19.0
Gold (Aurum) . .	Au.	2462.5	197.0
Hydrogen	H.	12.5	1.0
Iodine	I.	1585.0	126.8
Iron (Ferrum) . .	Fe.	350.0	28.0
Lead (Plumbum). .	Pb.	1294.6	103.6
Magnesium	Mg.	150.2	12.1
Manganese	Mn.	344.7	27.6
Mercury (Hydrargyrum)	Hg.	1250.0	100.0
Molybdenum	Mo.	575.0	46.0
Nickel	Ni.	369.3	29.6
Nitrogen	N.	175.0	14.0
Oxygen	O.	100.0	8.0
Phosphorus	P.	392.0	31.4
Platinum	Pt.	1236.7	98.9
Potassium (Kalium) . .	K.	490.0	39.2
Selenium	Se.	494.0	39.5
Silver (Argentum) . .	Ag.	1349.6	108.0
Sodium (Natrium) . .	Na.	287.5	23.0
Strontium	Sr.	545.9	43.7
Sulphur	S.	200.0	16.0
Tin (Stannum) . .	Sn.	735.3	58.8
Uranium	U.	742.9	59.5
Zinc	Zn.	406.6	32.5

* See Appendix.

TABLE II.

THE MOST IMPORTANT CHEMICAL COMPOUNDS (IN A PHOTOGRAPHIC POINT OF VIEW), WITH THEIR FORMULÆ AND COMBINING PROPORTIONS.

NAME.	FORMULA.	EQUIVALENT, OR MIXING PROPORTION. HYDROGEN=1.
Acetate of alumina	$\text{Al}_2\text{O}_3, 3\bar{\text{A}}$	204.2
— baryta	$\text{BaO}, \bar{\text{A}} + \text{HO}$	136.6
— copper, neutral } crystallised	$\text{CuO}, \bar{\text{A}} + \text{HO}$	99.7
— lead, neutral (sugar } of lead)	$\text{PbO}, \bar{\text{A}} + 3\text{HO}$	189.6
— soda	$\text{NaO}, \bar{\text{A}} + 6\text{HO}$	136.0
Acetic acid	$\text{C}_4\text{H}_3\text{O}_3 + \text{HO} = \bar{\text{A}} + \text{HO}$	60.0
Alcohol	$\text{C}_4\text{H}_5\text{O}_2 + \text{HO}$	55.0
Alum, ammonia-	$\text{NH}_4\text{O}, \text{SO}_3 + \text{Al}_2\text{O}_3, \}$ $3\text{SO}_3 + 24\text{HO}$	453.2
— potassa-	$\text{KO}, \text{SO}_3 + \text{Al}_2\text{O}_3, 3\text{SO}_3 \}$ $+ 24\text{HO}$	474.4
Ammoniacal gas (spirits of } hartshorn)	NH_3	17.0
Ammonia, solution or liquor of	$\text{NH}_3 + x\text{HO}$	
Amylum, <i>see</i> Starch		
Antimoniate of potassa	KO, SbO_3	216.2
Arseniate of potassa	$\text{KO}, \text{AsO}_3 + 2\text{HO}$	180.2
Baryta	Ba O	76.6
Benzoic acid	$\text{C}_{14}\text{H}_5\text{O}_3 + \text{HO}$	122.0
Biborate of soda (borax)	$\text{NaO}, 2\text{BO}_3 + 10\text{HO}$	190.8
Boracic acid, crystallised	$\text{BO}_3 + 3\text{HO}$	61.9
Bromic acid	BrO_3	120.0
Bromide of potassium	KBr	119.2
— silver	AgBr	188.0
— sodium	NaBr	103.0
Bromiodine	IBr_3	366.8
Camphor, Japan	$\text{C}_{10}\text{H}_8\text{O}$	76.0
Carbonate of ammonia	NH_3, CO_2	39.0
— — sesqui- } carbonate	$2\text{NH}_3, \text{O} + 3\text{CO}_2$	118.0
Carbonate of baryta	BaO, CO_2	98.6
— lime	CaO, CO_2	50.0
— magnesia	$\text{MgO}, \text{CO}_2 + 3\text{HO}$	69.1
— potassa (neutral)	KO, CO_2	69.2
— (acid or bicar- } bonate)	$\text{KO}, 2\text{CO}_2 + \text{HO}$	100.2
— soda (crystall.)	$\text{NaO}, \text{CO}_2 + 10\text{HO}$	143.0
— soda (bicarbonate)	$\text{NaO}, 2\text{CO}_2 + \text{HO}$	84.0

NAME.	FORMULA.	EQUIVALENT, OR MIXING PROPORTION. HYDROGEN = 1.
Carbonate of strontia	SrO, CO_2	73.7
Carbonic acid	CO_2	22.0
Caoutchouc	$\text{C}_8 \text{H}_7$	55.0
Chlorate of ammonia	$\text{NH}_4 \text{O}, \text{ClO}_3$	101.5
— baryta	$\text{BaO}, \text{ClO}_3 + \text{HO}$	161.1
— potassa	KO, ClO_3	122.7
— soda	NaO, ClO_3	108.5
Chloric acid	ClO_3	75.5
Chloride of aluminium (see quichl.)	$\text{Al}_2 \text{Cl}_3 + 12\text{HO}$	241.7
— ammonium (sal- ammoniac)	NH_4, Cl	53.5
— arsenic	AsCl_3	181.5
— barium	$\text{BaCl} + 2\text{HO}$	122.1
— cobalt	CoCl	65.0
— copper (subchloride) — crystallised	$\text{Cu}_2 \text{Cl}$ $\text{CuCl} + 4\text{HO}$	98.9 103.2
— cyanogen, gase- ous (proto-)	CyCl	61.5
— — solid (sesqui-)	$\text{Cy}_2 \text{Cl}_3$	158.5
— gold (terchlor-)	$\text{AuCl}_3 + 6\text{HO}$	357.5
— gold and sodium iodine, liquid	$\text{NaCl} + \text{AuCl}_2 + 6\text{HO}$	416.0
— (proto-)	ICl	162.3
— — solid (ter-)	ICl_3	233.3
— iron, proto-	$\text{FeCl} + 4\text{HO}$	99.5
— — sesqui-	$\text{Fe}_2 \text{Cl}_3 + 6\text{HO}$	216.5
— lead, neutral	PbCl	139.1
— lime (bleaching- powder)	$\text{CaO}, \text{ClO} + \text{CaCl}$	127.0
— magnesium, crystal. — manganese, proto-	$\text{MgCl} + 5\text{HO}$ $\text{MnCl} + 4\text{HO}$	92.6 99.1
— — sesqui-	$\text{Mn}_2 \text{Cl}_3$	161.7
— mercury, (corro- sive sublimate)	HgCl	135.5
— nickel	$\text{NiCl} + 10\text{HO}$	155.1
— — and ammonia (ammonio-chloride of nickel)	$\text{NiCl} + 2\text{NH}_3 + \text{HO}$	108.1
— nitrogen (terchl.)	NCl_3	120.5
— platinum, hy- drated bichloride	$\text{PtCl}_2 + 8\text{HO}$	241.9
— potassium	KCl	74.7
— silver	AgCl	143.5
— sodium (common salt)	NaCl	58.5

