Chemical re-agents or tests; and their application ... Improved and brought down to the present state of chemical science, by William Maugham / [Friedrich Christian Accum].

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Accum, Friedrich Christian, 1769-1838.
Maugham, William.

Publication/Creation

London : Tilt, 1828.

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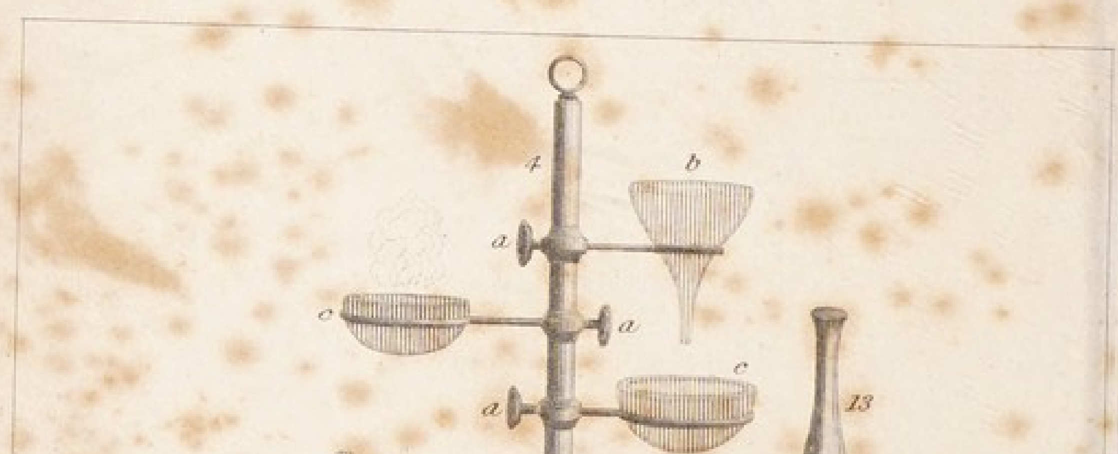

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Pub. by C. Tilt, 86 Fleet Street, Septr. 1829.

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CHEMICAL
RE-AGENTS OR TESTS;

AND THEIR APPLICATION

IN ANALYZING WATERS, EARTHS, SOILS, ORES,
METALLIC ALLOYS, &c.

BY FREDERICK ACCUM.

IMPROVED,

AND BROUGHT DOWN TO THE PRESENT STATE OF CHEMICAL SCIENCE,

BY WILLIAM MAUGHAM,
SURGEON,
AUTHOR OF THE PUPIL'S PHARMACOPŒIA, LECTURER ON CHEMISTRY
AND MATERIA MEDICA, ETC.

A NEW EDITION.

LONDON:
CHARLES TILT, FLEET-STREET.

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PREFACE.

THIS Essay on Chemical Re-agents or Tests, by Mr. Accum, was put into the hands of the Editor for revisal, previously to committing another edition to press ; and, on looking it through, he found it necessary to expunge several parts, to re-write others, and to make such additions as the nature of the subject, from recent discoveries, continually required. He trusts that the alterations which have been made will render it more acceptable than the preceding to the young chemist, who, having already become conversant with the first principles of the most delightful, as well as most useful, of all sciences, is desirous of applying his knowledge to practice, but who requires some leading medium to conduct him from the elementary treatises he may have consulted, to the writings of the more distinguished chemical philosophers of this and of other countries, so as to enable him readily to comprehend them, and to enter with facility on his analytical inquiries. This work is in some measure calculated to supply that medium.

The *first part* treats upon the history of some of the principal substances which have been employed as Re-agents or Tests; the manner of employing them being exemplified by a series of experiments which are exceedingly easy to perform, and which require no other agents than the tests mentioned, and a few articles of commerce, with such apparatus as is within the reach of every one.

In the *second part* a variety of useful examples of analysis have been selected from the labours of Klaproth, Thenard, Davy, Murray, Henry, and other celebrated analysts, with the view of further illustrating the nature and usefulness of this department of the science, and of leading to a more extended application of tests, in arriving at the composition of such bodies as present themselves to the observation of the inquiring student.

In the Appendix will be found a Table of Atomic Weights, for the convenience of reference, and its nature and use is explained in the Introduction.

Directions have not been given for preparing the different tests, except in some particular instances, because the student, from the knowledge he is supposed already to possess, will be able to prepare several of them himself, with the assistance of some respectable treatise on chemistry, and others may be more advantageously purchased ready prepared.

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INTRODUCTION.

The student who is unacquainted with the theory which relates to the proportions in which bodies combine chemically, will derive much scientific and useful information on this subject by consulting the little manual by Dr. Turner, called "An Introduction to the Study and Laws of Chemical Combination;" or he may refer to the "Elements of Chemistry" by the same author, in which the little work alluded to is embodied, with a few alterations. When he understands that the elementary or component parts of compound bodies always exist in the same proportion, a new field of inquiry will be opened to his view, his analytical labours will be materially facilitated, and he will perceive the basis on which chemistry rests as *a science.* The atomic weights, or the combining proportions of bodies, are now to be found in almost all treatises on chemistry, arranged in the form of tables similar to that contained in the Appendix; and their use in determining the quantity of the components in a compound will become evident by a few examples.

Suppose it be required to know how much pure lime exists in a precipitate of sulphate of lime weighing 230 grains. By turning to the table we find, opposite sulphate of lime 68, that compound consisting of 1 atom of sulphuric acid, which we find by the same table to be 40, and 1 atom of lime, which is 28. The numbers will be better seen thus :

Sulphate of Lime 68.	1 atom of sulphuric acid	40
	1 atom of lime	28
		68

Then, to ascertain how much lime is contained in the 230 grains, we have only to state,

As 68 : 28 :: 230 : 94.7

If a precipitate of chloride of silver weigh, when dried, 118 grains, the quantity of pure silver it contains is at once estimated; for, by turning to the table, we find chloride of silver to consist of

Chloride of Silver 146.	1 atom of chlorine	36
	1 atom of silver	110
		146

Then,

As 146 : 110 :: 118 : 88.9

The readiness of this method of proceeding in ascertaining the quantity of any of the components in a given weight of a compound becomes at once so obvious, that it is unnecessary to enlarge upon it in this place. The table of equivalents may be applied in a variety of other ways, which a knowledge of the theory of numbers, combined with practical experience, will occasionally dictate. It may be necessary to observe, that the combining proportion of some bodies has, perhaps, not yet been accurately determined; therefore, whenever a number is corrected by respectable authority, it will be necessary to alter the number in the table accordingly.

Much amusement, as well as information, will be obtained from Dr. Wollaston's Scale of Chemical Equivalents, which may be purchased at any mathematical instrument maker's, with a description of its construction and use; but as this scale does not determine the component parts of bodies with a great degree of accuracy, it will always be necessary to refer to a table of equivalents when we wish to approach as near as possible to the truth.

Every one desirous of excelling in analytical chemistry must be provided with proper scales and weights, so as to be able to ascertain the weight of a body to a very great degree of accuracy, which cannot be done with ordinary instruments. As Mr. Faraday has given ample directions respecting the important subject of *weighing*, the editor refers the student to his work on "Chemical Manipulation," which also abounds with other information of the greatest importance to all who wish to become experienced operators in the several departments connected with the study of chemistry.

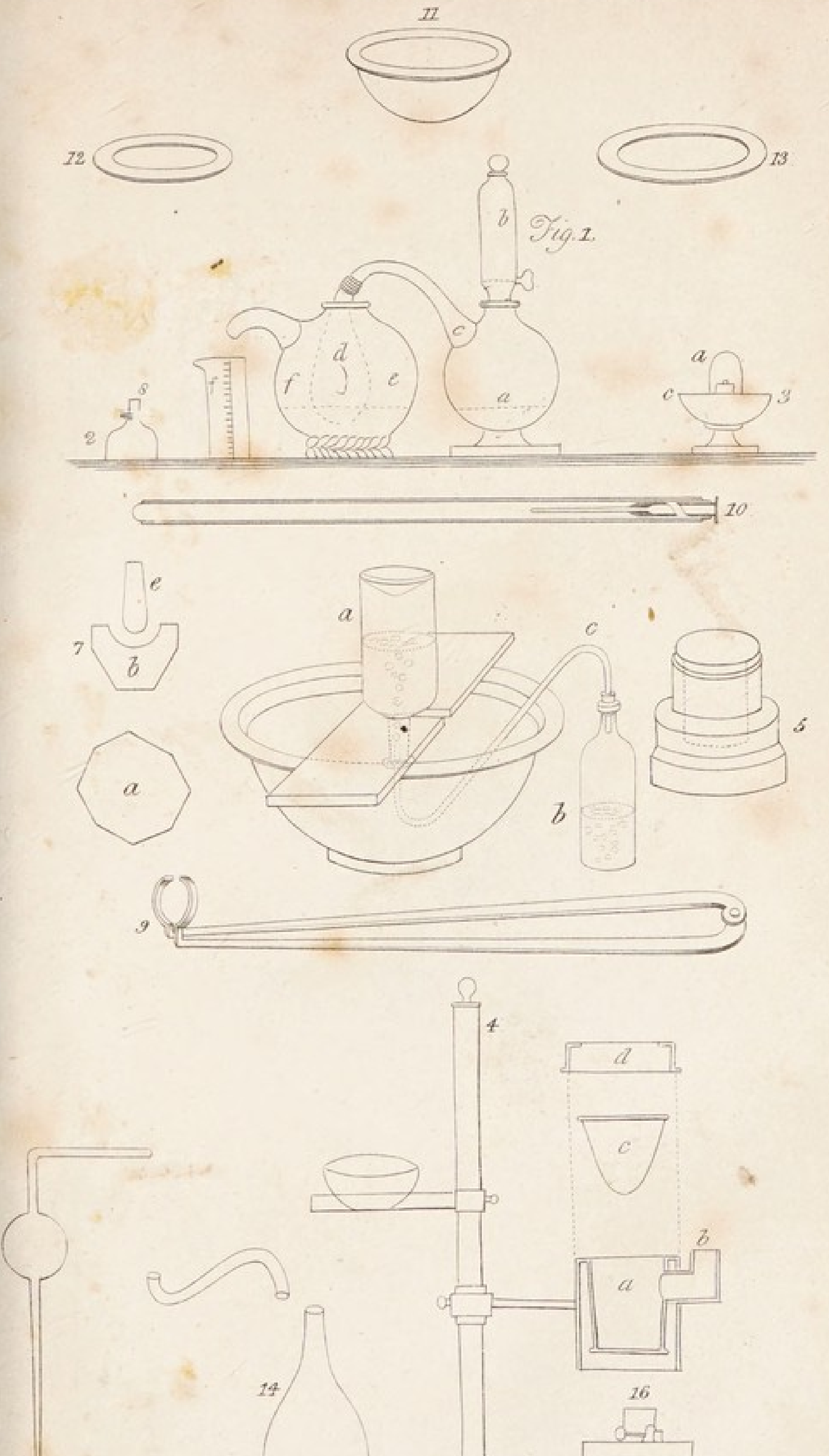

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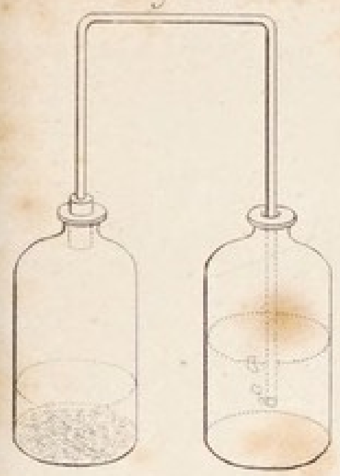
Plate 3.

Fig. 1.



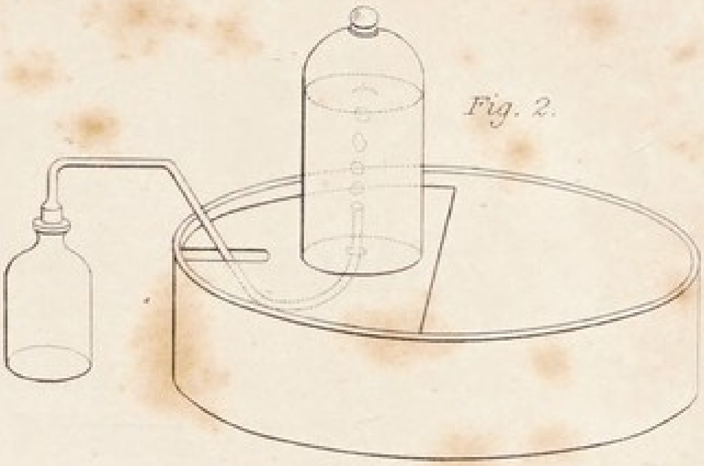


Fig. 2.

Fig. 8.

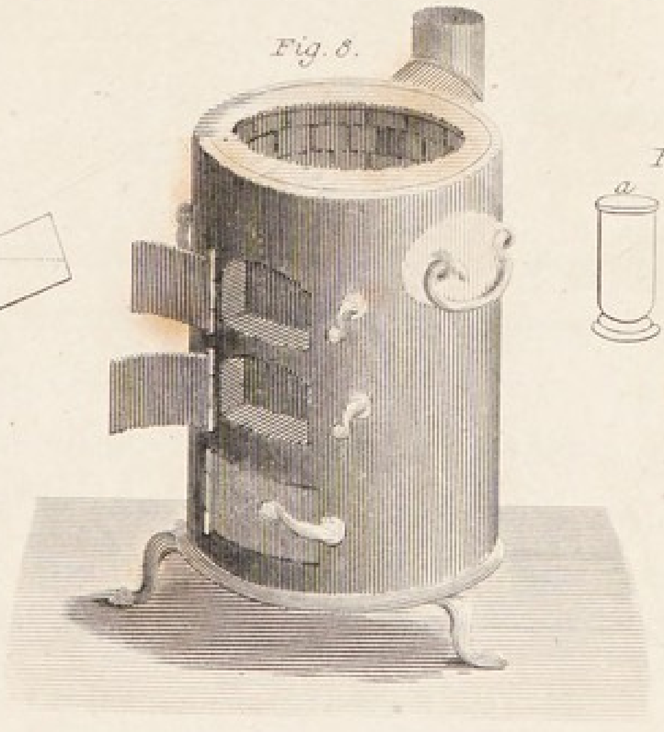


Fig. 3.

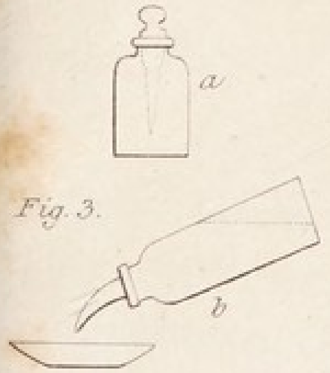
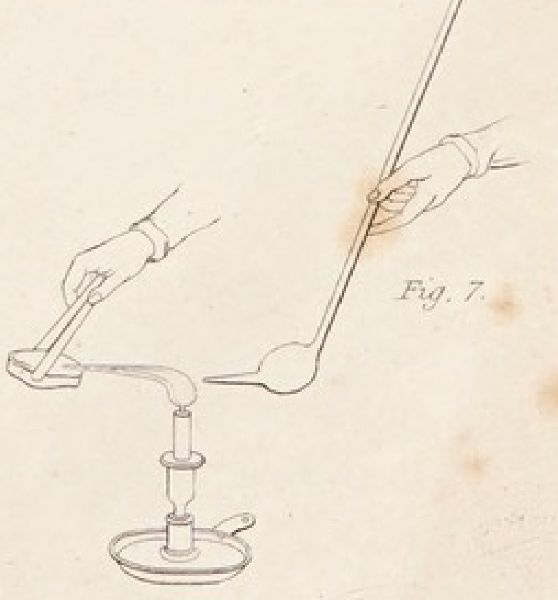


Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.



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CHEMICAL

RE-AGENTS, OR TESTS.

PART I.

DEFINITION AND GENERAL NATURE OF CHEMICAL RE AGENTS, OR TESTS.

THOSE substances, which when applied to other bodies, whose nature or composition is unknown, and which *quickly* act upon them, and produce such changes as are sufficiently striking to the senses, and from which the quality or constitution of the unknown body may be inferred, are called *Chemical Tests, or Re-agents.* They are therefore employed in practical and operative chemistry, for the analysis or decomposition of different bodies, or for ascertaining the constituent parts of chemical compounds.