NAME.	FORMULA.	EQUIVALENT, OR MIXING PROPORTION. HYDROGEN=1.
Chloride of strontium . . .	$\text{SrCl} + 6\text{HO}$	133.2
— sulphur (subchl.) . . .	$\text{S}_2 \text{Cl}$	67.5
— tin, crystallised } — proto- }	$\text{SnCl} + \text{HO}$	103.3
— cryst. bichloride	$\text{SnCl}_2 + 2\text{HO}$	147.8
Chloroform	$\text{C}_2 \text{HCl}_3$	119.5
Chromate of lead, neutral . . .	PbO, CrO_3	162.2
— potassa, neutral . . .	KO, CrO_3	98.0
— — acid or } — bichromate }	$\text{KO}, 2\text{CrO}_3$	148.8
Citrate of sesqui-oxide of iron . . .		
— sesquioxide of iron } — and ammonia }		
— sesquioxide of iron } — and potassa }		
— sesquioxide of iron } — and soda }		
— mercury		
— silver		
Citric acid, by crystallisation } at the common tem- } perature }	$\text{C}_{12} \text{H}_5 \text{O}_{11} + 5\text{HO} = \overline{\text{Ci}}$	210.0
— precipitated from } a hot saturated solu- } tion, and dried at } 212° }	$\text{C}_{12} \text{H}_5 \text{O}_{11} + 3\text{HO} = \overline{\text{Ci}}$	192.0
Cobalt, oxide of	CoO	37.5
Cotton	CHO	15.0
Cyanate of potassa	KO, CyO	81.2
Cyanic acid	$\text{CyO} + \text{HO}$	43.0
Cyanide of potassium	KCy	65.2
— silver	AgCy	134.0
Cyanogen	$\text{C}_2 \text{N} = \text{Cy}$	26.0
Ether	$\text{C}_4 \text{H}_8 \text{O}$	37.0
Ferricyanide of potassium (red } prussiate of potassa) }	$3\text{KCy}, \text{Fe}_2 \text{Cy}_3$	329.6
Ferrocyanide of potassium } (yellow prussiate of } potassa) }	$2\text{KCy}, \text{FeCy} + 3\text{HO}$	211.4
Fluoride of ammonium	NH_4, Fl	37.0
— calcium (fluorspar)	CaFl	39.0
— potassium	KFl	58.2
— sodium	NaFl	42.0
Formic acid	$\text{C}_2 \text{HO}_2 + \text{HO} = \overline{\text{Fo}}$	46.0
Gallie acid, crystallised	$\text{C}_7 \text{H}_2 \text{O}_4 + \text{HO} = \overline{\text{Ga}}$	85.0
Gold, oxide (teroxide) of	AuO_3	221.0
Hydrobromic acid	BrH	81.0
Hydrochloric acid	ClH	36.5

NAME.	FORMULA.	EQUIVALENT, OR MIXING PROPORTION. HYDROGEN = 1.
Hydrochloric acid, most concentrated hydrated }	$\text{ClH} + 6\text{HO}$	90.5
Hydrocyanic acid	CyH	27.0
Hydrofluante of ammonia		
Hydrofluoric acid	FlH	20.0
Hydriodate of ammonia	NH_3, HI	144.8
Hydriodic acid	HI	127.8
Hydrosulphuric acid (suphur- retted hydrogen) }	HS	17.0
Hyponitrate of protoxide of iron		
Hyponitric acid	NO_4	46.0
Hyposulphate of protoxide of iron }		
Hyposulphate of soda	$\text{NaO}, \text{S}_2 \text{O}_2 + 5\text{HO}$	124.0
Hyposulphuric acid	$\text{S}_2 \text{O}_5$	72.0
Hyposulphurous acid	$\text{S}_2 \text{O}_3$	48.0
Iodate of ammonia	$\text{NH}_4 \text{O}, \text{IO}_5$	192.8
Iodic acid	$\text{IO}_5 + \text{HO}$	175.8
Iodide of ammonium	NH_4, I	144.8
— iron (sesqui-)	$\text{Fe}_2 \text{I}_3$	436.4
— potassium	KI	166.0
— silver	AgI	234.8
— sodium	NaI	149.8
Iron, protoxide of	FeO	36.0
— sesquioxide of	$\text{Fe}_2 \text{O}_3$	80.0
— hydrated sesquioxide of	$\text{Fe}_2 \text{O}_3 + 3\text{HO}$	107.0
Lime, hydrate of	$\text{CaO} + \text{HO}$	37.0
Malic acid	$\text{C}_4 \text{H}_2 \text{O}_4 + \text{HO} = \text{M}$	67.0
Manganate of potassa	KO, MnO_3	98.8
— — per-	$\text{KO}, \text{Mn}_2 \text{O}_7$	158.4
Milk sugar	$\text{C}_{24} \text{H}_{22} \text{O}_{22} + 2\text{HO}$	360.0
Nickel, oxide of	NiO	37.6
Nitrate of ammonia	$\text{NH}_4 \text{O}, \text{NO}_5 + \text{HO}$	89.0
— baryta	BaO, NO_5	130.6
— sesquioxide of chro- mium }	$\text{Cr}_2 \text{O}_3, 3\text{NO}_5$	239.6
— copper	CuO, NO_5	93.7
— sesquioxide of iron	$\text{Fe}_2 \text{O}_3, 3\text{NO}_5$	242.0
— lead	PbO, NO_5	165.6
— mercury	$2(\text{HgO}, \text{NO}_5) + \text{HO}$	333.0
— mercury and ammonia	$(\text{NH}_3, \text{NO}_5) + 3\text{HgO}$	395.0
— nickel	$\text{NiO}, \text{NO}_5 + 6\text{HO}$	145.6
— potassa	KO, NO_5	101.2
— silver	AgO, NO_5	170.0
— — and ammonia	$\text{AgO}, \text{NO}_5 + 2\text{NH}_3$	204.0
— soda	NaO, NO_5	85.0
— strontia	SrO, NO_5	105.7
— zinc	ZnO, NO_5	94.5