The importance and extensive utility of this class of bodies, and their application in chemistry, which is almost entirely of modern date, must appear obvious to those who are at all conversant with the practice of chemistry: chemical tests constitute the compass by which the chemist steers; it is by means of these re-agents that we obtain a knowledge of the constitution of compound bodies: for as the chemical affinities of bodies towards each other are various, the constituent parts of compound bodies may often be easily disengaged by the application of other substances; and it is upon this consideration that the action of all re-agents, or tests, employed in chemical analysis, is founded; for the great object of acquiring a knowledge of the chemical nature of bodies, consists in separating analytically their component parts: this, however, is seldom practical without, at the same time, uniting them to another body; and it is this that leads to the object in view, namely, the knowledge of the composition of the substance under examination. It is thus that re-agents frequently act: the test combines with some principle of the body with which it is brought in contact, and a compound arises, whose characters at once indicate the nature of the principle which has entered into combination, because the combination of the principal re-agents with various bases, are well known. This method is, in reality, more frequently employed in the chemical examination of bodies, than the simple process of decomposition. Sometimes the re-agent displaces from the body under examination, certain constituent parts or principles only, which in that state may be examined more accurately, and with less trouble, because insulated and disengaged from their combinations.

It likewise frequently happens, that the re-agent made use of, is itself decomposed. This circumstance renders the phenomena and the products more complicated; but we are enabled, from the characters of these products, and their actions upon other bodies, to form a judgment of the component parts of the body analyzed. This last fact was little attended to by the ancient chemists; and this is one of the principal defects of their labours; because they referred many of those phenomena to the bodies which they submitted to their analysis, which, in reality, arose only from the decomposition of the re-agents employed in their operations.

Most of the tests employed in the processes of chemistry, indicate the component parts of bodies, by occasioning either *a precipitate, a sensible cloudiness, a change of colour, an effervescence*, or *such other obvious alterations of properties*, which, as experience has proved, denote the presence or absence of certain bodies.

Let us suppose, for example, that a drop of muriatic acid, when suffered to fall on a mineral or other substance, the constitution or nature of which is unknown to us, occasions an effervescence: we conclude from this phenomenon, that the mineral is a carbonate, that is to say, it contains carbonic acid. If a drop of the same acid occasions a white precipitate when added to a solution of the same mineral in nitric acid, we conclude that the unknown substance contains either silver or lead. Let us suppose that both these metals were present. To separate them from each other, we have merely to pour over the precipitate a small quantity of liquid ammonia: by this means, that portion of the precipitate which contains the silver, becomes dissolved, while the other part containing the lead, is left behind.

To pursue our inquiry further by means of tests, let us suppose that sulphate of iron produces a brown precipitate: we conclude from the appearance produced by the test, that gold is present.

If liquid ammonia changes the solution to a fine blue colour, we may expect copper: and if tincture of galls turns it purple or black, we may expect iron.

An example, which is easily performed, will illustrate the action of chemical tests more strikingly:—

Analysis of a Silver Coin.

1. To analyze a silver coin, put it into a tea-cup, or glass vessel; pour upon it about four times its weight of pure nitric acid, diluted with about double its weight of distilled water. The coin will become dissolved with effervescence. The solution thus obtained contains silver and copper, for European silver coins are all alloys of silver and copper: the copper gives the solution a green colour.

2. To separate the silver, add to the solution muriatic acid, or common salt previously dissolved in water: a white curdy precipitate will ensue, which is the silver thrown down in the state of chloride, it having abstracted

chlorine from the solution of common salt, or from the muriatic acid, and is then no longer soluble. Decant or filter the supernatant fluid, and put it aside. Collect the white precipitate, wash it by pouring water over it repeatedly, until the washings cease to become blue on the addition of solution of ammonia, and then dry it, and lastly, expose it to a heat sufficient to fuse it:—100 parts by weight contain 75·34 of silver.

3. The washings and the filtered liquor must be added together, and to the whole, pour an excess of solution of caustic potash, or of caustic soda, which will throw down the whole of the copper in the state of peroxide, which being washed, dried, and heated to redness, gives the quantity of real copper, 100 grains of it containing exactly 80 grains of metallic copper.

4. Another way of separating the copper from the liquid deprived of its silver, as above, is to pour into it a quantity of sulphuric acid, sufficient to decompose the nitrate of copper which it contains. Evaporate the solution to dryness, and re-dissolve the whole residue in distilled water. Immerse in the obtained solution a plate of zinc, and suffer it to remain

in it for about twenty-four hours. The zinc will precipitate the copper in a metallic state: wash the plate of zinc, to separate any copper which may adhere to it. Collect the copper, wash it with muriatic acid, diluted with four parts of water: an effervescence will take place, owing to the solution of a portion of zinc which had fallen down along with the copper. When this has been done, wash the metallic copper again, dry it, and weigh it.

If the analysis be rightly conducted, the weights of the silver and copper contained in the precipitates when added together, ought to equal the weight of the original coin.

It may be readily conceived, that a vast variety of substances, provided their chemical actions be well established, may serve as re-agents, or tests; and that even no compound is useless to a skilful chemist in his analytical operations. By long search and experience, we have, however, learned to make choice of some particular bodies only; the effects of which are rapid, and the application of which requires no skill; and to these bodies the name of re-agents, or tests, has been given by mutual consent.

There are, nevertheless, two circumstances which render it necessary that the substances used as tests should be applied with care and circumspection: one is, that the same body used as a re-agent frequently produces a similarly apparent effect, on two, or three, or more different matters contained in the compound to which it is presented; the other, that one re-agent may produce several of those effects with one and the same substance. Both these inconveniences may be remedied, by employing and comparing the effects of several of the re-agents, and by assisting their action by other agencies calculated to render the results unequivocal. This mode of proceeding, the only one that can render the use of chemical tests much more certain and advantageous, therefore supposes, that we do not precisely fix certain specific tests only for certain specific substances, under all circumstances; but that we take the facts we are in search of from the united effects produced by the summary action of several tests, applied under different circumstances, as will be pointed out in the sequel. It is evident, therefore, that certain bodies have the property of indicating and separating other bodies from compounds, of which they form a part. Hence the great object in all analytical inquiries is, to find a body *x* capable of separating a body *a* from another body *b*. He who is able to solve this problem in the greatest variety of circumstances, is the best analytical chemist.

The application and importance of the substances made use of as re-agents, was first pointed out by the illustrious Boyle. It had long before been known, indeed, that the blue colour of the violet flower was reddened by sulphuric acid, or by lemon juice and vinegar; but this philosopher proved, that the rèddening property belongs to all acids, and that it was a leading property which characterises this class of bodies. He was also the first who observed that alkalies render the blue colour of vegetables, green, which he instances in the juice of the flowers of the blue-bell and the blue iris. He mentions the effect of volatile alkali, or ammonia, in producing a blue transparent fluid, with solutions of copper; and he relates that the colour of rose leaves is destroyed by the fumes of burning sulphur, or sulphurous acid, but heightened by sulphuric acid. That water tinged red with Brazil-wood becomes yellow by acids; and that alkalies restore the original colour of the tincture. That silver is precipitated from its solutions by common salt, or muriatic acid; and that the precipitate is blackened on exposure to the rays of the sun, or the mere light of day. That sulphate of mercury acquires a yellow colour by the affusion of boiling water. That quicksilver dissolved in nitric acid occasions an orange-coloured precipitate with fixed alkalies; and that metals and metallic solutions are acted upon by sulphuretted hydrogen. He also points out the effects of lime water, and acetate of lead, as tests for various bodies, and he describes the compounds which they produce.

Soon afterwards, namely, in the year 1665, Dominico Duclos employed tincture of galls, sulphate of iron, and tincture of litmus, as re-agents in the analysis of some mineral waters of France; and made some useful critical remarks on the golden colour given to silver by sulphureous waters, and on other re-agents which had begun to be employed and recommended by Boyle.

In 1685, Boyle again gave some new instructions for using the tests which he had pointed out in the year 1663, and he strongly recommended his *fuming liquor* (hydro-sulphuret of ammonia) as a test useful in the analysis of mineral waters; as well as solutions of sea salt, sal ammoniac, nitric acid, muriatic acid, and ammonia, which he extolled as deserving the notice of the chemist.

In the year 1726, M. Boulduc pointed out the application of alcohol as a useful test in the analysis of mineral waters. And from that period chemical re-agents were employed, but the conclusions drawn from their effects were long, inaccurate, and erroneous.

The list of chemical re-agents, however, has been greatly augmented by the labours of modern chemists; and we are particularly indebted to Bergman, Scheele, Kirwan, and Westrumb, for the knowledge of the particular actions of numerous re-agents, and the modes of applying them with success in the multifarious researches of chemical science.

Bergman was the first who laid down rules for the right application of chemical tests, in his treatise, published 1780, *De Docimasia Humida*, and in his Rules for Analyzing Mineral Waters. Many additions and improvements were pointed out in the application of chemical tests by Klaproth, who devoted his whole life to analytical inquiries; and his works are to this day pronounced to be the best guide to those who wish to become proficients in this department of operative chemistry.

Vauquelin has also devoted a long active life to this department of chemistry; and Berzelius has given us the most complete collection of facts and analytical experiments that have yet appeared.

The names of other contributors to this department of chemical science might be added to the list; but those who are desirous of further information on the subject, and of knowing in what manner the *science* of chemistry has grown out of the mere *art*, will meet with much condensed and useful information in the *History of Chemistry* contained in the first volume of Brande's Manual of Chemistry.

PHENOMENA PRODUCED
BY
CHEMICAL TESTS,
AND
ART OF APPLYING THEM.

I. *Tincture of Litmus**.

1. This test is employed for detecting the presence of uncombined acids, as well as acids in excess (see No. 16), by which it becomes changed to red: its natural colour is a dark blue, inclining to purple. The red colour contained in the lichen, being combined with an alkali, on the addition of an acid the alkali is attracted, and the red colour of the vegetable is set free.

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* *Litmus, archil,* or *turnsole,* is obtained by reducing that species of lichen, called *lichen roccella*, into a powder, by grinding it in a mill, after which it is mixed with half its weight of pearlash, and some human urine: being then exposed to the air, it undergoes fermentation, which is further excited by adding more urine, until it become, first of a red, and then of a blue colour, after which it is mixed with a certain quantity of carbonate of potash, and spread out to dry.

2. Tincture of litmus, when kept for several months in a stopped bottle, loses its colour, and acquires an olive brown tint; but it speedily regains its original blue colour when the bottle is opened, and suffered to stand exposed to the air for a few minutes. If the colour of this tincture inclines too much to purple, add to it a few drops of solution of ammonia; but of this fluid, no more must be mixed with the tincture than is barely sufficient to produce the desired effect, otherwise the sensibility of the test is impaired.

3. If the redness vanishes by suffering the fluid, to which the test has been applied, to stand exposed to the open air, or when concentrated by boiling, and re-appears by a fresh addition of a portion of the fluid, we then are sure that the acid is either *carbonic acid gas*, or *sulphuretted hydrogen gas*—a substance which, in this, as well as in every other case, performs the function of an acid. If the redness is produced by carbonic acid gas, the fluid becomes *immediately* turbid by the admixture of *barytic water*, or *lime water;* but the first test is the more efficient; and a precipitate falls down, which is soluble with ef-

fervescence in dilute muriatic or nitric acid. But if the redness is owing to sulphuretted hydrogen gas, no precipitate takes place; and this forms a decisive criterion to distinguish the action of carbonic acid gas upon litmus, from that of sulphuretted hydrogen gas. Besides, a fluid containing sulphuretted hydrogen gas, even when the portion of the gas is very small, always exhales a strong fœtid odour, resembling the odour of putrid eggs, or the washings of a gun barrel, and a drop of solution of nitrate of silver, or acetate of lead, renders it instantly *black;* but no such effect is produced with carbonic acid gas.

Carbonic acid gas and sulphuretted hydrogen gas are expelled from water containing them without change by boiling.

4. If the reddened tincture of litmus does not become blue again, after it has been suffered to stand exposed to the free contact of air; or, which is better, when it has been concentrated by boiling to about one half of its original bulk, we are sure that the redness is occasioned by a fixed acid, the nature of which may be ascertained by other tests; as will be pointed out hereafter. Examples:—

5. Into a test tube* half filled with distilled water, let fall a drop or two of tincture of litmus: the blue colour of the tincture will not be altered.

6. Add to a wine-glassful of distilled water impregnated with carbonic acid gas (or take common Seltzer water of commerce), a small quantity of tincture of litmus: its colour will become changed to red. Put the water into an evaporating basin; place the basin on the ring over the lamp furnace†, and evaporate it by the heat of a spirit lamp to about one-third or one-half of its bulk: the tincture will, during this process, recover its original blue colour, because the carbonic acid gas becomes volatilized, and the litmus is left behind in its natural state.

7. To shew the extreme sensibility of this

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* *Test tubes* are glass tubes, three or four inches long, and from $\frac{1}{2}$ inch to $\frac{3}{4}$ of an inch in diameter, closed and rounded off at one end, and open at the other, with a rim a little turned over, to pour liquids out from them conveniently. They are useful for observing the changes of colour, and other phenomena produced by chemical tests, as well as for dissolving solids, precipitating solutions, &c. A series of these tubes should be always ready at hand in the laboratory, arranged in a wooden stand. They will bear heat without cracking. Ale glasses, or glasses of that form, having a lip for decanting supernatant fluids, are very useful for a variety of the above purposes.

† See description of the plates.

test, with regard to carbonic acid, let a few ounces of distilled water be tinged slightly blue by tincture of litmus, and blow through the coloured water the breath from the lungs, by means of a quill or tobacco pipe dipping into the fluid: the bubbles of respired air, whilst passing through the water, will speedily produce the reddening effect; though the quantity of carbonic acid gas contained in the air breathed out from the lungs, does amount only to 8 or 8½ per cent. If the water thus reddened be boiled, its original blue colour will re-appear, as in the before-mentioned experiment.

8. Let fall into a test tube, half filled with distilled water, a drop of lemon juice, vinegar, or any other acid, and add to the mixture a few drops of tincture of litmus: the tincture will instantly become changed to red: boil this fluid as before directed, and its colour will not vanish, but remain permanent, because the redness is owing to a fixed acid.

9. Add to the same quantity of distilled water, a grain of alum, of salt of sorrel, or of cream of tartar: no change will take place; but if a few drops of tincture of litmus be added, the fluid instantly becomes red; be-

cause these salts contain an excess of acid. See No. 16.

10. Take water impregnated with sulphuretted hydrogen gas, and add to half a wine-glassful, a little tincture of litmus: the fluid will exhibit a red colour; boil the reddened tincture, as in No. 6, and it will be seen that it first loses its colour, or nearly so; but on continuing the heat, the fluid becomes blue again; because the sulphuretted hydrogen gas is now volatilized.

11. To contrast the action of sulphuretted hydrogen gas, with the action of carbonic acid gas, upon tincture of litmus, provide two test tubes, containing very dilute tincture of litmus reddened by carbonic acid, and provide also two other tubes half filled with the same tincture, reddened with sulphuretted hydrogen gas. Drop into one of the first tubes containing the carbonic acid water, a little barytic water: it *immediately* will produce a cloudiness, which again disappears by the addition of dilute nitric acid. And in the other tube, containing the same tincture, let fall a few drops of solution of nitrate of silver, which will produce no effect. This being done, drop barytic water also into

one of the tubes containing the tincture of litmus, reddened by sulphuretted hydrogen gas: no precipitate will follow; but if the nitrate of silver be dropped into the other tube, a black precipitate will instantly be produced.

12. It is often desirable (particularly in the examination of mineral waters), not to content ourselves with adding a few drops of the test to a small quantity of the liquid, but to examine the mineral water with the re-agents in the large way; by so doing we are enabled to observe the phenomena which the test produces more distinctly, whilst at the same time, when a precipitate is produced, as is frequently the case, we obtain of it a quantity more convenient for extending our examination.