NAME.	FORMULA.	EQUIVALENT, OR MIXING PROPORTION. HYDROGEN=1.
Nitric acid, first hydrate . . .	$\text{NO}_5 + \text{HO}$	63.0
Oxalate of ammonia, neutral . .	$\text{NH}_4\text{O}, \text{C}_2\text{O}_3 + \text{HO}$	71.0
— — acid (bin-oxalate) . . .	$\text{NH}_4\text{O}, 2\text{C}_2\text{O}_3 + 2\text{HO}$	116.0
— baryta . . .	$\text{BaO}, \text{C}_2\text{O}_3 + \text{HO}$	121.6
— cobalt and ammonia . . .	$12\text{NH}_3 + \text{CoCo}_3\text{O}_{12} + 6\text{HO}$	478.5
— copper and soda . . .	$\text{C}_2\text{NaCuO}_4 + 2\text{HO}$	116.7
— sesquioxide of iron . . .	$\text{Fe}_2\text{O}_3, 3\text{C}_2\text{O}_3$	188.0
— sesquioxide of iron and ammonia . . .	$\text{Co}(3\text{NH}_4\text{O})\text{Fe}_2\text{O}_{12}$	266.0
— sesquioxide of iron and baryta . . .	$\text{CoBa}_3\text{Fe}_2\text{O}_{12} + 21\text{HO}$	582.8
— sesquioxide of iron and potassa . . .	$\text{CoK}_3\text{Fe}_2\text{O}_{12}$	305.6
— sesquioxide of iron and soda . . .	$\text{CoNa}_3\text{Fe}_2\text{O}_{12} + 10\text{HO}$	347.0
— sesquioxide of iron and strontia . . .	$\text{CoSr}_3\text{Fe}_2\text{O}_{12} + 18\text{HO}$	481.1
Oxalate of lead . . .	$\text{PbO}, \text{C}_2\text{O}_3$	147.6
— nickel . . .	$\text{NiO}, \text{C}_2\text{O}_3 + 2\text{HO}$	91.6
— — and ammonia . . .		
— potassa, neutral . . .	$\text{KO}, \text{C}_2\text{O}_3 + \text{HO}$	92.2
— — acid, or bin-oxalate (sorrel salt) . . .	$\text{KO}, 2\text{C}_2\text{O}_3 + \text{HO} + 2\text{aq.}$	146.2
— soda, neutral . . .	$\text{NaO}, \text{C}_2\text{O}_3$	67.0
Oxalic acid . . .	$\text{C}_2\text{O}_3 + \text{HO} + 2\text{aq.} = \overline{\text{Ox}}$	63.0
Phosphate of potassa . . .	KO, PO_5	118.6
— silver . . .	AgO, PO_5	187.4
— soda . . .	NaO, PO_5	102.4
Potassa . . .	KO	47.2
— hydrate of . . .	$\text{KO} + \text{HO}$	56.2
Prussian blue . . .	$3\text{FeCy} + 2\text{Fe}_2\text{Cy}_3 + 9\text{HO}$	511.0
Pyrogallic acid . . .	$\text{C}_6\text{H}_3\text{O}_3 = \text{p}\overline{\text{G}}$	63.0
Racemic acid, <i>see</i> Uvic acid . .		
Sal-ammoniac, <i>see</i> Chloride of ammonium . . .		
Silver, oxide of . . .	AgO	116.0
Soda . . .	NaO	31.0
— hydrate of . . .	$\text{NaO} + \text{HO}$	40.0
Stannate of potassa . . .	$\text{KO}, \text{SnO}_2 + 3\text{HO}$	149.0
Starch . . .	$\text{C}_{12}\text{H}_{10}\text{O}_{10}$	162.0
Succinate of ammonia, acid . . .		
— sesquioxide of iron . . .	$\text{Fe}_2\text{O}_3, 3\overline{\text{Su}}$	230.0
— potassa, acid . . .		
Succinic acid, crystallised . . .	$\text{C}_4\text{H}_2\text{O}_3 + \text{HO} = \overline{\text{Su}} + \text{HO}$	59.0

NAME.	FORMULA.	EQUIVALENT, OR MIXING PROPORTION. HYDROGEN = 1.
Succinic acid, sublimed .	$2C_4H_2O_3 + HO = \overline{Su}$	109.0
Sugar .	$C_{12}H_{22}O_{11}$	171.0
— of lead, see acetate of lead		
Sulphate of ammonia, crys- tallised .	NH_4, SO_3	57.0
Sulphate of sesquioxide of chromium and am- monia .	$NH_4O, SO_3 + Cr_2O_3, 3SO_3 + 24HO$	479.6
Sulphate of sesquioxide of chromium and po- tassa .	$KO, SO_3 + Cr_2O_3, 3SO_3 + 24HO$	500.8
Sulphate of cobalt and am- monia .	$(NH_4O, SO_3) + (CoO, SO_3) + 6HO$	197.5
Sulphate of copper (blue vitriol)	$CuO, SO_3 + 5HO$	124.7
Sulphate of copper and am- monia .	$NH_4O, SO_3 + CuO, SO_3$	145.7
Sulphate of protoxide of iron (green vitriol) .	$FeO, SO_3 + 7HO$	139.0
Sulphate of sesquioxide of iron and ammonia .	$(NH_4O, SO_3) + (Fe_2O_3, 3SO_3) + 24HO$	482.0
Sulphate of sesquioxide of iron and potassa .	$KO, SO_3 + Fe_2O_3, 3SO_3 + 24HO$	503.2
Sulphate of nickel .	$NiO, SO_3 + 7HO$	140.6
— potassa, neutral .	KO, SO_3	87.2
— soda, neutral .	NaO, SO_3	71.0
Sulphite of potassa, neutral .	$KO, SO_2 + 2HO$	97.2
Sulphuretted hydrogen, (hy- drosulphuric acid) .	HS	17.0
Sulphuric acid, English .	$SO_3 + HO$	49.0
Sulphurous acid .	SO_2	32.0
Tannic acid (Tannin) .	$C_{12}H_5O_9 + 3HO$	212.0
Tartrate of ammonia, acid .	$NH_4O, 2\overline{T} + HO$	167.0
— — neutral .	$OH_4O, \overline{T} + HO$	101.0
Tartrate of sesquioxide of iron — bitartrate (or acid tartrate) of sesqui- oxide of iron .		
Tartrate of sesquioxide of iron and ammonia .		
Tartrate of sesquioxide of iron and potassa .		
Tartrate of sesquioxide of iron and soda .		
Tartrate of potassa, acid or bitartrate .	$KO, 2\overline{T} + HO$	188.2

NAME.	FORMULA.	EQUIVALENT, OR MIXING PROPORTION. HYDROGEN = 1.
Tartrate of potassa, neutral .	$\text{KO}, \bar{\text{T}}$	113.2
— soda, neutral .	$\text{NaO}, \bar{\text{T}} + 2\text{HO}$	115.0
Tartaric acid	$\text{C}_4\text{H}_2\text{O}_6 + \text{HO} = \bar{\text{T}} + \text{HO}$	75.0
Tin, binoxide of (Stannic acid).	SnO_2	74.8
Turpentine, oil of	C_8H_8	34.0
Uvic acid	$\text{C}_4\text{H}_2\text{O}_6 + \text{HO} + aq. = \bar{\text{U}}$	84.0
Water	HO	9.0

TABLE III.

BRIEF ABSTRACT OF THE PRINCIPAL RE-ACTIONS OF METALLIC SALTS WITH
THE MOST IMPORTANT RE-AGENTS.

I. METALLIC OXIDES.

1. SALTS OF POTASSA.

Tartaric acid produces in solutions of salts of potassa a crystalline precipitate, which dissolves in an excess of sulphuric acid, hydrochloric acid, and nitric acid.

Bichloride of platinum produces a bright-yellow precipitate, which is not dissolved by free acid.

Hydrofluosilicic acid produces a gelatinous precipitate.

Cyanic acid produces in alcoholic solutions of salts of potassa a yellow crystalline precipitate.

Sulphate of alumina produces in concentrated solutions of salts of potassa a deposit of potassa-alum (sulphate of alumina and potassa.)

2. SALTS OF SODA.

Hydrofluosilicic acid produces in concentrated solutions of salts of soda a gelatinous precipitate; the other reagents enumerated sub. 1, fail to produce a precipitate in solutions of salts of soda.

Antimoniate of potassa produces in neutral solutions of salts of soda a white precipitate of antimoniate of soda.

3. SALTS OF AMMONIA.

Bichloride of platinum produces a yellow precipitate.

Tartaric acid produces only in very concentrated solutions of salts of ammonia a crystalline precipitate.

Sulphate of alumina produces a crystal of ammonia-alum (sulphate of alumina and ammonia).

Cyanic acid produces a precipitate only in the most highly concentrated solutions.

Hydrofluosilicic acid fails to produce a precipitate in weak solutions of salts of ammonia.

4. SALTS OF BARYTA.

Dilute sulphuric acid produces a precipitate insoluble in acids.

Chromate of potassa produces a yellow precipitate, soluble in nitric acid.

Hydrofluosilicic acid produces a crystalline precipitate, insoluble in hydrochloric acid and in nitric acid.

Potassa produces a bulky precipitate, soluble in a copious amount of water.

Ammonia fails to produce a precipitate.

Carbonate of potassa (neutral) produces a white precipitate, soluble in acids.

Carbonate of ammonia, a white precipitate, soluble in acids.

Phosphate of soda, a white precipitate, soluble in acids.

Oxalate of ammonia, a white precipitate.

Hydrosulphate of sulphide of ammonium fails to produce a precipitate.

Ferrocyanide of potassium produces a crystalline precipitate in concentrated solutions of salts of baryta.

5. SALTS OF STRONTIA.

Dilute sulphuric acid produces in solutions of salts of strontia a precipitate, which is almost insoluble in acids.

Chromate of potassa (neutral) produces after some time, a yellow crystalline precipitate.

Bichromate of potassa fails to produce a precipitate.

Hydrofluosilicic acid also fails to produce a precipitate.

Potassa, ammonia, carbonate of potassa, carbonate of ammonia, and phosphate of soda, present the same deportment with salts of strontia as with salts of baryta.

Oxalate of ammonia produces a white precipitate.

Hydrosulphate of sulphide of ammonium fails to produce a precipitate.

Ferrocyanide of potassium }
Ferricyanide of potassium } produce no precipitate.

6. SALTS OF LIME.

Dilute sulphuric acid produces only in concentrated solutions of salts of lime a precipitate of gypsum (sulphate of lime).

Sulphate of potassa fails to produce a precipitate, or produces a precipitate only after long standing.

Chromate of potassa produces no precipitate.

Hydrofluosilicic acid produces no precipitate.

Oxalate of ammonia produces a white precipitate, nearly insoluble in acetic acid.

Potassa, ammonia, carbonate of potassa, carbonate of ammonia, and phosphate of soda, present the same deportment with salts of lime as with salts of baryta.

Hydrosulphate of sulphide of ammonium produces no precipitate.

Ferrocyanide of potassium produces in concentrated solutions a white precipitate, soluble in hydrochloric acid.

Ferricyanide of potassium produces no precipitate.

7. SALTS OF MAGNESIA.

Sulphuric acid produces no precipitate in solutions of salts of magnesia.

Hydrofluosilicic acid produces no precipitate.

Potassa, ammonia, carbonate of potassa, and carbonate of ammonia produce bulky white precipitates, which are soluble in sal-ammoniac (chloride of ammonium); however, the precipitate produced by carbonate of ammonia dissolves in the chloride of ammonium only after boiling the fluid.

Phosphate of soda produces, more especially if free ammonia is present, a precipitate, which is altogether insoluble in chloride of ammonium.

Oxalic acid produces in presence of free ammonia, a precipitate, which is soluble in chloride of ammonium, and other salts of ammonia.

Hydrosulphate of sulphide of ammonium produces no precipitate.

Ferrocyanide of potassium produces a copious white precipitate.

Ferricyanide of potassium produces no precipitate.

8. SALTS OF PROTOXIDE OF MANGANESE.

Potassa produces a white precipitate, which acquires a brown tint in the air, and is soluble in chloride of ammonium.

Ammonia also produces a white precipitate, which acquires a brown tint in the air, and is soluble in chloride of ammonium.

Carbonate of potassa and carbonate of ammonia produce white precipitates, which remain unaltered in the cold, and are slightly soluble in chloride of ammonium.

Phosphate of soda produces a white precipitate, which remains unaltered.

Oxalic acid produces in concentrated solutions after some time, a white crystalline deposit, which is soluble in sulphuric acid and hydrochloric acid.

Ferrocyanide of potassium produces a reddish-white precipitate, which is soluble in free acid.

Ferricyanide of potassium produces a brown precipitate, insoluble in acids.

Hydrosulphate of sulphide of ammonium produces a flesh-colored precipitate, soluble in an excess of the reagent.

Sulphuretted hydrogen (Hydrosulphuric acid) produces no precipitate.

9. SALTS OF SESQUIOXIDE OF MANGANESE.

Potassa, ammonia, carbonate of potassa, and carbonate of ammonia, produce dark-brown bulky precipitates, which are insoluble in chloride of ammonium.

Phosphate of soda produces in an accurately neutralised hydrochloric acid solution of a salt of sesquioxide of manganese a very bulky brown precipitate.

Oxalic acid produces no precipitate, but after a time a discoloration of the fluid.

Ferrocyanide of potassium produces a grayish-green precipitate.

Ferricyanide of potassium, a brown precipitate.

Hydrosulphate of sulphide of ammonium, a flesh-colored precipitate.

Sulphuretted hydrogen reduces the sesquioxide to protoxide, with separation of sulphur.

10. SALTS OF OXIDE OF ZINC.

Potassa produces a white gelatinous precipitate, which redissolves in an excess of the precipitant.

Ammonia, the same.

Carbonate of potassa produces a white precipitate, soluble in potassa and ammonia.

Carbonate of ammonia produces a white precipitate, soluble in an excess of the precipitant.

Phosphate of soda, a white precipitate, soluble in acids, potassa, and ammonia.

Oxalic acid, a white precipitate, soluble in potassa, ammonia, and acids.

Ferrocyanide of potassium, a white gelatinous precipitate, insoluble in hydrochloric acid.

Ferricyanide of potassium, a yellowish-red precipitate, soluble in hydrochloric acid.

Hydrosulphate of sulphide of ammonium, a white precipitate, insoluble in an excess of the precipitant, and in alkalies.

Sulphuretted hydrogen produces in neutral solutions of salts of oxide of zinc a white precipitate ; but the precipitation is not complete.

11. SALTS OF PROTOXIDE OF COBALT.

Potassa produces a blue precipitate, which is insoluble in an excess of the precipitant, and acquires a green color in the air.

Ammonia produces the same blue precipitate ; this, however, redissolves in an excess of the precipitant, the solution presenting a brownish-red tint.

Carbonate of potassa produces a red precipitate, which, upon boiling, acquires a blue color.

Carbonate of ammonia produces a red precipitate, soluble in an excess of the precipitant, and in chloride of ammonium.

Phosphate of soda produces a blue precipitate.

Oxalic acid, after some time, a reddish-white precipitate.

Ferrocyanide of potassium, a green precipitate, which afterwards turns gray; this precipitate is insoluble in hydrochloric acid.

Ferricyanide of potassium, a dark-brownish-red precipitate, insoluble in hydrochloric acid.

Hydrosulphate of sulphide of ammonium produces a black precipitate, insoluble in an excess of the precipitant, and in alkalies.

Sulphuretted hydrogen fails to precipitate cobalt from acid solutions; it precipitates it imperfectly from neutral, but completely from alkaline solutions.

12. SALTS OF PROTOXIDE OF NICKEL.

Potassa produces an apple-green precipitate, insoluble in an excess of the precipitant, and unalterable in the air.