13. The following method of employing tincture of litmus in the analysis of mineral waters, is recommended by Dr. Philips Wilson, in his analysis of the Malvern waters; it shews the superiority of the application of chemical tests in the large way, wherever the nature of the subject will admit of it: — Let two glass basins of the same size, with cylindrical sides and flat bottoms, of at

least four inches diameter and three inches high (finger glasses, such as are used at table), be placed on a sheet of white paper, and another sheet of white paper placed behind them, and let the observer stand between the glasses and the side from which the light comes, that he may receive the incident light reflected from behind and below the glasses. Let one of the basins be filled to about one or two inches in height with the water or liquid in which we suspect the presence of an acid, and let the same quantity of distilled water be put into the other glass basin, and to each let the same number of drops of tincture of litmus be added, taking care that the quantity of litmus be no more than is sufficient to give the slightest tinge, to show decidedly the purple blue colour in the distilled water. By comparing the colour of the water in the two basins, a very minute quantity of acid may thus be detected, especially by a person accustomed to use the test in this way.

14. Mr. Kirwan could not discover more than $\frac{1}{12000}$ of sulphuric acid by litmus. By the foregoing mode of using this test, it is rendered many times more sensible, as will appear from the following experiment:—To

two ounces of water, sulphuric acid was added in the proportion of 1 to 307200. This was put in one of the glass basins placed as above; and in the other basin, two ounces of water, which, from previous experiments, had been found did not affect the colour of litmus. On dropping into both basins the same quantity of the test, the colour was sensibly redder in the basin which contained the acid than in the other; the difference was such, as could be readily observed by a person accustomed to make such experiments.

When the acid was not diluted in the proportion of 1 to 460800, no difference of shade could be observed. The specific gravity of the acid employed by Dr. Wilson was 1,85. which is the usual strength of the acid of commerce; so that one grain of this acid contained 0,7946 grains of real acid, as nearly as can be ascertained from Kirwan's table of the specific gravity of sulphuric acid mixed with different proportions of water; and hence it therefore appears, that 0,7946 grains of sulphuric acid may be detected by the litmus, when used in the manner stated, in 307200 grains of water; so that one grain of real sulphuric acid may be detected by this test in 386597 grains, or 50,33 pints of water.

II. *Litmus Paper.*

15. Paper stained with tincture of litmus is also used as a test for detecting acids, in an uncombined state or in excess. If the redness is occasioned by carbonic acid gas, the paper, like the tincture with which it is stained, regains its original colour on drying, or by exposure to a gentle heat. Water impregnated with sulphuretted hydrogen gas, likewise produces an evanescent feeble redness with this test.

16. It is to be observed, that some salts which do not contain an excess of acid redden litmus, from which circumstance an inexperienced person might infer that such salts were *super* or *bi-salts*: thus *nitrate of lead* consists of one atom of the protoxide of lead, and one atom of nitric acid, and is therefore, strictly speaking, a neutral compound; but it has the same action on litmus paper as, for instance, the *bisulphate of potass,* which consists of one atom of potass and two atoms of sulphuric acid, and consequently having the

acid in excess. The action of an acid on litmus paper has already been explained (No. 1.); and Berzelius supposes, that the paper being reddened by some neutral salts is in consequence of the alkali of the litmus paper having a greater affinity for the acid of such salts than their own bases have, so that when the alkali is thus withdrawn, the red colour of the litmus is restored.

17. Litmus paper may be purchased ready for use, or may be readily prepared by dipping fine paper in tincture of litmus, and suffering it to dry slowly. The paper employed should first be freed from the size which all kinds of writing paper contain: this may be done by a repeated affusion of distilled water. The paper should also be free from earthy substances, especially carbonate of lime, and alkalies; which may be ascertained by burning a sample of the paper, and examining its ashes.

18. The colour of litmus paper ought to be a pale, not dark, violet blue. This paper, when long exposed to the contact of air and light, loses its colour, and then becomes unfit for use. It should, therefore, be preserved in opaque, stopped bottles, or placed between

the leaves of a book. This test paper is reddened by water containing $\frac{1}{4695}$ part of sulphuric acid. Examples :—

19. Dip a piece of litmus paper into distilled water, and its blue colour will not be altered.

Dip a piece of the same paper into water impregnated with carbonic acid gas (or into common Seltzer water, or the aërated water of commerce) : the water will acquire a reddish tint, and in a few minutes the blue colour of the paper will also be changed to red. Remove the paper, and dry it near a fire, and its original colour will re-appear, because the carbonic acid which produced the redness is volatilized.

20. Add a few drops of sulphuric, nitric, or muriatic acid, to half a wine-glassful of distilled water, and dip into the fluid a slip of litmus paper : its blue colour will in a like manner be changed to red.

Take the paper out of the water, and dry it in a warm place : its original blue colour in this case will not re-appear, because the acid which produced the redness cannot be volatilized by mere heat.

21. Immerse a slip of litmus paper in any sort of wine, cider, perry, ale, porter, or

other kind of fermented liquor; its blue colour will become changed to red, because all vinous fluids, even the mildest, contain a portion of a free acid; some more, others less. The paper thus reddened will not become blue again on exposure to heat. The redness occasioned by vinous liquors, on the addition of litmus, is owing to the presence of citric, tartaric, malic, or acetic acid.

22. Dip a piece of litmus paper into water strongly impregnated with sulphuretted hydrogen gas: its blue colour will gradually be changed to a faint red; dry the paper, and its original colour will re-appear.

III. *Syrup of Violets, &c.*

23. Syrup of violets is also an excellent test of acids; but it is not readily obtained pure. If genuine, a solution of corrosive sublimate added to it will turn it green; if it be spurious, it is turned red by the same test.

24. Paper stained with the juice of the violet flower, or the scrapings of purple radishes, answers the same purpose.

25. These bodies are also tests for alkalies, which turn them green.

IV. *Litmus Paper reddened by Vinegar, or some other dilute Acid.*

26. Litmus paper, when slightly reddened by an acid, has its blue colour restored by pure alkalies, their carbonates, and alkaline earths, because the acid which caused the redness is again neutralized, and consequently its action destroyed; so that in this instance, as usual, acids and alkalies are in direct opposition to each other, the acid restoring the colour to its original state, after it has been changed by the alkali, and *vice versâ*. A single coloured test paper of litmus becomes, therefore, a delicate test for both acids and alkalies.

27. To know whether the change which this paper undergoes be owing to an alkali, or to lime dissolved in carbonic acid, it is necessary that the fluid be evaporated to at least one half of its original bulk before the test paper is applied; because the excess of carbonic acid, with which lime can only exist in solution, becomes then volatilized, and the lime, combined with a smaller portion of carbonic acid, can no longer exist in the liquid, but is precipitated in the form of a white powder, or

neutral carbonate of lime: the heat applied having annihilated the bond of union which existed between the neutral carbonate of lime, and the excess of carbonic acid. It is by this deposition of carbonate of lime by boiling water in a tea-kettle, that its interior becomes coated, or *furred* as it is commonly called.

28. If the blue colour of this paper still continues to re-appear after the liquid has been concentrated by boiling, there is then reason to believe that the reddening cause is owing to a fixed alkaline salt, the nature of which may be discovered by tests employed for discovering these bodies; and the action of barytes and strontia may be rendered obvious by other means. Examples :—

29. To one quarter of a pint of distilled water, strongly impregnated with carbonic acid gas (or common Seltzer water, or aërated water of commerce), add about fifteen or twenty grains of finely pulverized white marble or chalk; let the mixture stand for some hours closely corked, and shake the bottle frequently during that time: part of the marble or chalk will become dissolved in the water. When the fluid has become clear,

decant part of it, or, which is better, filter it, and immerse in the solution a piece of litmus paper reddened by an acid; the tint of the paper will gradually vanish, and its original blue colour will re-appear; shewing the presence of carbonate of lime.

30. Take another portion of the same water, and evaporate it, by means of a lamp furnace, to at least one half of its bulk. During this process it will become turbid, a multitude of minute air bubbles will become disengaged, and the carbonate of lime, which was dissolved in the water by virtue of its excess of carbonic acid, becomes again precipitated in the form of a neutral carbonate of lime, when the excess of the carbonic acid is volatilized.

When the precipitate has subsided, let the water be filtered, and immerse in it a piece of reddened litmus paper; the colour of which will now no longer be altered.

31. To a test-tubeful of distilled water, add a few grains of carbonate of potass, carbonate of soda, carbonate of ammonia, or a little of any of the pure alkalies, and dip a piece of reddened litmus paper into this solution: immediately the red colour of the paper

will vanish, and its original blue colour will re-appear. Evaporate another portion of the same water to one half of its bulk, and examine it again with the reddened paper; notwithstanding the evaporation, the red colour will disappear, and the blue be restored; except in the case of ammonia.

32. Dip a piece of litmus paper, slightly reddened with an acid, in half a wine-glassful of distilled water, to which previously a few drops of liquid ammonia have been added: the red colour will vanish, and the paper regains its original blue colour. Remove the paper near a fire, the blue colour will now disappear, and the red colour will be restored.

33. Litmus paper reddened by an acid has also its colour restored by alkaline earths, namely, by barytes, strontia, &c. as may be seen by dipping the paper into barytic water, &c. To discriminate whether the change be owing to one of these bodies, or to the action of alkalies, or carbonate of lime with excess of carbonic acid, add to the solution, largely diluted with distilled water, a drop of sulphuric acid, which will occasion a precipitate, if the effect be owing to the presence of barytes

or strontia, for these bodies *instantly* produce with sulphuric acid an insoluble precipitate; whereas the carbonates of potash, soda, and ammonia, as well as carbonate of lime, are not *visibly* affected by it.

V. *Tincture of Red Cabbage.*

34. Tincture of cabbage is very liable to spoil; it soon undergoes a kind of putrefaction, which destroys its colour. It is obtained by cutting fresh leaves of the *red cabbage* into small pieces, and pouring over them boiling-hot distilled water, and suffering the whole to macerate for a few hours. The clear fluid being then decanted, and mixed with one-eighth of its bulk of spirit of wine, is fit for use.

35. The cabbage leaves may be preserved for many years, by drying them in a warm place, at a temperature of about 120° F. having previously cut them into small pieces. To prepare the test liquor from the dry leaves, let them be digested in distilled water, to which a minute portion of sulphuric acid has been added, which will produce a red tincture. Then let the acid be neutralized by marble

powder, caustic soda, or potash, but not by ammonia; the red colour will vanish, and the tincture will become blue. This being done, filter the liquor; and lastly, add to it one-eighth of its bulk of spirit of wine. The test thus prepared keeps much longer than when obtained from the fresh leaves of the plant. The same process may be observed for obtaining the tincture from the fresh leaves, instead of that given above.

36. Tincture of red cabbage is of a bright blue colour, and is an exceedingly delicate test both for acids and alkalies, when present in an uncombined or free state. A very minute portion of any alkali changes its vivid blue colour to green, whilst acids turn it red. The alkaline earths, barytes, strontia, and lime, here also act as alkalies. Examples :—

37. Add to half a wine-glassful of tincture of red cabbage a small quantity of the white of an egg, either in a liquid state, or rendered concrete by boiling. The tincture loses its blue colour, and is changed to green, because the white of the egg contains soda.

38. Let distilled water be tinged blue, by adding to it tincture of red cabbage, and fill with this coloured fluid two test tubes. Drop

into one of them a little lemon or orange juice, which will instantly change the blue colour red, and by adding the minutest quantity of carbonate of potash, &c. or any pure alkali to the other tube, the blue becomes changed to green.

39. The action of barytes, strontia, and lime, need not to be illustrated, because they act precisely like alkalies upon this tincture, and we are in possession of excellent tests for discriminating these bodies, as will be seen hereafter.

VI. *The Acid Infusion of Red Cabbage.*

40. If the fresh or dried leaves of the red cabbage be macerated in boiling water, to which a little dilute sulphuric acid is added, the red infusion will be rendered blue by alkalies, &c. when added in sufficient quantity to neutralize the acid. If the infusion be made with a known quantity of acid, it will serve as a test of the quantity of alkali in any solution. The red liquor of pickled cabbage is also an alkaline test.

VII. *Tincture of Brazil-wood, and Brazil-wood Paper.*

41. Tincture of Brazil-wood, which is of a fine dark red colour, becomes changed to violet or purple by alkalies, either in a pure state, or when combined with carbonic acid; and also by alkaline earths. It is, however, liable to mislead, because a solution of carbonate of magnesia, or carbonate of lime in excess of carbonic acid, produces a similar change. If, therefore, the test be employed in the analysis of a mineral water, containing carbonate of lime, or magnesia, these substances should first be got rid of by concentrating the water by boiling, for the excess of carbonic acid which held these earths in solution flies off, and the neutral carbonates fall down. If the test be then applied to the filtered water, we may know whether the change of colour is produced by a free or uncombined alkali, or by a carbonated earth. If by the former, the purple colour becomes more intense, because the evaporated water holds a greater quantity of alkali in solution than it did in its natural state; but if the

change be produced by a carbonated earth, the effect will be the reverse. Besides this, gypsum, or sulphate of lime, is also capable of altering the colour of this test. The paper coloured with tincture of Brazil-wood is usually employed instead of the tincture, it being more convenient for use. Brazil-wood paper, when rendered violet by a dilute solution of an alkali, may be used as a test for acids, which cause the original red colour to reappear. Examples :—

42. Into distilled water dip a piece of Brazil-wood paper: its red colour will not be altered. Add to half a test-tubeful of the same water a grain of carbonate of potash, or of any other carbonated alkali, and in this solution immerse a slip of Brazil-wood paper: its red colour will instantly be changed to violet.

43. Dissolve in distilled water, impregnated with carbonic acid gas, some calcareous earth, for example, powdered chalk, or marble, and let the water stand to settle. Put into the clear solution a piece of Brazil-wood paper, and the red colour will gradually be changed to a very pale violet.

Let another portion of the same water be evaporated to one half of its bulk, and when cold, filter it; and dip into the filtered fluid Brazil-wood paper, which now no longer will suffer a change of colour, because the excess of carbonic acid being driven off, the carbonate of lime is precipitated, as was explained before.

44. Shake up for a few minutes twenty or thirty grains of chalk or marble powder, with two or three ounces of distilled water, to which previously six or eight drops of sulphuric acid have been added. Part of the lime of the chalk becomes dissolved in the sulphuric acid, and the water will contain sulphate of lime. After the solution has been suffered to stand for five or six hours, or till it is clear, let it be filtered, and dip into it a piece of Brazil-wood paper, the colour of which will be changed to a faint violet, which is in consequence of the presence of sulphate of lime.

45. Add to half a test-tubeful of distilled water, a few drops of liquid ammonia, and let fall some drops of this fluid upon a slip of Brazil-wood paper. It will produce brown stains, which will vanish again when the paper is held near the fire; because the ammonia becomes volatilized.

VIII. *Tincture of Turmeric, and Turmeric Paper.*

46. This is an excellent test for discovering the presence of alkalies. The colour of the tincture is an intense yellow; it is changed to a brick red, or orange, by alkalies, whether in a caustic state or combined with carbonic acid, but it is not affected by carbonated earths; so that by this test we are at once enabled to distinguish the presence of a carbonated alkali from a carbonated earth, when held in solution by an excess of carbonic acid.

47. Paper stained a pale yellow with this tincture, being more convenient in its application than the tincture itself, is usually employed in the laboratory. By means of it, the exact point of saturation of acids with alkalies may be ascertained with great nicety, which is often of considerable consequence in chemical operations.

48. Turmeric paper thus rendered brown or orange coloured by alkalies, has its original yellow colour restored by acids. Instead of turmeric paper, a fresh cut surface of the entire turmeric root may be wetted with distilled water, and by being rubbed on white

paper, a very visible yellow mark will be made, on which a drop of the liquor to be examined may be put.

49. It is, however, to be borne in mind that this test is not at all times a criterion of neutrality in a compound; because, as observed No. 46, it is acted upon by carbonated alkalies, which consist of one atom of acid, and one atom of base, and are therefore, in strict terms, neutral bodies. It even has an alkaline re-action on the bicarbonated alkalies; and, in consequence, a deficiency of acid in such compounds might be supposed by those who are unacquainted with the action of this test. Accordingly, we find *carbonate of soda*, and *carbonate of potass*, as well as the *sesquicarbonate of ammonia*, called in the London Pharmacopœia, and in the older works on chemistry, *subcarbonates*. Those salifiable bases, on the other hand, which, from analogy, might be expected to have an alkaline re-action on the test, and which are in this respect inert, derive their inactivity from their want of solubility. Examples:—

50. Dip a piece of turmeric paper in a little distilled water: its yellow colour will remain unaltered. Add a grain of potash, or soda,

either in a pure state, or in the state of carbonate, to the distilled water, and immerse in the solution a piece of turmeric paper; it will instantly acquire a brown colour; and if the paper be now dipped in a dilute acid, its original yellow colour will re-appear.

51. Hold a piece of turmeric paper, slightly wetted with distilled water, over the open mouth of a bottle, containing liquid ammonia: the colour of the paper will be changed to brown. Remove the paper, and hold it near the fire, the brown colour will vanish, and its original yellow colour will re-appear; because the ammonia becomes volatilized.

52. To Seltzer water, or aërated water of commerce, or distilled water impregnated with carbonic acid gas, add a portion of marble powder or chalk; shake the mixture in a stopped phial, frequently, during the space of twelve hours, to effect a solution of carbonate of lime; and lastly, filter it, or suffer the mixture to stand undisturbed till it becomes transparent. Dip into this solution of supercarbonate of lime, a slip of turmeric paper: its yellow colour will suffer no alteration. Hence this test paper is not changed to orange by carbonate of lime, but only by carbonated

alkalies, and on this account is preferable to Brazil-wood paper. Barytes, strontia, and lime, act in this case also like alkalies. Observe, this test is acted upon by boracic acid, by strong acids generally, and by several metallic salts.

53. The action of turmeric paper is very great, as may be seen from the following statement, which is copied from Dr. P. Wilson's analysis of the Malvern waters :

" Half a grain of carbonate of soda was " dissolved in twelve ounces of distilled water, " which were heated to 136°. Paper stained " with turmeric was allowed to remain in it " for one minute at this temperature. Its " colour was not at all altered. This water " was gradually evaporated at a temperature " never exceeding 140°, and at short intervals " slips of paper stained with turmeric were " dipped into it, and allowed to remain in it " exactly a minute : and as soon as the tinge " it gave to the paper was decidedly orange, " it was removed from the fire and measured; " at this time the temperature was 124°. The " quantity of water was found to be nine " ounces.

" Four ounces of Holywell water were " heated to 136°; at this temperature it did

" not affect the colour of paper stained with " turmeric, when allowed to remain in it one " minute. The evaporation was continued in a " temperature never exceeding 140°, and gra- " dually lessened to 124°, the slips of paper " being used at short intervals as before. " When a decidedly red tinge was observed, " on allowing the paper to remain in it for a " minute in a temperature of 124°, it was re- " moved from the fire and measured: it was " found to have lost just one-fourth. From " this experiment it is evident the quantity of " carbonate of soda in a gallon of Holywell " water was easily calculated. The result is " 5,33 grains.

" Half a grain of carbonate of soda was dis- " solved in eleven ounces of distilled water, " and exposed to a temperature of 115°; the " paper stained with turmeric immersed in " it; but I now measured the water as soon " as the least discolouration appeared in the " paper, after it had remained in it for one " minute in the above temperature, and " found the quantity to be ten ounces and a " half.

" Four ounces of Holywell water disco- " loured the paper allowed to remain in it for " the same length of time, in the same tem-

" perature, when one-eighth was evaporated. " I was surprised on making the calculation, " to find that this experiment gave precisely " the same result as the preceding 5,33 grains " of carbonate of soda in a gallon of water, " that is, 128 ounces, and which quantity of " alkali was thus detected by turmeric " paper."

54. Dip a piece of turmeric paper in water, to which a little liquid ammonia has been added: the paper will become brown; remove it into water acidulated with sulphuric, nitric, acetic, or muriatic acid, &c. and its yellow colour will be restored.

IX. *Sulphuric Acid.*

55. Highly concentrated sulphuric acid discovers, by a brisk effervescence, carbonic acid gas, when present in an uncombined state in any liquid, or when in combination with an earthy, alkaline, or metallic base. It is likewise used for decomposing the salts of lead and mercury, with which it produces a white precipitate. The precipitate obtained with mercury acquires a yellow colour by the affusion of boiling water. It is also a capital

test for barytes and strontia, with both of which it forms highly insoluble compounds. This acid is frequently employed in analytical experiments, for ascertaining the nature of certain classes of salts, so far, at least, as to discover the nature of the acid with which the base of the salt is united. But when used for that purpose, it is necessary that the saline compound to be examined, be in a solid state, or at least nearly so. The salt to be assayed is covered with sulphuric acid, and the mixture warmed a little: a vapour or cloud will be thus produced; because the sulphuric acid expels several other acids from their combinations with bases. And as these acids are capable of assuming the gaseous state, and are condensible by moisture, they produce vapours with the moisture of the atmosphere; and from the nature of these vapours, the nature of the acid may be learnt. For example: if the salt belong to the class of *nitrates*, the sulphuric acid will disengage white vapours from it without effervescence; and if some copper filings be added, red vapours, with effervescence, will be evolved: the salt also deflagrates when laid on ignited coals: if the salt belongs to the class of *muriates*, the vapours are white; if it belongs to the class of *acetates*, the vapours have a strong smell of vinegar; and if they corrode glass, when suffered to be in contact with it, for ten or twenty minutes, the salt contains fluoric acid. Other tests may then be applied to confirm or destroy the conjectures thus obtained by this agent, as will be shewn in other parts of this work. Sulphuric acid has also been recommended as a test for lime, when it exists in combination with certain bases, but it is of little value for that purpose, because the sulphate of lime which it produces is soluble in 500 parts of water, and is much more soluble when there is an excess of acid. When employed for that purpose, the solution, when highly concentrated, is suffered to cool; the sulphate of lime then separates in long transparent crystals, which is a very common form for it to occur in chemical analyses. It is then distinguished by its want of taste, its difficult solubility when removed into pure water, and also by its affording a precipitate with oxalic and barytic salts. Examples:—

56. To half a wine-glassful of distilled water add about twenty or thirty drops of sulphuric acid, and stir the fluid with a glass

rod: the mixture will take place quietly, and no air bubbles will be disengaged. To the same quantity of water, impregnated with carbonic acid gas, or to common Seltzer water, or aërated water of commerce, add a like quantity of sulphuric acid. A multitude of very minute air bubbles will be rapidly disengaged, which indicate the presence of carbonic acid gas.

57. Having dissolved ten or fifteen grains of chloride of sodium (common salt) in about two tea-spoonfuls of water, add to it ten or fifteen drops of strong sulphuric acid. White fumes will be disengaged, which indicate the presence of muriatic acid. And if a glass rod, or a feather, moistened with liquid ammonia, be brought near the mixture, the fumes will become more visible, and dense white clouds will be produced in the vicinity of the body, moistened with the liquid ammonia. The sulphuric acid decomposes the common salt, and expels one of its constituent parts, namely, the muriatic acid*; which, as it becomes libe-

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* When a chloride is dissolved in water, a muriate is formed by the chlorine of the chloride uniting with the hydrogen of the water, and forming muriatic acid; while the oxygen of the water uniting with the metallic base, forms an oxide, which unites with the muriatic acid, forming a muriate in solution.

rated, assumes the gaseous form, and would be invisible if no humidity were present; but being condensed by the moisture which it meets with in the atmosphere, it appears as a cloud. The dense white cloud is owing to the production of *muriate of ammonia,* a salt formed by the vaporous muriatic acid combining with the volatilized ammonia.

58. Put into a small evaporating basin, or watch glass, ten or twenty grains of pulverized nitrate of potash (saltpetre), and pour upon it twenty or twenty-five drops of sulphuric acid; stir the mixture with a glass rod, and warm it gently over a spirit lamp: white fumes will be produced, which indicate the presence of nitric acid. If a little of the salt be thrown on ignited coals, it will deflagrate*.

59. Put ten or twenty grains of acetate of lead, or acetate of potash, into an evaporating basin, or tea-cup, and moisten it with sulphuric acid: a strong odour of vinegar will immediately become predominant, because the sulphuric acid expels the acetic acid from the

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* In this experiment, if yellow fumes appear, which will be the case if heat be applied, it is owing to the formation of nitrous acid vapour, by the partial decomposition of the nitric acid.

acetate of lead, and unites with its base to produce sulphate of lead.

60. Take common fluor spar (Derbyshire spar) reduced to powder, put about one ounce or more of it into a leaden basin (a piece of common sheet lead turned up at the edges, so as to form a rim, will answer the purpose); make it into a liquid paste with common sulphuric acid, and then heat the mixture over a spirit lamp; dense white fumes will become disengaged; and if a plate or glass be laid over the basin, it will speedily lose its polish, and become corroded by the vapour, or disengaged fluoric acid gas. In this manner etchings on glass may be made. The glass is to be covered over with hard engraver's varnish, called etching-ground, or bees-wax will answer the purpose, for the sake of experiment. When the coating is dry, the design intended to appear upon the glass is traced upon the varnish or wax by means of a needle, or other sharp-pointed instrument, as is done in common copperplate etching; taking care that every stroke or line is carried clean and smooth through the coat of varnish or wax down to the surface of the glass, so that the light may be seen through the traces or cuts. If the

glass thus prepared be exposed to the volatilized fluoric acid gas, by laying it over the basin, the etching will be made in five or ten minutes. The varnish or wax may afterwards be removed by oil of turpentine.

Fluor spar consists of fluoric acid united to lime: on adding to it sulphuric acid, which has a stronger affinity for lime than the fluoric acid has, the latter becomes disengaged in the gaseous state, and corrodes the glass in those parts where the varnish does not defend it from its action. Care should be taken not to inhale any of the vapour.

X. *Nitric Acid.*

61. This acid is employed as a test for ascertaining, in an expeditious manner, the purity of tin, for which purpose it is employed in the concentrated state; and when largely diluted with water, it becomes a test for readily distinguishing iron from steel. In the analysis of vegetable substances, the concentrated nitric acid assists us to discover *resin;* for when concentrated nitric acid is digested repeatedly with gum or mucilage, gluten, jelly, extract, gum resin, or any other of the

immediate vegetable products, it converts them partly into oxalic acid; whereas true resin suffers no such change; and even after long digestion, this substance becomes only converted by means of nitric acid, into a pale, porous, orange-coloured mass. And if nitric acid be repeatedly abstracted from it, the result is not oxalic acid, but a deep orange-coloured substance, which is soluble in water, and in alcohol; and although the resinous properties be lost, no vestige of oxalic acid can be discovered in the solution. Nitric acid is also used to detect starch in vegetable substances. The substance is to be digested for some days in dilute nitric acid, and to the solution alcohol is to be added; which throws down the starch from the acid.—*Ann. de Chim. l. v.* 28.

62. And in the analysis of organic substances in general, nitric acid serves the purpose of a test for detecting the presence of azote or nitrogen, and thus it enables us to establish the presence of animal matter; because when this acid is made to act without the assistance of heat upon a substance, the nature of which is to be determined in that respect, azote, or nitrogen, is to be produced. For, in fact, we are

not acquainted with any other ready method in discriminating in analysis animal matter from vegetable matter: because we possess no other means of extracting azote perfectly in its insulated state. The elements of animal matter are peculiarly prone to combination, and among them particularly the azote. Nitric acid is likewise useful as a test for detecting uric acid in the analysis of urine; it produces with this substance a pink or rose colour.

63. Tin of commerce frequently contains either a minute portion of copper or lead, and sometimes both these metals are present. To ascertain the purity of tin by means of nitric acid, put one part of the filings of the suspected metal into a basin, or other convenient vessel, and add to it about three or four parts of nitric acid: a very violent action becomes exerted; the acid is decomposed with great rapidity, copious red fumes are disengaged, and the temperature of the mixture rises considerably. The tin becomes so highly oxidized, that it does not pass into a state of solution, but forms a white powder, in which, after having been washed, there are no traces

of nitric acid, and which is therefore nearly a pure oxide.

64. When this has been effected, pour a small quantity of distilled water upon the mass, stir the mixture together, and suffer it to stand undisturbed, or filter it, till the supernatant fluid is become clear. Decant the clear fluid, and add to it liquid ammonia in excess : if the tin contained copper, the fluid will now assume a blue colour. The copper will also be precipitated if a polished plate of iron, or zinc, be put in the solution. To assay it for lead, add to another portion of the clear fluid a few grains of sulphate of soda, dissolved in water, which will occasion a white precipitate if lead be present, of sulphate of lead, which is highly insoluble, and therefore falls to the bottom of the vessel.

65. To distinguish malleable iron from steel by means of this test, let the acid be diluted with so much water, that it will only feebly act upon the blade of a common table knife. If a drop of the acid thus diluted is suffered to fall upon steel, and allowed to remain upon it for a few minutes, and then washed off with water, it will leave behind a *black* spot. But if a

drop of this acid be suffered to act upon iron in the same manner, the spot will not be black, but of a whitish grey colour. The black stain is owing to the carbon of the steel being set at liberty, in consequence of the iron being dissolved and separated from it by the action of the acid. Iron free from carbon gives only a grey stain.

The utility of this test is not confined to finished articles, manufactured of steel; but its application enables the workman in iron and steel to ascertain, also, the *quality* and *uniformity* of texture of unfinished articles. Examples :—

66. Put some of the lean part of any meat into a retort, along with very dilute nitric acid, and apply a gentle heat with a spirit lamp, azote or nitrogen will be disengaged, and may be collected in the usual manner over water.

That the azote is not furnished by the nitric acid, may be proved by saturating a certain portion of the acid employed in the experiment with an alkali; for it will be seen, that the portion of acid thus tried saturates as much alkali as a like portion of the same acid which has not been made to act upon the animal substance: consequently, the azote must have been produced from the animal substance submitted to the action of the acid.

XI. *Muriatic Acid.*

67. This acid may be used for detecting the presence of silver and lead, with the solutions of which it forms a white precipitate. The precipitate produced with silver becomes quickly blackened on exposure to light; it is perfectly insoluble in water, and soluble in liquid ammonia. The precipitate occasioned by lead suffers no such changes; it is soluble in about twenty-two parts of water at 60°, and in dilute nitric acid.

68. This acid is also employed for discovering ammonia when in a disengaged state: a glass rod or other substance moistened with this acid, and held in an atmosphere of ammoniacal gas, becomes immediately surrounded by dense white clouds of muriate of ammonia.

69. It is likewise an useful auxiliary agent for ascertaining the presence of oxide of manganese in mineral substances; because it produces with it chlorine gas. Suppose a mineral be presented to us, and we wish to know

whether it contains a notable quantity of oxide of manganese, we may proceed in the following manner:

1st, Reduce the mineral to powder, pour upon it muriatic acid, and apply a moderate heat. If chlorine gas be disengaged in abundance, the mineral is chiefly manganese.

2nd, To be certain of this, melt a little borax or soda in a platinum spoon, add to it a little of the ore, and keep it melted by the *interior* flame of the candle. The colour of the mass in the spoon will be at first red; but this colour will gradually disappear if the ore be manganese. Now add a little nitre, or keep it melted for some time in the *exterior* flame, and the red colour will again appear.—*Annals of Philosophy*, 1814, xxvi. p. 312.

Examples:—

70. Mix five or six drops of acetate or nitrate of lead with half a wine-glassful of distilled water, and add to it a drop or two of muriatic acid: a dense white precipitate will fall down, which is chloride of lead. This compound being soluble in about twenty-two parts of water, in which respect, as well as in not changing colour by a short exposure to light, it may be distinguished from chloride of silver (*see nitrate of silver*) which it resembles;

and water may therefore be used to separate the chloride of lead from that of silver; but dilute nitric acid is preferable. The chloride of lead is likewise soluble in acetic acid, by which it may further be distinguished from chloride of silver, as well as from sulphate of lead.

In this experiment the chloride of lead is formed by the lead contained in the acetate uniting with the chlorine of the muriatic acid.

71. Mix in an ale-glass a few grains of muriate of ammonia intimately with double its weight of quick lime, and bring a feather, or glass rod, moistened with muriatic acid, near the mixture; dense white fumes will become visible, which indicate the presence of ammonia, which is also known by its peculiar smell.