Ammonia produces a slight green precipitate, which redissolves immediately upon further addition of the reagent, imparting a fine blue color to the fluid. Potassa precipitates from this fluid, hydrated protoxide of nickel ($\text{NiO} + \text{HO}$).

Carbonate of potassa produces an apple-green precipitate.

Carbonate of ammonia produces an apple-green precipitate, which redissolves in an excess of the precipitant, imparting a bluish-green color to the solution.

Phosphate of soda produces a greenish-white precipitate.

Oxalic acid, after some time, a greenish precipitate.

Ferrocyanide of potassium, a white precipitate, insoluble in hydrochloric acid.

Ferricyanide of potassium, a yellowish-green precipitate, insoluble in hydrochloric acid.

Hydrosulphate of sulphide of ammonium, a black precipitate, not altogether insoluble in an excess of the precipitant, and in alkalies.

Sulphuretted hydrogen produces no precipitate in acid solutions; from neutral solutions of salts of protoxide of nickel, with weak acids, it precipitates the nickel only imperfectly.

13. SALTS OF PROTOXIDE OF IRON.

Potassa, ammonia, carbonate of ammonia, and carbonate of potassa, produce whitish precipitates, which speedily acquire a green tint, and, upon exposure to the air, a reddish-brown color. Chloride of ammonium and tartaric acid prevent the precipitation by ammonia absolutely, by potassa partially.

Phosphate of soda produces a white precipitate, which upon exposure to the air acquires, after a time, a bluish-green color.

Oxalic acid produces, after some time, a yellow precipitate; oxalates of the alkalies produce the same precipitate immediately.

Ferrocyanide of potassium produces a white precipitate, which very speedily turns blue upon exposure to the air; this precipitate is insoluble in hydrochloric acid.

Ferricyanide of potassium produces a dark-blue precipitate, insoluble in acids.

Terchloride of gold produces a brown precipitate of metallic gold.

Nitrate of silver, a grayish-white precipitate of metallic silver.

Hydrosulphate of sulphide of ammonium, a black precipitate, insoluble in an excess of the precipitant, but very readily soluble in hydrochloric acid.

Sulphuretted hydrogen produces a slight precipitate only in solutions of salts of protoxide of iron with weak acids.

14. SALTS OF SESQUIOXIDE OF IRON.

Potassa, ammonia, carbonate of potassa, and carbonate of ammonia, produce reddish-brown bulky precipitates, which are partially soluble in an excess of the carbonate of potassa or carbonate of ammonia.

Phosphate of soda produces a white precipitate, which dissolves, in presence of ammonia, in an excess of the precipitant, imparting a reddish-brown color to the solution.

Oxalic acid produces a yellow coloration, but no precipitate.

Ferrocyanide of potassium, a dark-blue precipitate, insoluble in hydrochloric acid.

Ferricyanide of potassium produces no precipitate.

Hydrosulphate of sulphide of ammonium produces a black precipitate;

but if the solution contains only a very trifling quantity of iron, this reagent simply imparts a greenish color to the fluid.

Sulphuretted hydrogen reduces the sesquioxide to protoxide, with separation of sulphur.

15. SALTS OF OXIDE OF LEAD.

Potassa produces a white precipitate, which re-dissolves, upon the application of heat, in a large excess of the precipitant.

Ammonia produces a white precipitate, insoluble in an excess of the precipitant.

Carbonate of potassa, a white precipitate, insoluble in an excess of the precipitant, but soluble in potassa.

Carbonate of ammonia, the same.

Phosphate of soda, a white precipitate, soluble in potassa.

Oxalic acid, in neutral solutions a white precipitate.

Ferrocyanide of potassium, a white precipitate.

Ferricyanide of potassium produces no precipitate.

Hydrosulphate of sulphide of ammonium produces a black precipitate, insoluble in an excess of the precipitant.

Sulphuretted hydrogen, in neutral and acid solutions, a black precipitate.

Dilute sulphuric acid, a white precipitate, soluble in potassa.

Hydrochloric acid, in concentrated solutions, a white precipitate, soluble in a large quantity of water.

Chromate of potassa, a yellow precipitate, insoluble in dilute nitric acid, soluble in potassa.

16. SALTS OF TEROXIDE OF BISMUTH.

Potassa produces a white precipitate, insoluble in an excess of the precipitant.

Ammonia, the same.

Carbonate of potassa and carbonate of ammonia, the same.

Phosphate of soda, a white precipitate.

Oxalic acid, after some time, a crystalline precipitate.

Ferrocyanide of potassium, a white precipitate, insoluble in hydrochloric acid.

Ferricyanide of potassium, a pale-yellow precipitate, insoluble in hydrochloric acid.

hydrosulphate of sulphide of ammonium, a black precipitate, insoluble in an excess of the precipitant.

alphuretted hydrogen, even in acid solutions, a black precipitate.

bromate of potassa, a yellow precipitate, soluble in dilute nitric acid.

17. SALTS OF SUBOXIDE OF COPPER.

potassa saturates first the free acid of the solution (subchloride of copper dissolves only in an excess of hydrochloric acid), and then produces a yellowish-brown precipitate, insoluble in an excess of the precipitant.

ammonia in excess produces no precipitate, but after some time it imparts a blue color to the fluid.

carbonate of potassa produces a yellow precipitate.

carbonate of ammonia acts in the same way as ammonia.

phosphate of soda produces a white precipitate.

oxalic acid, a white precipitate.

ferrocyanide of potassium, a white precipitate.

ferricyanide of potassium, a reddish-brown precipitate.

hydrosulphate of sulphide of ammonium, a black precipitate, insoluble in an excess of the precipitant.

alphuretted hydrogen, a black precipitate.

18. SALTS OF OXIDE OF COPPER.

potassa produces a blue precipitate, which acquires a black color on being boiled with potassa.

ammonia, a greenish precipitate, which re-dissolves in an excess of the precipitant, imparting a blue color to the solution.

carbonate of potassa, a bright-greenish precipitate.

carbonate of ammonia acts in the same way as ammonia.

phosphate of soda produces a bluish-white precipitate, soluble in ammonia.

oxalic acid, a bluish-white precipitate.

ferrocyanide of potassium, a reddish-brown precipitate, insoluble in hydrochloric acid.

ferricyanide of potassium, a yellowish-green precipitate, insoluble in hydrochloric acid.

Hydrosulphate of sulphide of ammonium, a black precipitate, insoluble in an excess of the precipitant, and in ammonia.

Sulphuretted hydrogen, a black precipitate.

Chromate of potassa, a reddish-brown precipitate, readily soluble in nitric acid ; this precipitate dissolves also in ammonia, imparting an emerald-green color to the solution.

19. SALTS OF OXIDE OF SILVER.

Potassa produces a light-brown precipitate, insoluble in an excess of the precipitant, but soluble in ammonia.

Ammonia produces, in neutral solutions, a brown precipitate, readily soluble in an excess of the precipitant ; in presence of free acid, the re-agent produces no precipitate by neutralisation.

Carbonate of potassa produces a white precipitate, soluble in ammonia.

Carbonate of ammonia, a white precipitate, soluble in an excess of the precipitant.

Phosphate of soda, a yellow precipitate, soluble in ammonia.

Oxalic acid, a white precipitate, soluble in ammonia.

Ferrocyanide of potassium, a white precipitate.

Ferricyanide of potassium, a reddish-brown precipitate.