72. Add a few drops of liquid ammonia to half a test-tubeful of distilled water, and moisten with this fluid a piece of paper, or any other substance. If a glass rod or feather, wetted with muriatic acid, be now made to approach the paper, dense white vapours will be formed.—For the action of this acid as a test for silver, see *Nitrate of Silver.*

XII. *Tartaric Acid.*

73. The two alkalies, soda and potash, resemble each other so closely in their most obvious chemical characters, that they are not readily distinguishable, except by uniting them to acids, and examining the salts resulting from this combination. Thus sulphate of potash is a hard bitter salt, requiring a large quantity of water for solution, and therefore a saline precipitate of sulphate of potash is formed, when strong sulphuric acid is added to a concentrated solution of potass; whereas sulphate of soda (*Glauber's salts*) is very soluble, and is known by its taste. Nitrate of potash crystallizes in long six-sided prisms, but nitrate of soda in rhombs. However, by means of tartaric acid this trouble may be saved, for it produces with potash, when added in excess, a highly insoluble salt—bitartrate of potass; but with soda, a salt which is easily soluble in water. The alkali to be examined is first dissolved in muriatic or any other acid, and a solution of tartaric acid added in excess: if the salt has potash for its basis, there will be a crystalline precipitate in

a few seconds; but the mixture will remain clear, if the basis of the salt is soda. But, for the successful action of this test, it is necessary that the solutions of the salts be as concentrated as possible, and that the tartaric acid be always added in excess.

74. As potash is separated from all its salts by tartaric acid, this serves to distinguish the tartaric from other acids.

75. Potash may be known by deliquescing, when exposed to the air in a solid form: soda, under the same circumstances, effloresces.

76. All the salts of soda are soluble in water; and they afford no precipitate on the addition of any re-agent. Examples:—

77. Make a concentrated solution of sulphate of soda, or of any other salt of soda, in distilled water, and add to it a concentrated solution of tartaric acid in excess: no change will take place, because the salts of soda are not altered by tartaric acid.

78. Make a concentrated solution of sulphate of potash, or of any other salt of potash, and add to it tartaric acid in excess: a crystalline salt will gradually collect, and fall to the bottom of the tube. The salt is bitartrate of potash

79. Dissolve eight or ten grains of caustic soda in a little water, and add to the solution tartaric acid in excess: no change will take place.

80. Dissolve the same quantity of caustic potash in a like quantity of water, and add to the solution tartaric acid: in a few seconds the mixture will become turbid, and a quantity of white granular powder will fall to the bottom, which is bitartrate of potash, and may be distinguished as such when rinced with cold water, by feeling hard and granular in the mouth, with a slightly acidulous taste.

XIII. *Boracic Acid.*

81. Boracic acid is employed in analytical chemistry, not directly as a re-agent or instrument of analysis, because its affinities and action have little energy compared with other acids. But it is of use to the mineralogist, as a flux for the blow-pipe assay: it particularly facilitates the solution of silica, and produces, with earthy substances, a very limpid fusion. It is not volatilized by the most intense heat, and the mass which it affords with a vast number of mineral sub-

stances, does not readily sink into the pores of the charcoal upon which the assay is made. It may even be mixed with charcoal powder without producing an incomplete vitrification. It is capable of dislodging all the acids, except the phosphoric, from their combinations; and at the same time, from the colour which it produces with different metallic oxides, &c. some conjecture may be formed concerning the nature of the substance upon which it is made to act.

82. It is likewise a very useful agent for discovering the presence of alkalies in mineral substances, and has been recommended particularly for that purpose by Sir Humphry Davy*. He fuses one part of the mineral under examination with two parts of boracic acid, dissolves the fused mass in dilute nitric acid, and concentrates the solution by evaporation, to separate the silica. The liquid is then mixed with carbonate of ammonia in excess, and is boiled and filtered. By this means all the earthy and metallic ingredients are separated. The liquid is next mixed with a sufficient quantity of nitric acid, and evapo-

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* Philosophical Transactions, 1805; and Nicholson's Journal, xiii. 86.

rated till the whole of the boracic acid is separated. Nothing now remains but the nitric acid combined with the alkaline constituents of the mineral (and with ammonia), the nature of which may then be readily ascertained by tartaric acid, or muriate of platinum, the nitrate of ammonia being first got rid of by an exposure to a dull red heat.

XIV. *Acetic Acid.*

83. Acetic acid is of particular use in the analysis of vegetable substances, to separate resin from gluten, both of which are dissolved by acetic acid; but the latter remains in solution when water is added, and the former becomes precipitated. And as this acid does not, like the sulphuric and nitric acid, alter the resin when digested with it, even for a considerable time, but lets this substance fall again, apparently unaltered, by the admixture of water, it affords a very useful re-agent in the complicated analysis of vegetable substances.

XV. *Oxalic Acid.*

84. Oxalic acid is a test in chemical experiments to determine the presence of lime in liquids, in whatever combination this earth exists; for it attracts lime with greater force than any other acid, and therefore is capable of decomposing completely all the known salts of that earth. The oxalate of lime is insoluble in water; so that when this acid is added to a solution containing lime, a white precipitate of oxalate of lime falls down, from which, when collected, washed, and dried in a moderate heat, the actual quantity of lime may be readily inferred.

See *Oxalate of Ammonia.*

85. Oxalic acid is also a useful re-agent for separating oxide of iron from oxide of titanium. If a solution of this acid be added to muriate of titanium, a precipitate falls down, which is a pure oxalate of titanium, and which may be decomposed by exposure to a heat sufficient to destroy the oxalic acid*. This

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* "The oxalate affords the metal by intense ignition with charcoal: it is, however, scarcely possible to obtain it in any state of agglutination: in some trials made in the Royal Institution, nothing like globules of the metal could be procured, and the crucibles were always fused."—*Brande's Chemistry, vol.* ii. *page* 196.

acid may likewise be employed for separating oxide of iron from oxide of cerium. If these two oxides exist together, it is only necessary to boil them in a solution of oxalic acid; the oxide of iron becomes dissolved, and the oxide of cerium remains behind in the form of a white powder, as oxalate of cerium; which may then be decomposed by heat. *M. Laugier. Ann. de Chimie*, tome lxxxix, p. 306.

XVI. *Muriate of Ammonia.*

86. This is one of the tests employed for detecting platinum, with the solution of which it produces (if the platinum be pure) a bright yellow precipitate; but, if it contain iridium, the precipitate slightly verges to the orange. The precipitate is a triple compound, consisting of one atom of *bichloride of platinum* and one atom of *muriate of ammonia*, according to Dr. Thomson, but it is generally considered as an *oxide of platinum*, *ammonia*, and *muriatic acid*; and by this character platinum is distinguished from all other metals, and may be separated when combined with them. This precipitate, when exposed to a strong red heat, furnishes a grey spongy mass, which is

metallic platinum; the chlorine and muriate of ammonia being driven off.

87. This test therefore furnishes a ready expedient for detecting the adulteration of gold with platinum, which would elude the hydrostatic trial. The gold may be precipitated by a solution of green sulphate of iron (see *sulphate of iron*), and the platinum, by muriate of ammonia.

88. When this test is added to a solution of the *ore of platinum*, in nitro-muriatic acid, the precipitate afforded by the first addition of muriate of ammonia is of a buff colour; and if the fluid above it, which is still of a reddish brown colour, be poured off, and muriate of ammonia again be added to it, a precipitate is thrown down of a bright orange colour; but no clear yellow precipitate can be obtained from the solution. The orange colour of the precipitate, as stated already, is owing to the presence of the metal called *iridium**, which is associated with the ore of platinum;

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* The ore of platinum contains *palladium*, *rhodium*, *osmium*, and *iridium*; and when digested in nitro-muriatic acid, the platinum, palladium, and rhodium, are dissolved, as well as any gold, iron, copper, and lead, which may also be present: a black powder remains, which consists of osmium and iridium.

a clear yellow colour of the precipitate is therefore a criterion of the purity of platinum. The yellow precipitate forms an useful pigment for the painter, being a very bright and permanent colour.

89. Muriate of ammonia is also used as a test to detect alkalies, and alkaline earths, all of which decompose this salt, and render obvious its ammonia. For this purpose the salt must be in a dry state, or nearly so, and a moderate heat may be employed to disengage the ammonia. But as many metals, and metallic oxides, are also capable of decomposing muriate of ammonia in the dry way, some collateral proofs must be employed to render the presence of the alkali, or alkaline earths, unequivocal; besides this, we have better tests for alkalies and alkaline earths.

90. Mr. Chevenix recommends this salt as an useful agent for separating alumina from its alkaline solutions; the alkali combines with the muriatic acid, and the liberated ammonia determines the precipitation of the alumina, which, after being washed and dried, is perfectly pure. Examples:—

91. Mix a little muriate of platinum with half a test-tubeful of distilled water, and add

to the mixture a solution of muriate of ammonia: a yellow precipitate will fall down, as already explained, No. 86.

92. Mingle a solution of muriate of platinum with a solution of muriate of gold, and drop into the mixture a solution of muriate of ammonia, till no further precipitate ensues, and suffer the fluid to stand undisturbed till the supernatant fluid is become perfectly clear, it will still have a yellow colour. Add to it a fresh prepared solution of green sulphate of iron, it will now again become turbid, or suddenly acquire a green colour, and a dark greenish, or rather a brown precipitate, will slowly be deposited, which is metallic gold. If the precipitate obtained by muriate of ammonia be heated to redness by means of the blowpipe, or (if the quantity be considerable) in the bowl of a tobacco-pipe put into a common fire, metallic platinum will be obtained in the form of a grey porous mass.

XVII. *Solution of Corrosive Sublimate*[*].

93. This test should be kept in the dark, because light renders it turbid; a white precipitate, which is the protochloride of mercury, or calomel, separates, and the action of the test is impaired.

94. This preparation of mercury is employed as a test for indicating the presence of alkalies and alkaline earths. The fixed alkalies, when caustic, produce with it a yellow, and carbonated alkalies an orange-coloured precipitate; lime water produces with it also an orange-yellow precipitate[†]. But this salt is seldom used, for we have better tests to discover alkalies.

95. Its action as a re-agent in the analysis of animal substances is of greater value; for by means of it we are enabled to detect minute quantities of albumen, a substance which

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[*] That which was formerly considered a permuriate or oxymuriate of mercury, is now proved to be a perchloride of mercury when in a solid state. It is, however, a permuriate when in solution. See note, page 44. This compound is best distinguished by its old name, *corrosive sublimate*.

[†] The precipitate thrown down by the fixed alkalies and lime-water is the *peroxide of mercury*; that thrown down by the carbonated alkalies is *percarbonate of mercury*.

largely enters into the composition of many animal products: it produces with albumen a white flocculent precipitate: it does not, however, separate the whole of the albumen, unless heat be employed to assist the coagulation.

96. There are other tests for detecting albumen; for instance, sub-acetate of lead, and nitrate of silver; but the sub-acetate of lead (Goulard's extract), and nitrate of silver, act also on other varieties of animal matter; but corrosive sublimate does not.

97. Corrosive sublimate, likewise, may be made a test for detecting salts with a base of ammonia, when applied in the manner to be stated presently. Examples:—

98. Dissolve one or two grains of carbonate of potash, or carbonate of soda, in half a test-tubeful of distilled water, and add to it a few drops of the solution of corrosive sublimate; an orange-coloured precipitate will immediately fall down to the bottom of the tube.

99. Dissolve a few grains of caustic potash, or soda, in half a test-tubeful of water, and drop into the fluid a solution of corrosive sublimate: at first a sulphur-yellow precipitate will fall down; but, by increasing the

admixture of permuriate, the precipitate will assume a dull orange colour.

100. Half fill a test-tube with fresh prepared lime water, and add to it a few drops of the solution of corrosive sublimate: an orange-yellow precipitate will instantly fall down.

101. Mix a small quantity of the albumen or white of an egg, with distilled water, and suffer it to stand till the insoluble part has subsided. Decant the clear fluid, and drop into it a solution of corrosive sublimate; a milkiness will ensue, and after some time a white flocculent precipitate becomes deposited.

The same effect takes place if serum of blood, or any other albuminous matter, be mixed with water. A drop of a saturated solution of permuriate of mercury, when added to water containing $\frac{1}{1000}$ part of its weight of albumen, produces a visible cloudiness; and at the end of some hours a flocculent precipitate falls to the bottom of the vessel. The same re-agent produces a sensible effect on a liquid containing only half that quantity, or $\frac{1}{2000}$ of albumen, if the mixture be suffered to stand for some hours.

This test may also be employed to ascertain the *quantity* of albumen in an animal fluid; it is to be added in excess, and the mixture heated; a precipitate falls down, which, when collected and carefully dried, contains about 78 per cent. of albumen.

102. Dissolve one grain of muriate of ammonia in a wine-glassful of distilled water, and add to the fluid a single drop of a solution of potash, or of soda. If now a drop or two of the solution of permuriate of mercury be added, the mixture will become milky, and a white precipitate falls down, consisting of muriatic acid, peroxide of mercury, and ammonia.

103. Add one grain of nitrate of ammonia to a wine-glassful of distilled water; and after having added to it also a drop of a solution of any alkali, let fall into the mixture a drop of the solution of corrosive sublimate, and a white precipitate, similar to that in the last experiment, will instantly fall down.

It is essential that the solution be neutral: the delicacy of permuriate of mercury, when thus applied for detecting ammoniacal salts, is extremely great. One grain of muriate of ammonia, dissolved in sixteen ounces of water, may be detected by it. For the application of this test we are indebted to Mr. F. Brande.

XVIII. *Protonitrate of Mercury*[*]

104. Is employed as one of the re-agents for detecting uncombined ammonia, with which it produces an ash-grey or black precipitate: it is said to detect one part of ammonia in 30,000 parts of water, by affording a blackish yellow tint when added to the solution: it may likewise be used for detecting muriatic acid, with which it occasions a white precipitate. One part of strong muriatic acid, combined with 300,000 parts of water, may readily be discovered by this re-agent, indicating a slight dull tint.

105. It is also an useful agent for detecting not only the presence, but likewise the quantity, of phosphoric acid contained in any fluid; for it produces with this acid a white precipitate, which is soluble in an excess of phosphoric acid, and also in nitric acid, but the precipitate produced by muriatic acid is not. The precipitate obtained by phosphoric acid (phosphate of mercury) may be decomposed by

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[*] When mercury is acted upon by nitric acid without heat, a protonitrate of mercury is formed: when mercury is acted upon by nitric acid with heat, a pernitrate of mercury is formed. The former of these is called usually, though improperly, *sub-nitrate*.

mere exposure to heat, and thus the phosphoric acid is obtained in a pure state. Or, if the precipitate be exposed to the blowpipe heat upon charcoal, it first melts, with effervescence and a green flame, into a yellowish glass; by continuing the heat, the mercury is volatilized, and may be condensed in its metallic state on a plate of copper held over the vapour; the phosphoric acid then burns off into phosphorus.

Some precautions, however, are necessary when this test is employed for discovering phosphoric acid: namely, it is essential that the fluid should not contain any free alkali, or alkaline earth.

106. With a solution of muriate of gold it produces a dense precipitate, of a bluish black colour; and with muriate of platinum, an orange-coloured precipitate.

107. Protonitrate of mercury may also be applied for discovering sulphuric acid, with which it affords a white crystalline or pulverulent precipitate, which becomes yellow when repeatedly washed with boiling water. Examples:—

108. Add to half a test-tubeful of distilled water a drop of liquid ammonia, no change will take place; but if a few drops of a solu-

tion of protonitrate of mercury are added, an ash-grey precipitate instantly falls down to the bottom of the tube.

109. Add to half a wine-glassful of distilled water a drop of muriatic acid, or a single grain of common salt, and pour into the solution a few drops of protonitrate of mercury, white clouds will be produced, and a white precipitate fall down to the bottom, which will not disappear, or become re-dissolved, by the admixture of nitric acid.

110. Dissolve a few grains of phosphate of soda in half a test-tubeful of distilled water, and add to it a solution of protonitrate of mercury, a white precipitate will fall down (phosphate of mercury). When the precipitate has subsided, decant the supernatant fluid, and assay the precipitate by adding to it nitric acid, which will speedily dissolve it.

111. Add to half a test-tubeful of distilled water three or four drops of sulphuric acid, or dissolve in the water six or nine grains of sulphate of soda, and add to the fluid protonitrate of mercury, a dense white precipitate will take place, and speedily settle at the bottom. This precipitate, by the repeated affusion of boiling hot water, acquires a yellow colour.

112. Mix with half a test-tubeful of distilled water a few drops of muriate of gold, and add to the mixture one or two drops of protonitrate of mercury, a bluish black precipitate will instantly be formed.

113. Let fall one drop of muriate of platinum into half a wine-glassful of distilled water, and add to this mixture a drop of protonitrate of mercury, a bright orange-coloured precipitate will fall down to the bottom of the tube.

XIX. *Nitrate of Silver.*

114. The solution of silver in nitric acid is an excellent test for discovering muriatic acid and chlorine, as well as muriates and chlorides : it produces with them a curdy white precipitate, which is insoluble in water and nitric acid, but readily soluble in liquid ammonia, and which becomes speedily blackened on exposure to light.

115. The delicacy of this test is astonishingly great : one grain of common salt, dissolved in 42,250 grains of water, that is, rather more than five pounds of water, is rendered obvious

by it, white clouds being produced in the fluid; and this quantity of water, it may be proved, does not contain more than $\frac{1}{108333}$ part of its weight of real muriatic acid.

116. In applying this test, certain precautions are necessary, because it is also acted on by alkaline and earthy carbonates, and by sulphuric and sulphurous acids, and their combinations: this may be guarded against by first removing these acids by nitrate or acetate of barytes; and the action of the carbonates may be prevented, by supersaturating them previously with pure nitric acid. The precipitate produced by carbonated alkalies (*carbonate of silver*) is soluble in dilute nitric acid with effervescence; the precipitate produced by muriatic acid is not.

117. With the assistance of an alkali, nitrate of silver becomes likewise an excellent test for detecting minute portions of arsenic, with which it produces a yellow precipitate: it likewise indicates minute portions of sulphuretted hydrogen, and hydrosulphurets in general, for it produces with them a black precipitate of sulphuret of silver. It affords, with chromic acid, a carmine red precipitate of chromate of silver. Examples:—

118. Mix a drop of muriatic acid with a wine-glassful of distilled water, and add to the mixture a drop of the solution of nitrate of silver: a white curdy precipitate will immediately be produced, and will fall rapidly to the bottom of the glass. In this case the chlorine in the muriatic acid unites with the silver of the nitrate, and forms *chloride of silver,* the precipitate in question, and the oxygen of the silver combines with the hydrogen of the muriatic acid. If a muriate be present, the same also takes place, and the nitric acid attaches itself to the base of the muriate, forming a *nitrate* in solution. This is exemplified in No. 120, where *nitrate of soda* is held in solution, and *chloride of silver* precipitated.

100 grains of the precipitate thoroughly dried, but not melted, contain 75,342 grains of silver; the remaining 24,658 grains consist of chlorine. It may be reduced in the following manner to the metallic state, and affords the purest silver which can be obtained:

Mix one part of the dry chloride of silver, thrown down in the last experiment, with three of carbonate of soda, or of potash*, freed from water by heat; put the mixture into the

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* *Subcarbonate* of soda, or of potash of commerce.

bowl of a tobacco-pipe, and make it red hot in a common coal fire. When the mass has been in perfect fusion for about ten minutes, suffer it to become cold. On breaking the pipe, a brilliant button of pure silver will be found at the bottom of the vessel.

119. Nitrate of silver is used as a test by the refiners for examining and purifying their aquafortis or nitric acid: they let fall into the acid of commerce a few drops of a solution of nitrate of silver. If the acid remains clear, it is fit for their use; otherwise, they add a small quantity more of the solution, which immediately turns the whole of a milky white colour; the mixture being then suffered to rest for some time, deposits a white sediment (chloride of silver), from which it is cautiously decanted, examined again, and, if necessary, further purified by a fresh addition of the solution of nitrate of silver.

120. Add a grain or two of common salt to half a test-tubeful of distilled water, and drop into the solution nitrate of silver: the mixture will instantly become turbid, and a dense white precipitate will fall down to the bottom of the tube.—See No. 118.

Decant the supernatant fluid, and pour liquid ammonia upon the precipitate, which will immediately produce with it a transparent solution, namely, muriate of silver and ammonia. This is one of the characters by which chloride of silver is discriminated from chloride of lead; for the latter is not soluble in liquid ammonia, but the former is.

121. Prepare chloride of silver in the manner stated; namely, by decomposing a solution of common salt in water, with nitrate of silver; wash the precipitated chloride, while still wet, with water, dry it on blotting-paper, and keep it exposed to the light of day: its beautiful white colour will speedily be changed, and in a few hours it will have acquired a bluish black colour. This likewise takes place by the action of air, independent of light; for if it be exposed in an utter dark place to a brisk current of air, it will become blackened; but not so speedily as in the rays of the sun.

122. When the quantity of muriatic acid in a fluid is extremely small indeed, no actual precipitate can be collected; but the solution, which was limpid before mixture, becomes more or less opalescent afterwards, as may be shewn by dropping nitrate of silver into a decanter full of common spring or river water,

which will almost immediately become more or less clouded or milky, according to the quantity of muriatic acid which it contains, in some combination or other; but no precipitate can be collected. In the analysis of mineral waters, this test saves much trouble to the operator. If the water, for example, contain only common salt, or any other muriate, all other ingredients having been previously separated, we have only to decompose it by nitrate of silver, and to dry the precipitate. In experiments of this kind, it must be remembered that chlorides become muriates when dissolved in water.—See note, page 44.

123. Let five or six grains of sulphate of soda (Glauber's salt), or sulphate of magnesia (Epsom salt), or alum, be dissolved in a test-tubeful of distilled water, and put half the mixture into another or second tube. Add to the contents of the first tube a few drops of nitrate of silver: a considerable turbidness will take place; because the oxide of silver combines with the sulphuric acid of the sulphate, and forms with it an insoluble compound salt (sulphate of silver): decant the supernatant fluid, and transfer the precipitate,

which has a pulverulent form, into a basin or small flask containing distilled water, which will speedily dissolve it when assisted by a gentle heat, but this is not the case with chloride of silver, which is perfectly insoluble in water.

124. Add to the other half of the solution of sulphate of soda, in the last experiment, nitrate of barytes, till no further cloudiness takes place; separate the precipitate, which is sulphate of barytes, by throwing the whole on a filter, and assay or test the fluid which passes through the filter again with nitrate of silver, which now no longer will produce a precipitate, because the sulphuric acid has been removed by the nitrate of barytes.

125. Dissolve a few grains of carbonate of potash, or of soda, in half a wine-glass of distilled water, and add nitrate of silver to the solution. A white precipitate will fall down; namely, carbonate of silver. But if a little pure nitric acid be added, this precipitate will become re-dissolved with an effervescence, which is not the case with chloride of silver.

126. Again: add a few grains of carbonate of potash, or of soda, to half a wine-glassful

of distilled water, and drop into it so much nitric acid as may be sufficient to neutralize whichever carbonate is used: this may be known by the solution not changing turmeric paper brown. If into this fluid nitrate of silver be dropped, it will not become turbid, and the effect of the carbonated alkali is thus counteracted by nitric acid. If a grain of common salt, or any other chloride, or any body containing muriatic acid, be added to the fluid, the nitrate of silver will immediately indicate the presence of muriatic acid by a copious, white, curdy, or flocculent precipitate of chloride of silver.

127. The power of nitrate of silver is so great, that it will discover the minute quantity of muriate of soda which constantly adheres to the skin, and is deposited there, from the perspirable matter of the living body. To shew this fact, put some distilled water with a few drops of solution of nitrate of silver into a test tube, and shake it, closing the tube with the finger on the open end, applied as a stopper. The mixture, after a few minutes shaking, will become perceptibly turbid, on account of having removed from the cuticle of the finger so minute a portion of muriate

of soda, as defies the imagination; but the presence of which is thus rendered, by the test, obvious to the senses.

128. Nitrate of silver, either combined with potash, soda, or ammonia, forms an excellent test for detecting the minutest portion of arsenic: its application was first pointed out by Mr. Hume. The power of this arsenical test is astonishingly great: by means of it we are enabled to detect one part of arsenic in four hundred thousand parts of water*. Mr. Hume advises to saturate first the arsenic with any alkali, and then to apply the nitrate of silver (lunar caustic) to the surface of the solution, in which the poison is suspected to exist; if a bright yellow colour appear, we may expect the presence of arsenic.

129. Put two or three grains of arsenious acid (white arsenic), and eight ounces of rain or distilled water, into a Florence flask; heat the mixture over a lamp till the solution boils, and then add to it a grain or two of carbonate of potash or of soda; shake the flask frequently while the solution boils, which may be done by putting on a glove; then pour a

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* See Hume's Method of detecting Arsenic, Phil. Magazine, August 1812.

few table-spoonfuls of the solution into an ale-glass, and present to the mere surface of the liquid a stick of dry nitrate of silver: a yellow precipitate will instantly appear, proceeding from the point of contact of the nitrate of silver with the fluid, and will settle towards the bottom of the glass as a flocculent and copious precipitate, which is arsenite of silver. Dr. Marcet has lately pointed out the following modification of this test:—

130. Let the fluid suspected to contain arsenic be filtered, and suffer the one end of a glass rod, wetted with liquid ammonia, to be brought into contact with it, and let the other end of the rod, also wetted with the solution of nitrate of silver, be immersed in the mixture: a yellow precipitate will appear at the point of contact, and will gradually fall down to the bottom. As this precipitate is soluble in ammonia, the greatest care is necessary not to add an excess of that alkali.

131. The objection arising from the action of muriatic acid upon this test, when thus employed for arsenic, is easily obviated; for if a little muriatic acid be added to the fluid suspected to contain arsenic, and the nitrate of

silver very cautiously be added, till the precipitate ceases, the muriatic acid will be removed, and the arsenic remains in solution, and the addition of liquid ammonia will produce the yellow precipitate in its characteristic form*.

132. Mr. Hume has paid particular attention to the nature of this test, and we are indebted to him for some particulars concerning its application. The following statement is copied from Mr. Hume's essay on this subject:—

"Dissolve a few grains, say ten, of nitrate of silver, commonly called lunar caustic, in about nine or ten times its weight of distilled water; to this add, by a drop at a time, liquid ammonia, till a precipitate is formed. Continue cautiously to add the ammonia, now and then shaking the bottle, till the precipitate be taken up, and the solution again becomes transparent, or nearly so, as the ammonia need not be in great excess, if in any; for, solution of ammonia being lighter than water, the superfluous portion would be likely

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* Notwithstanding what is here stated, there is much objection to this test as regards arsenious acid in mixture with *muriates.*

to remain on the surface of the fluid to which this test liquor is to be applied*.

"Here we have one neat and simple liquid, which, if kept in a phial with a glass stopper, will not easily spoil, and therefore may be always at hand: its application is also equally simple, for nothing more is required than to dip a piece of glass into this liquor, and apply it to the surface of the solution containing arsenic. Should the material suspected to contain the poison be a solid substance, such as a mixture of sugar, meal, bread, meat, or any other kind of food, let some boiling water be poured upon the suspected body, and filtrate the solution through paper; then, having allowed this to become cold, apply the test liquor with a piece of glass in the way before mentioned.

"The strip of glass can be readily procured at any glazier's shop; or, if not at hand, a few drops of the test from the phial may be put into the liquid, as there is not so much uncertainty from a slight excess of alkali, nor even of the test liquor itself, as to require very great caution."

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[*] This test of Mr. Hume's is called the *ammoniaco-nitrate of silver* test.

133. Mr. Hume further observes, " that in proportion to the degree of dilution of the fluid containing arsenic, more or less time should be allowed for the effect to become perceptible. It has been stated, that phosphate of soda produces an effect with this test similar to the change produced by arsenic; and that false conclusions might be drawn, were similar steps pursued with two solutions of phosphate of soda, and arsenite of potash. A piece of dry nitrate of silver being presented for a moment to the surface of either of the liquids, would certainly give, in resemblance, the *yellow* and plentiful precipitate, and a bystander would consequently have his faith shaken respecting the validity of the claims in favour of the silver test.

" Take an opposite position, in this way. —Let two glass vessels be charged, one with phosphate of soda, the other a simple solution of oxide of arsenic*, and, as all these experiments ought to be, both made with distilled water: now, apply the dry nitrate of silver, as before, to the phosphate, and the same yellow precipitate will appear; but no such effect will happen to the solution of arsenic.

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* Arsenious acid, or *white arsenic.*

A separate piece of nitrate of silver should be taken in these experiments, to avoid error; for the morsel that has been dipped into the phosphate, should not be suffered to touch the arsenical solution. Any slight opacity in the *simple* solution of arsenic, on the contact with the nitrate, is not to be regarded as arising from any union with arsenic. Being now convinced that there is no *yellow* precipitate yet generated, let the operator hold a piece of blotting-paper, very slightly moistened with a solution of ammonia, and nearly over the surface of the arsenical fluid, at the same time moving the vessel so as to cause an undulation, and there will instantly form a copious yellow indication of the presence of arsenic.

134. "These experiments may be further illustrated and substantiated by a great deal of very strong collateral evidence, and by more than one method: I shall now only mention one of these, and for that we are indebted to Dr. Ayrton Paris.

"Either let two of these parallel experiments, just mentioned, be made upon two separate pieces of clean writing paper; or, otherwise, spread a little of the fresh-prepared arsenite of silver on one piece, and of phosphate of silver on the other. Suffer these to remain exposed till dry, and the phosphate of silver will gradually assume a *black* colour, or nearly so; while the other, the arsenite of silver, will pass from its original vivid yellow to an Indian yellow, or nearly a *fawn* colour. If these two experiments be performed with due skill and precision, another distinctive peculiarity will occur, which ought to be watched. Proceed in this way:—Pour about a dram, or more, of the solution of phosphate of soda on one piece of writing-paper; and, to save time, as much of the arsenite of potash on another piece; then to each of them present a separate and small stick of dry nitrate of silver, drawing it backwards and forwards, so as to disperse the colour. The first appearance to be remarked is, that the arsenite of silver puts on a yellow *flocculent* figure, the colour curdling, accumulating, and assembling together in spots, as if it were a *yellow* chloride of silver; while the phosphate offers to our view a homogeneous colour, totally different in respect to texture, being quite smooth and uniform, as if it were laid on with a brush: there is also, at first, an evident difference in the colour*."

135. The effect of nitrate of silver, for detecting minute portions of sulphuretted hydrogen, may be shewn by immersing part of the white of an egg, coagulated by heat, in distilled water mixed with a small quantity of nitrate of silver, and suffering it to stand for about twenty-four hours: during this time the whole solution, as well as the albumen, will acquire a dark brown colour, because the albumen of the egg contains sulphur. The blackening of a silver spoon, on touching it with the white of a boiled egg, also illustrates this fact.

136. Put water, impregnated with sulphuretted hydrogen gas, into a saucer or wine-glass, and hold over, and also close to the surface of the water, a slip of paper wetted with a solution of nitrate of silver: the sulphuretted hydrogen gas escaping from the fluid, will instantly cause the solution of silver

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* The plan of this work does not admit of speaking of other tests of arsenic in this place; but they may be referred to in other parts of the book by first turning to the article *Arsenic*, in the Index.

to become blackened; the silver which it contains will re-appear in a metallic form, and being combined with sulphur, the whole assumes a brilliant metallic and iridescent appearance.

137. Write on paper with a dilute solution of nitrate of silver: the writing will be invisible when dry, and kept defended from the light. But if the paper be immersed in water impregnated with sulphuretted hydrogen gas, or if a feather or sponge dipped in this fluid be passed over it, the characters will instantly acquire a dark brown or black colour, the intensity of which is according to the strength of the nitrate of silver employed.

XX. *Acetate of Silver.*

138. This re-agent, the chemical action of which is, in every respect, similar to nitrate of silver, is particularly well adapted for examining mixtures of nitrates and muriates, if we wish to ascertain and separate the muriatic acid, without adding any additional quantity of extraneous nitric acid to the mixture, which would be the case if nitrate of silver be employed. We become thus also enabled to

discriminate the alkali combined with the muriatic acid more readily, by its appropriate tests, namely, muriate of platinum, &c.; or even without the usual tests for alkalies, namely, by simply evaporating to dryness the fluid from which the muriatic acid has been separated by means of the acetate of silver, and re-dissolving the dry mass in alcohol. If this solution, after being evaporated to dryness, afford a deliquescent salt, we have reason to believe that the base of the salt is potash; and if it effloresce, and remain dry on exposure to the air, there is then reason to believe that it is soda; or, for example, when nitrate of potash accompanies sulphates and muriates without any other nitrate, the sulphates being decomposed by acetate of barytes, and the muriates by acetate of silver, the fluid, after filtration, may be evaporated to dryness, and the residuum treated with alcohol, which dissolves the acetates, and leaves the nitrate; the quantity of which may be easily estimated. If an alkali be present, it ought, of course, to be previously saturated with an acid. As the acetate of silver, like the nitrate, is affected by the presence of sulphuric and sulphurous acids, these must be previously removed, as directed, No. 116.