Hydrosulphate of sulphide of ammonium, a black precipitate, insoluble in an excess of the precipitant, and in ammonia.

Sulphuretted hydrogen, a black precipitate.

Hydrochloric acid, a white precipitate, soluble in ammonia.

Chromate of potassa, a dark reddish-brown precipitate, soluble in dilute nitric acid, in ammonia, and in a large quantity of water.

Sulphate of protoxide of iron, a grayish-white precipitate of metallic silver.

Protochloride of tin, acidulated with hydrochloric acid, and added rather largely to the solution of a salt of silver, produces a precipitate of metallic silver.

20. SALTS OF SUBOXIDE OF MERCURY.

Potassa produces a black precipitate, insoluble in an excess of the precipitant.

Ammonia, the same.

Carbonate of potassa produces a dirty-yellow precipitate, which is slightly soluble in an excess of the precipitant, and upon boiling acquires a black tint.

Carbonate of ammonia, a black precipitate.

Phosphate of soda, a white precipitate.

Oxalic acid, a white precipitate.

Ferrocyanide of potassium, a white gelatinous precipitate.

Ferricyanide of potassium, a reddish-brown precipitate.

Hydrosulphate of sulphide of ammonium, a black precipitate, insoluble in an excess of the precipitant, and in ammonia; potassa dissolves the precipitate, leaving a little metallic mercury behind.

Sulphuretted hydrogen produces a black precipitate.

Hydrochloric acid, a white precipitate, insoluble in very dilute simple acids.

Chromate of potassa, a red precipitate.

21. SALTS OF OXIDE OF MERCURY.

Potassa produces a yellow precipitate, insoluble in an excess of the precipitant; in presence of sal-ammoniac (chloride of ammonium), the precipitate formed is white; in highly acid solutions, potassa produces no precipitate, or at all events only a slight one.

Ammonia produces a white precipitate, insoluble in an excess of the precipitant.

Carbonate of potassa, a reddish-brown precipitate, insoluble in an excess of the precipitant; in presence of sal-ammoniac, the precipitate is white.

Carbonate of ammonia produces a white precipitate.

Phosphate of soda, a white precipitate; in solutions of chloride of mercury, however, only a slight turbidity.

Oxalic acid, a white precipitate; in solutions of chloride of mercury, no precipitate.

Ferrocyanide of potassium, a white precipitate.

Ferricyanide of potassium, a yellow precipitate; in solutions of chloride of mercury, no precipitate.

Hydrosulphate of sulphide of ammonium, a black precipitate, insoluble in an excess of the precipitant, and in ammonia, but completely soluble in potassa.

Sulphuretted hydrogen, the same as hydrosulphate of sulphide of ammonium.

Chromate of potassa, a yellowish-red precipitate.

22. BICHLORIDE OF PLATINUM.

Potassa produces a yellow precipitate, which re-dissolves in an excess of the precipitant upon heating; the precipitate is not perceptibly soluble in free acids.

Ammonia produces a yellow precipitate, insoluble in free acids, but soluble in a copious amount of water.

Carbonate of soda produces a brownish-yellow precipitate only upon long-continued ebullition.

Carbonate of ammonia and carbonate of potassa produce a yellow precipitate, insoluble in an excess of the precipitant.

Phosphate of soda produces no precipitate.

Oxalic acid produces no precipitate.

Ferrocyanide of potassium precipitates potassio-bichloride of platinum (bichloride of platinum and chloride of potassium).

Ferricyanide of potassium, the same.

Nitrate of suboxide of mercury produces a copious yellowish-red precipitate.

Sulphate of protoxide of iron produces no precipitate.

Protochloride of tin produces no precipitate, but imparts a dark brownish-red color to the fluid.

Hydrosulphate of sulphide of ammonium produces a brownish-black precipitate, soluble in a large excess of the precipitant.

Sulphuretted hydrogen produces after some time, a brownish-black precipitate.

23. TERCHLORIDE OF GOLD.

Potassa produces no precipitate.

Ammonia, a yellow precipitate (fulminating gold).

Carbonate of potassa, no precipitate in the cold, but upon ebullition a reddish-yellow precipitate.

Carbonate of ammonia acts the same way as ammonia.

Phosphate of soda produces no precipitate.

Oxalic acid separates metallic gold in a state of extremely minute division; the minute metallic particles impart to the fluid in which they remain suspended, a greenish-black color.

Ferrocyanide of potassium imparts an emerald-green color to the solution.

Ferricyanide of potassium produces no precipitate.

Nitrate of suboxide of mercury, a black precipitate.

Sulphate of protoxide of iron, a dark-brown precipitate of metallic gold.

Protochloride of tin, acidulated with hydrochloric acid, produces a deep-purple-colored precipitate (powder of Cassius), which is insoluble in hydrochloric acid.

Hydrosulphate of sulphide of ammonium, a dark-brown precipitate, which re-dissolves completely in an excess of the precipitant.

Sulphuretted hydrogen, a black precipitate.

24. SALTS OF PROTOXIDE OF TIN.

Potassa produces a white precipitate, soluble in an excess of the precipitant.

Ammonia, a white precipitate, insoluble in an excess of the precipitant.

Carbonate of potassa and carbonate of ammonia, the same as ammonia.

Phosphate of soda, a white precipitate.

Oxalic acid, a white precipitate.

Ferrocyanide of potassium, a white gelatinous precipitate.

Ferricyanide of potassium, a white precipitate, soluble in free hydrochloric acid.

Hydrosulphate of sulphide of ammonium, a brown precipitate, soluble in a great excess of the precipitant.

Sulphuretted hydrogen, a brown precipitate.

25. BICHLORIDE OF TIN.

Potassa produces a white, bulky precipitate, which in the case of the volatile bichloride, re-dissolves very readily in an excess of the precipitant, but with difficulty only in the case of the aqueous solution of the modification of the bichloride, insoluble in hydrochloric acid.

Ammonia produces a white precipitate, which in the case of the volatile bichloride, re-dissolves, though not completely, in an excess of the precipitant, but re-dissolves only sparingly in the case of the aqueous solution of the modification of the bichloride, insoluble in hydrochloric acid.

Carbonate of potassa produces a white precipitate, which in the case of the volatile chloride, re-dissolves in an excess of the precipitant; but is insoluble in it, in the case of the aqueous solution of the modification of the bichloride, insoluble in hydrochloric acid.

Carbonate of ammonia produces in both solutions precipitates, which are not completely re-dissolved by an excess of the precipitant.

Phosphate of soda produces a white precipitate.

Oxalic acid produces no precipitate.

Ferrocyanide of potassium, after some time, a thick, yellowish jelly, insoluble in hydrochloric acid.

Ferricyanide of potassium produces no precipitate in a solution of the volatile bichloride; a yellow precipitate in an aqueous solution of the modification of the bichloride, insoluble in hydrochloric acid.

Hydrosulphate of sulphide of ammonium produces a yellow precipitate, soluble in an excess of the precipitant, in ammonia, potassa, and carbonate of potassa.

Sulphuretted hydrogen, a yellow precipitate; in dilute solutions only after long standing.

26. SALTS OF OXIDE (TEROXIDE) OF ANTIMONY.

Potassa produces a white bulky precipitate, which re-dissolves completely in an excess of the precipitant.

Ammonia, a copious bulky precipitate, insoluble in an excess of the precipitant.