139. Acetate of silver is decomposed by exposure to light: the bottle containing a solution of it becomes covered within with a metallic coat of silver, and a black powder separates. It, therefore, must be kept in opaque bottles, or in the dark.

XXI. *Sulphate of Silver.*

140. The combination of silver with sulphuric acid, may occasionally be used with advantage as a test for detecting muriatic acid, where nitrate of silver is not so applicable; because it is not affected, like nitrate of silver, by salts, containing sulphurous or sulphuric acid; so that when sulphate of silver is employed, we are certain that the precipitate produced by this test, when no uncombined alkali or earth is in the solution, is produced by muriatic acid only.

141. This test is best kept in opaque bottles, for light has an action upon it; the silver which it contains is in part reduced, and falls down as a black powder.

XXII. *Phosphate of Soda.*

142. This salt, in combination with bicarbonate of ammonia, is employed as a re-agent for separating magnesia. The process was first pointed out by Wollaston, and is as follows:—Pour a solution of bicarbonate* of ammonia into the fluid suspected to contain magnesia: no magnesia becomes precipitated if this earth be present, because the carbonic acid of the bicarbonate of ammonia is sufficient to keep it in solution: but on adding phosphate of soda, the magnesia is transferred to the phosphoric acid, with which, and the ammonia, it falls down, as an insoluble triple salt. It is essential that the solutions should be somewhat concentrated; and that the *bicarbonate* of ammonia be used. Phosphate of soda, when deprived of its water of crystallization, is likewise employed as a flux for the

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* The salt, commonly called *subcarbonate of ammonia*, is either a *sesquicarbonate*, being composed of 1½ atom of carbonic acid and 1 atom of ammonia, or, which amounts to the same thing, of 1 atom of carbonate, and 1 atom of bicarbonate of ammonia, and when it is exposed to the air, it parts with ammonia, and is converted into a *bicarbonate*, consisting of 1 atom of ammonia, and 2 atoms of carbonic acid: this bicarbonate is the salt meant in the text.

blowpipe: it materially facilitates the fusion of earthy substances and metallic oxides, and forms a more manageable flux than phosphate of soda and ammonia, which is frequently recommended for similar purposes. Examples:

143. Add to a solution of sulphate of magnesia a solution of bicarbonate of ammonia, in sufficient quantity to saturate the acid: no change will take place: but if to this fluid, which now contains sulphate of ammonia and carbonate of magnesia, a cold and saturated solution of phosphate of soda be added, it immediately becomes turbid, and a white powder subsides, which is a triple salt; namely, phosphate of magnesia and ammonia, and is called the *ammonio-magnesian phosphate*: 100 grains are considered equivalent to about 20 grains of magnesia, when dried at a temperature not exceeding 100° F.

144. If, instead of drying the precipitate at a gentle heat, we calcine it, the ammonia, as well as the water it contains, are driven off, and a biphosphate of magnesia remains. Mr. Brande says, in processes of this kind, he has never been able to throw down the whole of the magnesia, a portion being under all circumstances retained in solution; and Mr. Phil-

lips observes, that some fallacy in the use of this test may be occasioned by the carbonate of lime, which sesquicarbonate of ammonia sometimes contains; so that the addition of phosphate of soda may throw down *phosphate of lime*, as well as the ammoniaco-magnesian phosphate.

145. Dissolve magnesia in muriatic acid, and add to the solution bicarbonate of ammonia: no change will take place; but if a strong solution of phosphate of soda be added to the fluid which contains the muriate of magnesia and bicarbonate of ammonia, the mixture becomes turbid, and phosphate of magnesia and ammonia is deposited.

XXIII. *Lime Water.*

146. This fluid is frequently employed for ascertaining the presence of carbonic acid, not combined with a base, or combined in excess, with which it produces a white pulverulent precipitate, which again disappears when an excess of the fluid containing the carbonic acid is added, because the excess of carbonic acid re-dissolves the neutral carbonate which produced the cloudiness: the

transparency of the mixture is likewise restored by muriatic or nitric acid. The action of lime water is therefore modified according to the quantity of the substance upon which it is made to act. There is another object which requires to be considered with regard to this test, to avoid fallacious results, namely, the precipitation of salts with a base of magnesia or alumina, which, with lime water, also produce a white precipitate; and a cloudiness is further produced when sulphates are made to act upon this test. But the precipitate occasioned by lime, may readily be discriminated, as will be stated presently.

147. Lime water is further made use of as a test for corrosive sublimate, with which it produces, according to the quantity added, either a yellow or a brick-dust coloured precipitate; and occasionally also for detecting the presence of white arsenic, with the solutions of which, when added in excess, it forms a white precipitate (arsenite of lime), which, being scarcely more soluble than sulphate of lime, sinks to the bottom in the form of minute crystals. Arsenite of lime is soluble in excess of the arsenious solution, and it may be farther observed, that it is dissolved by all

acids which will dissolve lime. Lime water has lost the reputation it formerly had, as a test for shewing the presence of arsenious acid; for, in mixed fluids, on account of its lightness, it is readily suspended by a variety of substances.

148. Some chemists have endeavoured to estimate the quantity of carbonic acid when contained in a mineral water, by the admixture of lime water, namely, by adding lime water to the mineral water, fresh from the fountain head, and collecting, drying, and weighing, the carbonate of lime thus produced. But this method is fallacious in most cases, for the lime water also precipitates all the carbonate of lime held in solution by carbonic acid and the carbonate of magnesia; and besides, it decomposes other magnesian salts, and causes their earth to precipitate.

149. Lime water does not keep, but is speedily rendered useless, on account of the carbonic acid gas which it attracts from the air, when the bottle containing it is frequently opened: it may be readily prepared for immediate use in the following manner:—

Take two ounces of fresh burnt quick-lime, put it into a stone-ware vessel, and gradually sprinkle on it so much distilled or rain water as is sufficient to slake the lime, and keep the vessel covered, whilst the lime slakes and falls into powder. This being done, pour on it a pint of distilled or rain water, and mix the lime thoroughly with the water by stirring. After the lime has subsided, repeat the stirring and agitation for several times successively during the space of twenty-four hours, and then preserve the liquor, upon the lime left undissolved, in a well-corked bottle, and filter or decant off the lime-water when wanted for use.

Water as cold as possible should be used, as it is a remarkable property of lime that it is less soluble in hot than in cold water. For the knowledge of this fact we are indebted to Mr. R. Dalton. The solution is ordered to stand upon the undissolved lime, that it may be saturated, as fast as any carbonate is formed, by the attraction of carbonic acid gas from the atmosphere.

The proportion of water above directed to be used dissolves a very small part of the lime; but lime being of little value, and seldom thoroughly good, a little waste of this material is of no importance, where the object is to obtain a saturated solution of it in water, quickly and easily.

The most convenient state for keeping lime fit for immediate use, is to convert it into a *hydrate*, which may be done by sprinkling so much water on dry quick-lime as is just sufficient to cause the lime to fall into a perfectly dry powder. This compound, or *hydrate of lime*, consists of 1 atom of lime $= 28 + 1$ atom of water $= 9$; so that 28 parts of lime after *slaking* amount to 37 parts. It may safely be preserved in this state in glass bottles; which cannot be done with quick-lime in its perfectly dry form, for in that state it almost constantly breaks the bottle, on account of its swelling, from the moisture which it attracts when the bottle is occasionally opened. Examples:—

150. Half fill an ale-glass with fresh-prepared lime-water, and blow through the water, by means of a tobacco-pipe or quill, the air respired from the lungs. The lime-water will, by this operation, be rendered turbid, because the carbonic acid gas expired from the lungs combines with the dissolved lime, and forms with it a neutral carbonate of lime, which being insoluble in water, becomes precipitated. The precipitate may be made to

disappear by the admixture of muriatic or nitric acid.

151. Half fill a test tube with water impregnated with carbonic acid gas (see Note A), and add to it lime-water : a white precipitate (carbonate of lime) will fall down, which again becomes dissolved by the admixture of a few drops of muriatic or nitric acid.

152. Fill a two-ounce phial with carbonic acid gas, and add to it about a table-spoonful of lime-water; close the phial and shake it: the lime-water will become milky, because a neutral carbonate of lime is produced. Put the turbid mixture aside, and again fill the phial with carbonic acid gas, and pour this mixture again into the phial filled a second time with the gas : the lime-water will now become perfectly transparent, or if not, expose it for a third time to a fresh portion of carbonic acid gas, or

Into a bottle, containing about half a pint of lime-water filtered, pass carbonic acid gas, by means of a bent tube, inserted air-tight into the neck of another bottle containing small pieces of marble (see fig. i. plate 3) and dilute muriatic acid; the lime-water, as before, at first becomes turbid, but presently afterwards it is again rendered transparent, as in the last case.

The transparency thus effected, is owing to the neutral carbonate of lime having combined with an additional quantity or excess of carbonic acid gas; a new body or supercarbonate of lime being produced, which is soluble in water. We therefore see, that if water holding carbonic acid gas in solution, be added in small quantity only to lime-water, an instant milkiness ensues, and a precipitate of carbonate of lime is produced; but if an excess of the carbonated water be added, it becomes clear again. If the fluid be heated, or merely suffered to be exposed to the open air, the excess of carbonic acid gas flies off, and a neutral carbonate of lime is re-produced, which, being insoluble, falls down as a white precipitate.

153. Hence all pump or well waters, holding in solution super-carbonate of lime, &c. become turbid by boiling, and a crust or *fur*, as it is called, is deposited in tea-kettles and other vessels in which such waters are frequently boiled; the heat expels the excess of carbonic acid, which held the earthy carbonate in solution, and the neutral carbonate of

lime is deposited. It is thus that nature dissolves calcareous masses, which have been collected and deposited by these waters. When the waters, by their exposure to the air, lose the quantity of carbonic acid which favoured the solution of the lime, deposits are formed, and thus originate calcareous incrustations found in caverns, springs, &c. When these waters suddenly lose the excess of carbonic acid which was essential to the solution of the lime, there is an irregular precipitation; hence those tender calcareous cellular stones, and calcareous spongy *tuffs:* but if the evaporation of the carbonic acid takes place slowly, it produces crystallizations, such as *stalactites*, &c.

154. To a few ounces of fresh prepared lime-water add two or three grains of carbonate of potash: the solution will become turbid, and yield a white precipitate; because the carbonic acid of the alkaline carbonate unites with the lime, and forms with it a carbonate of lime, which being insoluble, falls to the bottom. Add dilute muriatic or nitric acid, and the precipitate will be again dissolved.

155. Dissolve five or six grains of sulphate

of magnesia (Epsom salt) in half an ale-glassful of distilled water, and pour a little fresh prepared lime-water into the solution : it will become turbid, and a white pulverulent precipitate will gradually fall down to the bottom of the glass. Lime-water, therefore, decomposes also the salts of magnesia.

156. Mix five or six drops of a concentrated solution of corrosive sublimate, with half a test-tubeful of lime-water : no brick-dust or orange-coloured precipitate will be produced, but a yellow precipitate will fall down : on adding gradually more of the solution of corrosive sublimate, the mixture will acquire an orange colour, and a precipitate of the same hue will be deposited.

157. Let fall eight or ten drops of a solution of arsenious acid, into a wine-glass containing about one table-spoonful of distilled water ; and fill the remainder of the glass with fresh-prepared lime-water : the mixture will become milky in a few minutes, and a white flocculent precipitate (arsenite of lime) will gradually collect at the bottom of the glass. If to the turbid liquid thus obtained a few drops of acetic or nitric acid be added, it will become clear again, because the precipitate

becomes completely re-dissolved; and the same result takes place by a copious admixture of the solution of arsenious acid.—See No. 147.

XXIV. *Tan, or Tannin,* (see Note B.)

158. This substance is employed for detecting animal gelatine, or jelly, with which it forms an elastic, adhesive mass, which soon dries in the open air, and becomes converted into a brittle resinous-like substance, which is insoluble in water, and capable of resisting a great number of chemical agents. It greatly resembles over-tanned leather. The power of tan, as a test of gelatine, is very great. Dr. Bostock found a copious and *immediate* precipitate, on adding a moderately strong infusion of tan to water containing only $\frac{1}{1000}$ of isinglass, and a very considerable precipitate when the gelatine was only $\frac{1}{2000}$. An *immediate* precipitate with tan, may therefore be considered as a pretty certain indication of gelatine. To render this test accurate, it is necessary to attend to the circumstance, that tan likewise produces a precipitate with albumen. This, however, is much less evident;

it does not take place *immediately*, but only after the mixture has stood for some time; and the distinction between these bodies is likewise easily established by the use of other tests.

159. Dr. Bostock has also pointed out a very ingenious method of detecting and ascertaining the *quantity* of gelatine contained in an animal fluid. If oxymuriate of mercury produces no precipitate (see *corrosive sublimate*), we may be certain of the absence of albumen. Then the infusion of tan being mixed with the liquid in such a proportion that the filtered fluid will neither precipitate infusion of tan, nor the animal liquid under examination, a precipitate falls down, composed of about two parts of tan and three parts gelatine. Hence this precipitate, dried in a steam bath, and multiplied by 0.6, gives the weight of gelatine in the liquid examined, very nearly. Examples :—

160. Mix a small quantity of dissolved glue, or isinglass, with water, and drop into it a solution of tan: a copious flocculent precipitate will immediately fall down, consisting of tan and gelatine.

161. Dissolve a small quantity of portable soup (which may be had at the confectioner's)

in boiling water, and add to it a solution of tan: an abundant curdy precipitate will take place, as in the preceding experiment. The same will be the case if tan be dropped into broth.

XXV. *Nitrate of Cobalt.*

162. This salt has of late been recommended by Mr. Gahn, the celebrated German mineralogist, and discoverer of the metallic nature of manganese, as a test for readily discovering the presence of alumina in mineral substances when submitted to the trial of the blowpipe assay. It is to be used in the following manner: put, on the substance to be tried, a drop, or less, of a concentrated solution of nitrate of cobalt, and then expose it to the flame of the blowpipe dart. If the mineral contains alumina in any notable quantity, and is not too much charged with iron, or other colouring metals, it will soon acquire a blue colour, more or less vivid and intense, according to the purity and abundance of the alumina which it contains.

163. The test may be applied to the hardest gems, or softest clays. When the mineral is a hard stone, it is only necessary to pul-

verize it well, and to drop on it a minute portion of the test, and then to expose it to the action of the blowpipe dart, upon a piece of platinum foil. The test, however, labours under one disadvantage, for the earth, zircon, produces the same blue colour; but as the characters of zircon earth are exceedingly well marked, the application of a few additional tests readily enables us to know to which of the earths the colour is owing. Examples:—

164. Let fall a drop of solution of nitrate of cobalt upon a piece of common pipe-clay, of the size of a pea, and heat the mixture gradually, on a slip of platinum foil, before the blowpipe flame: the clay will acquire a bright blue colour.

165. Moisten a piece of quicklime, chalk, magnesia, or a minute portion of pulverized flint, with nitrate of cobalt, and expose the mixture to the heat of the blowpipe dart: these earths will not acquire a blue colour; the mere effect of the nitrate of cobalt will be, to impart to them, before the blowpipe flame, a dull grey or black colour.

166. Again: take a piece of light yellow ochre, drop on it a minute quantity of nitrate

of cobalt, and make it red hot by means of the blowpipe flame: this substance will acquire a dark blue or purple colour, because ochre is chiefly composed of alumina. The oxide of iron which it contains acquires a red colour when heated, and this, with the blue effected by alumina, produces the purple or violet tinge*.

XXVI. *Acetate of Lead*†.

167. This is another test which may be employed for detecting muriatic acid, and sulphuric acid, with both of which it occasions a white precipitate, namely, chloride of lead, and sulphate of lead. The precipitate produced by muriatic acid, is soluble in dilute nitric and acetic acid; but the precipitate produced by sulphuric acid is not. Its action upon muriatic acid is much inferior to nitrate of silver. It is also decomposed by alkaline and earthy carbonates; but this may be prevented by a previous admixture of nitric acid. Acetate of lead may also be employed as a test for phosphoric acid, with which it produces a white precipitate; even a solution

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* See Table of Metallic Oxides before the Blowpipe.