Carbonate of potassa, a white bulky precipitate, which redissolves completely in an excess of the precipitant, upon heating.

Carbonate of soda and carbonate of ammonia, the same as ammonia.

Phosphate of soda, a copious precipitate; however, the precipitation is not complete.

Oxalic acid, a bulky white precipitate; after some standing, the precipitation is complete.

Ferrocyanide of potassium, a white precipitate, insoluble in hydrochloric acid.

Ferricyanide of potassium, no precipitate.

Hydrosulphate of sulphide of ammonium, a red precipitate, soluble in an excess of the precipitant.

Sulphuretted hydrogen, a red precipitate.

27. SALTS OF SESQUIOXIDE OF CHROMIUM.

Potassa produces a bright-green precipitate, which readily redissolves in an excess of the precipitant, but separates again completely upon ebullition.

Ammonia produces a grayish-blue precipitate, which, however, separates completely upon ebullition.

Carbonate of potassa produces a bright-green precipitate, which completely redissolves in a very considerable excess of the precipitant, and is not thrown down again from this solution upon boiling.

Carbonate of ammonia produces a bright-green precipitate, soluble in an excess of the precipitant.

Phosphate of soda, a bright-green precipitate.

Oxalic acid, no precipitate.

Ferrocyanide and ferricyanide of potassium, no precipitate.

Chromate of potassa, in neutral solutions, a dark brownish-yellow precipitate, in acid solutions simply a coloration of that hue, the actual separation of the precipitate ensuing only upon addition of ammonia.

Hydrosulphate of sulphide of ammonium, a greenish precipitate of hydrate of sesquioxide of chromium.

Sulphuretted hydrogen, no precipitate.

II. METALLIC ACIDS.

1. ANTIMONIC ACID.

Acids, more especially nitric acid, throw down the antimonie acid completely from alkaline solutions; hydrochloric acid in excess dissolves the precipitate readily in the cold; nitric acid and sulphuric acid dissolve it only upon heating.

Sulphuretted hydrogen produces no precipitate in alkaline solutions ; but in acid solutions, an orange-yellow precipitate, which is soluble in hydrosulphate of sulphide of ammonium.

2. CHROMIC ACID.

Mineral acids impart a reddish-yellow color to the solution.

Hydrochloric acid decomposes the chromic acid upon continued ebullition ; chlorine escapes, and the dissolving sesquioxide of chromium imparts a green color to the fluid.

Sulphuretted hydrogen imparts a green color to the solution mixed with hydrochloric acid ; this coloration is caused by the reduction of the chromic acid.

Salts of baryta produce a pale-yellow precipitate ;

Salts of oxide of lead and of teroxide of bismuth, a lemon-yellow precipitate ;

Salts of silver, a purple-red precipitate ;

Salts of suboxide of mercury, a brick-colored precipitate ;—which precipitates are all of them soluble in nitric acid.

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3. MANGANIC ACID.

Acids, and even water, produce a red coloration, and a brown precipitate.

Hydrochloric acid, besides this, reduces the manganic acid, with evolution of chlorine, and the dissolving sesquichloride of manganese imparts a dark-brown color to the fluid, which disappears again upon heating, owing to the formation of protochloride of manganese.

4. PERMANGANIC ACID.

Potassa produces a green coloration, owing to the formation of manganic acid.

Nitric acid and sulphuric acid effect, upon heating, a partial decomposition into binoxide of manganese, which falls down as a brown powder, and oxygen, which is liberated.

Hydrochloric acid acts upon permanganic acid the same as upon manganic acid.

Sulphuretted hydrogen produces a precipitate of sulphide of manganese, mixed with sulphur thrown down along with it, and which makes the precipitate look almost white.

Hydrosulphate of sulphide of ammonium in excess produces a flesh-colored precipitate of sulphide of manganese.

5. ARSENIC ACID.

Salts of baryta and of lime produce in solutions of arseniates (but not in solutions of arsenic acid) a white precipitate, which is very readily soluble in hydrochloric acid and nitric acid, and also in sal-ammoniac (chloride of ammonium).

Nitrate of lead produces a white precipitate.

Nitrate of silver, a brownish-red precipitate.

Nitrate of oxide of copper, a pale-green precipitate, soluble in nitric acid, and in free ammonia.

Sulphuretted hydrogen, in acid solutions, a yellow precipitate, which is soluble in hydrosulphate of sulphide of ammonium, and also in potassa and in ammonia.

Hydrosulphate of sulphide of ammonium produces no precipitate.

6. ARSENIUS ACID.

Chloride of barium and chloride of calcium produce no precipitate in aqueous solutions of arsenious acid; in solutions of arsenites, they produce a white precipitate, soluble in sal-ammoniac (chloride of ammonium).

Salts of lead produce a precipitate in moderately strong solutions of arsenites; in over-dilute solutions they fail to produce a precipitate.

Nitrate of silver produces in solutions of arsenites a yolk-colored precipitate, soluble in nitric acid and in ammonia; in solutions of arsenious acid, nitrate of silver can hardly be said to produce a precipitate.

Sulphate of oxide of copper produces in solutions of arsenites a green-finch-colored precipitate, soluble in potassa and in ammonia.

Sulphuretted hydrogen, in the acid solution, a yellow precipitate, soluble in hydrosulphate of sulphide of ammonium, caustic and carbonated alkalies, and in nitric acid.

Hydrosulphate of sulphide of ammonium, no precipitate.

APPENDIX.

Brief explanations of some of the chemical terms which occasionally occur in the present work; intended for the benefit of persons unacquainted with chemistry.

CHEMISTS divide bodies into simple and compound bodies. The simple bodies are also called elements, or elementary substances. These terms, however, by no means imply that the bodies so called are really simple or elementary, but simply that they appear to us so at the present time, having hitherto resisted all attempts to decompose them. The elementary substances at present known to us amount to sixty-two in number. They are usually divided into two great classes, viz., metals and non-metallic bodies, or metalloids. This division is however entirely arbitrary, as the two classes completely merge into each other. The class of metalloids comprises fifteen elementary bodies; however, in the present work (Table I.) we have given only thirteen of them, viz., arsenic, boron, bromine, carbon, chlorine, fluorine, hydrogen, iodine, nitrogen, oxygen, phosphorus, selenium, and sulphur. The class of metals comprises forty-seven simple bodies, of which we have only given, however, twenty-four in Table I., viz., aluminium, antimony, barium, bismuth, calcium, chromium, cobalt, copper, gold, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, platinum, potassium, silver, sodium, strontium, tin, uranium, and zinc.

Every elementary substance is designated in chemical notation by the initial of its latin name in capital; or, where the names of several substances begin alike, by the first letter conjoined with a second small one, the most characteristic in the word. This simple or compound letter-mark is called the *symbol* of the substance; it designates not only the substance in the abstract, but represents one equivalent of it. Thus, *e.g.*, Hg (from the Greek hydrargyrum) represents one equivalent

of mercury ; Fe (from the Latin *ferrum*), one equivalent of iron ; O, one equivalent of oxygen ; H, one of hydrogen ; Ca, one of calcium, &c.

The compound bodies result from the union of two or several elementary substances. The combinations of metals with each other are called *alloys* ; or, where mercury is one of the constituent elements, *amalgams*. The metalloids combine with each other, and with the metals, forming bases, acids, and salts. Thus, for instance, the metalloid chlorine combines with hydrogen, forming the well-known muriatic acid, which is more commonly called by chemists hydrochloric acid ; chlorine combines also with the metal sodium, forming common salt (chloride of sodium) ; oxygen combines with the metal potassium, forming the well-known alkaline base, potassa, &c. The combination of bases with acids gives also rise to the formation of salts ; thus, *e.g.*, sulphuric acid, a compound of sulphur and oxygen, forms with the base potassa a salt, the sulphate of potassa. Two salts frequently combine with each other, forming what chemists call double salts ; thus, for instance, the sulphate of alumina and the sulphate of potassa form a double salt, known as the double sulphate of alumina and potassa.

The chemical union of bodies is governed and regulated by certain fundamental laws, called the laws of combination, and which may be briefly stated as follows :

1. All chemical compounds are definite in their nature, the ratio of the elements being constant ; in other terms, the same chemical compound invariably contains the same elements combined in unvarying proportions.

2. Where a body is capable of combining with another in several proportions, these proportions bear a simple relation to each other. Thus one equivalent of A will combine with 1, 2, 3, 4, 5, equivalents of B ; or two of A, with 1, 2, 3, 4, 5, 7, of B ; or 3 of A with 5, 7 of B ; and so on. This law, which was first advanced by Dalton in 1807, is called the law of multiple proportions. The most simple proportions occur most frequently : we generally find between the component elements of compound bodies, the proportions of 1 to 1, of 1 to 2, of 1 to 3, of 1 to 4, of 1 to 5 ; or of 2 to 3, of 2 to 5, of 2 to 7.

3. The quantities in which two bodies unite with a third body, express also the relative proportions in which they unite with each other, presuming always, of course, that they do unite with each other. For instance, hydrogen combines with oxygen in the proportion of 1 part by weight of the former to 8 parts by weight of the latter ; chlorine combines with oxygen in the proportion of 35.5 parts by

weight of the former to 8 parts by weight of the latter. Chlorine combines accordingly with hydrogen in the proportion of 35.5 of the former to 1 of the latter. As oxygen has a most extensive range of affinity, and very great powers of combination, uniting in fact with all the elementary substances, with the single exception of fluorine, and as its compounds are susceptible of the most rigid and exact analysis, this body has been chosen by chemists as the starting substance in the construction of the table of chemical equivalents. The number assigned to the equivalent of the starting substance is entirely arbitrary. Continental chemists usually assign the number 100 to the equivalent of oxygen, 12.5 to that of hydrogen, 443.75 to that of chlorine; but it will be readily seen that the relative ratio remains the same: 100 is to 12.5 as 8 is to 1, to 443.75, as 8 is to 35.5. 8 has been chosen here as the more convenient figure of the two, and because it is the proportion in which oxygen combines with one part by weight of hydrogen to form water, supplying us thus in the equivalent of the hydrogen, with a unity of which the equivalents of all other simple substances should be integer multiples, according to a theory advanced by a most eminent English chemist (Prout); a glance at the table of equivalents of elementary bodies will, however, suffice to show that in the present state of our knowledge, at all events, this hypothesis is not sufficiently supported to justify its admission.

4. The combining quantity or proportion of a compound is the sum of the combining quantities of its components. Let us take, for instance, chloride of sodium. The equivalent of chlorine is 35.5, that of sodium 23; the combining proportion or equivalent of the chloride of sodium is therefore 58.5.

Most of the compounds which the metalloids form with the metals, are now generally designated in chemical nomenclature as *ides*; but many of them were formerly, and are still by some chemists designated as *urets*. The termination *ide* (or *uret*) is substituted for the termination of the name of the metalloid, and the preposition *of* interposed between this and the unaltered name of the metal. Thus, for instance, the compound formed by the union of the metalloid chlorine with the metal sodium, is called chloride of sodium; the compound formed by oxygen with silver, is called oxide of silver, &c., &c.

As has already been stated, bodies may combine with each other in several proportions bearing a definite simple relation to each other.

Thus oxygen combines with manganese in six* different proportions,

* There exists even a seventh oxide of manganese (*varvicite*), which contains seven equivalents of oxygen to four of manganese.

viz., 1 to 1, 3 to 2, 2 to 1, 4 to 3, 3 to 1, and 7 to 2. The first compound (1 of oxygen to 1 of manganese), is called the protoxide of manganese; the second (3 of O to 2 of Mn), the sesquioxide; the third (2 of O to 1 of Mn), the deutoxide or binoxide; the fourth being, in reality, a compound of the protoxide with the sesquioxide, is properly called proto-sesquioxide; the fifth compound of oxygen with manganese (MnO_3), having acid properties, *i. e.*, combining with bases to form salts, is termed manganic acid. The composition of this acid would be indicated by the term teroxide of manganese; the term oxide, however, is not applied to bodies having acid properties; thus we do not say, for instance, teroxide of arsenic, or pentoxide of arsenic, but arsenious* acid for the former, and arsenic acid for the latter; and the sixth compound (Mn_2O_7) is called hypermanganic or permanganic acid. Compounds containing less than one equivalent of oxygen to one equivalent of metal, are called suboxides; thus, Cu_2O (two equivalents of copper to one of oxygen) is called suboxide of copper. The same rules hold generally good also in the nomenclature of compounds of oxygen with the metalloids, and in those of sulphur and other metalloids with the metals and with each other. Most of the metalloids form acids with oxygen, as chlorine, iodine, bromine, sulphur, phosphorus, nitrogen, carbon, selenium, boron, silicon, arsenic, tellurium; some form acids with hydrogen, as chlorine, iodine, bromine, fluorine, sulphur; these latter acids are called respectively, hydrochloric, hydriodic, hydrobromic, hydrofluoric, hydrosulphuric acids. With regard to the neutral or basic compounds, which the metalloids form among themselves, the termination *ide* is always given to the oxygen, wherever that body forms one of the constituents; chlorine follows next after oxygen in this respect; thus we say, chloride of iodine, of sulphur, of nitrogen; bromine follows next after chlorine (bromide of iodine); the next is fluorine (fluoride of

* The terminations *ous* and *ic*, applied to acids, signify different degrees of oxidation, the latter being the higher of the two: the salts formed by acids in *ous* are called *ites*, as, e. g., sulphite of soda, a compound of sulphurous acid and soda (oxide of sodium); those formed by acids in *ic*, are called *ates*, as, e. g., sulphate of soda, a compound of sulphuric acid and soda. When oxygen forms more than two acids with a metal or metalloid, the terms *hypo* and *hyper* (from two Greek prepositions, signifying respectively *under* and *over*) are prefixed to the name of the acid; thus we have, for instance, *hyposulphurous acid*, a compound containing less oxygen than the *sulphurous acid*; and *hyperchloric acid*, a compound containing more oxygen than the *chloric acid*. Instead of *hyper*, chemists use mostly the simple *per*, saying, for instance, *perchloric acid*, instead of *hyperchloric*, *permanganic*, instead of *hypermanganic*.

silicon) ; after this comes sulphur (sulphide of arsenic, sulphide of carbon). The compounds which phosphorus, carbon, arsenic, selenium, form with hydrogen, are called respectively phosphuretted, carburetted, arseniuretted (or arseniетted), seleniuretted hydrogen.

The Price-list of the Apparatus, &c., may be had of the Publisher
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THE END.