† Commonly, but improperly, called *super-acetate of lead.*

of phosphate of lime is completely decomposed by this salt, all the phosphoric acid is separated, and, by double decomposition, a precipitate of phosphate of lead is produced, which is readily known by the following characters. When heated by the blowpipe on a piece of charcoal, it melts easily into a pearl-white globule, which immediately on discontinuing the flame cools into a button of a polyhedral form; and if the flame be continued, the phosphoric acid is gradually decomposed, and burns off with a luminous vapour, smelling of phosphorus; and at last a globule of pure lead is left. The precipitate or phosphate of lead, when dried at a low red heat, contains 20 per cent. of phosphoric acid. If sulphuric acid, in any combination, should happen to be present in the solution of phosphate of lime, it will also be decomposed by the acetate of lead, and the precipitate will therefore be a mixture of sulphate and phosphate of lead. These are separable by dilute nitric acid, which will dissolve the phosphate of lead, but not the sulphate. Acetate of lead is one of the most delicate tests for discovering minute portions of sulphuretted hydrogen gas, or hydrosulphurets in general, with which it instantly forms a black precipitate. It has been recommended as a test for carbonic acid, but is seldom employed for that purpose, for we have better tests for carbonic acid. It has also been used as a test for uncombined boracic acid, particularly in the analysis of mineral waters. In that case the uncombined alkalies and earths, if any be present, must be saturated with acetic acid. The sulphates, if any be present, must be decomposed by acetate or nitrate of barytes, and the muriates by acetate or nitrate of silver. The filtered liquor, if boracic acid be contained in the water, will continue to give a precipitate, which is soluble in nitric acid of the specific gravity 1.3, and this precipitate or borate of lead may be decomposed by boiling it with sulphuric acid, which forms with it sulphate of lead, and the boracic acid is set at liberty. The fluid containing the boracic acid may then be evaporated to dryness, and if the residue be digested in alcohol, it takes up the boracic acid.

Acetate of lead strongly attracts carbonic acid from the air ; it ought to be kept, therefore, in well-stopped bottles. Examples :—

168. Drop into a test-tube, half filled with

distilled water, a grain of common salt, or a drop of muriatic acid, and add to the solution a drop of acetate of lead: a white precipitate will immediately fall down, which is chloride of lead. This precipitate is again soluble, with the assistance of heat, in nitric or acetic acid, and also in a large quantity of boiling water:—100 parts of the dried precipitate indicate about 74.28 of metallic lead.

169. Add to half a test-tubeful of distilled water, a grain or two of sulphate of soda, or of sulphate of potash, and assay it by the admixture of acetate of lead: an abundant white precipitate will fall down, which is sulphate of lead.

170. Repeat the same experiment with a single drop of sulphuric acid, added to a wine-glassful of water; and the same appearance as the last will take place:—100 parts of the precipitate (sulphate of lead), after having been heated moderately to redness, indicate about 68.42 of lead.

171. Acetate of lead is the test usually employed in commerce for detecting the genuineness of lemon juice. This article, which is largely imported in the liquid state, is not unfrequently adulterated with some

strong and cheaper acid. The sulphuric acid is most to be suspected. It is detected in the following way: put some of the juice in a glass, and add to it a solution of acetate of lead: this will produce a copious white sediment; after which, add a few drops of strong nitric acid. If the juice contained no sulphuric acid, the white precipitate will be redissolved, and the liquor become again clear, the citrate of lead, and malate of lead, of which a small portion will also be formed, being readily soluble in nitric acid; but if the lemon juice was mixed with sulphuric acid, the sulphate of lead will remain at the bottom. If this be collected, washed, and dried, the quantity of sulphuric acid may be estimated from the known proportions of this salt, as stated in No. 170.

172. Dissolve a few grains of carbonate of soda, or potash, in a wine-glassful of distilled water, and pour half the solution into another glass. Drop into one of the glasses a little acetate of lead: a white precipitate (carbonate of lead) will immediately be formed. Add to the other glass, nitric acid, till the potash contained in the fluid is neutralized. This being done, pour into it also a

few drops of acetate of lead: no precipitate will now appear, because the action of the carbonated alkali is thus counteracted, and the test will now indicate muriatic and sulphuric acid.

173. Add to any quantity of water impregnated with sulphuretted hydrogen gas, a drop of acetate of lead: clouds of a dark brown colour will immediately appear, and a precipitate of the same colour will be deposited, which is sulphuret of lead.

174. The effect of a sympathetic ink with acetate of lead, may serve to shew, in a striking manner, the action of this test, with regard to sulphuretted hydrogen, namely, by writing on paper with a pen dipped in solution of acetate of lead: no characters will be visible if the writing has been made with a dilute solution of the re-agent; but if the paper be held over a saucer, or other vessel containing water impregnated with sulphuretted hydrogen gas, or when the paper is moistened with this liquid, the letters assume a brilliant metallic and iridescent appearance.

175. Dissolve two grains of phosphate of soda in half a test-tubeful of distilled water, and drop into the solution a little acetate of

lead: a white precipitate will take place, which is phosphate of lead. This precipitate disappears again by the admixture of nitric acid.

176. Affuse upon pulverized phosphate of lime, commonly called bone ash (bone burnt to whiteness), sulphuric acid: a partial decomposition will take place, because bone, which is phosphate of lime, gives up part of its lime to the sulphuric acid, and an acidulous phosphate of lime is produced*. If into this fluid, when diluted with water, a few drops of acetate of lead be suffered to fall, a white precipitate takes place, which consists of all the phosphoric acid united to oxide of lead. The sulphuric acid also falls down, in combination with another portion of the oxide of lead, and forms sulphate of lead. These two precipitates may be separated by dilute nitric acid, which dissolves the phosphate, but does not touch the sulphate of lead.

177. Let fall into water impregnated with carbonic acid gas, two or three drops of acetate of lead: a white powder will fall down,

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* It is not decided in what state of combination the acid and lime exist in the salt thus produced.

which is *carbonate of lead**. The same effect will take place if the air respired from the lungs be blown, by means of a quill or glass tube, through a solution of acetate of lead. The carbonate of lead is soluble in caustic potash; and by the action of the blowpipe on charcoal, the acid is driven off, and the lead is reduced to the metallic state.

XXVII. *Sub-Acetate of Lead.*

178. This combination of lead with acetic acid, which is vulgarly called *Goulard's Extract*, is recommended by Dr. Bostock to discover the presence of *mucus*†, or animal mucilage; and to discriminate it in the analysis of animal fluids, from gelatine, with which it has been so often confounded. Sub-acetate of lead instantly acts upon animal mucus, and produces with it a copious white and flaky precipitate, but it is not sensibly rendered turbid by a solution of animal gelatine. A solution

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* *White lead* of commerce is carbonate of lead.

† Subacetate of lead is acted upon by a variety of animal as well as vegetable matters; and this consequently interferes with the certainty of this test, as regards its application for detecting the presence of *mucus.*

of sub-acetate of lead may also be employed for separating the extractive, acid, and colouring matter from wine, so as to enable us to abstract from the remaining colourless liquor, by means of a carbonated alkali, all the water which it contains; and to ascertain, in a ready manner, the quantity of alcohol or brandy which was present in the wine. And this method of obtaining alcohol or brandy from wine, at once destroys the commonly received opinion, first entertained by Fabroni, namely, that the spirit obtained from wine is formed during the distillatory process; whilst, on the contrary, it clearly proves, that brandy or spirit of wine exists ready formed in all vinous liquors, and that it may be separated from them without distillation*. And further, that the quantity thus separated is precisely equal to the proportion yielded by the common method of distillation. The process, which is as follows, was first pointed out by Mr. Brande:—

179. Add to eight parts, by measure, of the

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* The theory of the process of the vinous fermentation of vegetable infusions containing saccharine matter, is not understood; neither is that of the acetous fermentation, which succeeds the vinous.

wine to be examined, one part of a concentrated solution of sub-acetate of lead: a dense insoluble precipitate will ensue; it is a combination of the test with the colouring, extractive, and acid matter of the wine. Shake the mixture for a few minutes, pour the whole upon a filter, and collect the filtered fluid. It contains the brandy or spirit, and water of the wine, together with a portion of the acid of the sub-acetate, provided the latter has not been added in excess; for in that case a part, of course, remains undecomposed. Add, in small quantities at a time, to this fluid, warm, dry, and *pure* carbonate of potash *(not salt of tartar, or carbonate of potash of commerce)*, which has previously been freed from water by heat, till the last portion added remains undissolved. The brandy or spirit contained in the fluid will thus become separated; for the carbonate of potash abstracts from it the whole of the water with which it was combined; the brandy or spirit of wine forming a distinct stratum, which floats upon the aqueous solution of the alkaline salt. If the experiment be made in a glass tube, from one half an inch to two inches in diameter, and graduated into

100 equal parts, the per centage of spirit, in a given quantity of wine, may be read off by mere inspection.

By operating on artificial mixtures of alcohol and water, Mr. Brande found, that when the alcohol is not less than sixteen per cent the quantity indicated by the dry and warm carbonate of potash, after the colouring and acid matter have been separated by subacetate of lead, was always within one-half part of 100 of the real proportion contained in the mixture.

TABLE

Exhibiting a comparative view of the quantity of Alcohol (specific gravity, .825) obtained by Mr. Brande from various Wines and Spirituous Liquors.

[Brande's Manual of Pharmacy.]

	Proportion of Spirit per cent. by measure.		Proportion of Spirit per cent. by measure.
Lissa	26,47	Marcella	25,05
Ditto	24,35	Average	25,09
Average	25,41	Port	25,83
Raisin Wine	26,40	Ditto	24,29
Ditto	25,77	Ditto	23,71
Ditto	23,20	Ditto	23,39
Average	25,12	Ditto	22,30
Marcella	26,03	Ditto	21,40

	Proportion of Spirit per cent. by measure.
Port	19,00
Average	22,96
Madeira	24,42
Ditto	23,93
Ditto (Sercial)	21,40
Ditto	19,24
Average	22,27
Currant Wine	20,55
Sherry	19,81
Ditto	19,83
Ditto	18,79
Ditto	18,25
Average	19,17
Teneriffe	19,79
Colares	19,75
Lachryma Christi	19.70
Constantia (White)	19,75
Ditto (Red)	18,92
Lisbon	18,94
Malaga (1666)	18,94
Bucellas	18,49
Red Madeira	22,30
Ditto	18,40
Average	20,35
Cape Muschat	18,25
Cape Madeira	22,94
Ditto	20,50
Ditto	18,11
Average	20,51
Grape Wine	18,11
Calcavella	19,20
Ditto	18,10
Average	18,65
Vidonia	19,25
Alba Flora	17,26
Malaga	17,26
Hermitage (White)	17,43
Rousillon	19,00
Ditto	17,26
Average	18,13
Claret	17,11
Ditto	16,32
Ditto	14,08
Ditto	12,91
Average	15,10
Zante	17,05
Malmsey Madeira	16,40
Lunel	15 52
Sheraaz	15,52
Syracuse	15,28
Sauterne	14,22
Burgundy	16,60
Ditto	15,22
Ditto	14,53
Ditto	11,95
Average	14,57
Hock	14,37
Ditto	13,00
Ditto (old in cask)	8,88
Average	12,08
Nice	14,63
Barsac	13,86
Tent	13,30
Champagne (Still)	13,80
Ditto (Sparkling)	12,80
Ditto (Red)	12,56
Ditto (Ditto)	11,30
Average	12,61
Red Hermitage	12,32
Vin de Grave	13,94

	Proportion of Spirit per cent. by measure.
Vin de Grave	12,80
Average	13,37
Frontignac	12,79
Cote Rotie	12,32
Gooseberry Wine	11,84
Orange Wine (average of six samples, made by a London manufacturer)	11,26
Tokay	9,88
Elder Wine	8,79
Cider, highest average	9,87
Ditto, lowest ditto	5,21
Perry, av. of 4 samples	7,26

	Proportion of Spirit per cent. by measure.
Mead	7,32
Ale (Burton)	8,88
Ditto (Edinburgh)	6,20
Ditto (Dorchester)	5,56
Average	6,87
Brown Stout	6,80
London Porter, average	4,20
Ditto Small Beer, ditto	1,28
Brandy	53,39
Rum	53,68
Gin	51,60
Scotch Whiskey	54,32
Irish Ditto	53,90

180. The action of sub-acetate of lead as a test for mucus, may be shewn in the following manner. Rince and macerate an oyster in cold distilled water; evaporate to dryness the mucous matter thus obtained; re-dissolve the dry mass in distilled water, and filter it: if to this fluid a few drops of sub-acetate of lead be added, a copious white flocculent precipitate will be obtained.

The same effect will be produced if the solid matter obtained by evaporating saliva to dryness, be re-dissolved in water, filtered, and submitted to the action of this test.

XXVIII. *Muriate of Platinum.*

181. This is a valuable test for distinguishing the salts of potash from those of soda: it produces with all the salts of potash, a yellow precipitate, which is not an oxide of platinum, but a *bichloride of platinum* and *chloride of potassium;* but it does not affect the salts with a base of soda. In using this test, it is essential that there be no excess of acid; and the solution should be somewhat concentrated. Its action is greater than tartaric acid. It is also a test for tin. Examples:—

182. Add to half a test-tubeful of distilled water, a few grains of potash, or carbonate of potash; and then add a drop of the solution of muriate of platinum: the fluid will instantly become turbid, and the yellow precipitate, above described, will fall to the bottom of the tube.

183. Add to a like quantity of distilled water a few grains of soda, or of carbonate of soda, and add to it also muriate of platinum: no change will take place, because soda is not precipitable by this test.

184. Drop into a concentrated solution of

sulphate of potash a little muriate of platinum: the same phenomena will take place as in No. 181.

185. Add to a solution of sulphate of soda a few drops of muriate of platinum: no change will take place.

Apply the same test to any of the salts of potash or soda, (except *ferrocyanate of potash*), and in this manner the two alkalies, potash and soda, and their combinations, are easily discriminated. See also *Tartaric Acid.*

XXIX. *Protosulphate of Iron**.

186. This salt has been recommended for ascertaining the presence of oxygen gas, of which mineral and other waters sometimes contain a small quantity. The presence of this gas is discovered by dissolving in the water a small quantity of this salt. If the water be entirely free of oxygen, and the phial containing it be well stopped, the solution is transparent; but if otherwise, it soon becomes slightly turbid, from the oxide of iron attracting the oxygen of the water; and a small portion of it, in this more highly oxi-

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* Commonly called *green sulphate of iron* and *green vitriol.*

dized state, leaving the acid, becomes precipitated.

187. Sulphate of iron is also employed for detecting the presence of gold, with which, when in a state of solution, it produces a brown precipitate, which is metallic gold. It also throws down palladium in a metallic form. It is likewise useful for detecting gallic acid, with which, like all other salts of iron, it produces a precipitate which speedily becomes black on exposure to the air. Examples:—

188. Fill a phial brim full with the water to be examined, and drop into it a few crystals of sulphate of iron, and cork the bottle close: in a little time the sulphate of iron will be dissolved; and if the mixture be suffered to stand for six or eight hours, a brown oxide of iron, or ochry precipitate, will fall to the bottom, if oxygen gas be present in the water.

189. The action of this test must be received with some limitation; for common air, which is present in all natural waters, produces, in part, a like effect; and it is only from comparing the quantity of the precipitate with common spring water, that some notion may be formed. Mr. Henry expelled the air from

a portion of spring water by boiling: 100 cubic inches of the water yielded 4.76 inches of gas. This gas he found a mixture of 3.38 inches of carbonic acid, and 1.38 of atmospheric air. It is to the presence of these two elastic fluids that water owes its taste, and many of the good effects which it produces on animals and vegetables. Hence the vapidness of newly boiled water from which these gases are expelled.

190. Add to half a test-tubeful of distilled water a few drops of muriate of gold: no change will take place; but if protosulphate of iron, dissolved in water, be added, a brown precipitate will fall down, which is gold in a metallic state. This precipitate being washed with dilute muriatic acid, which separates any adhering iron, affords pure gold.

XXX. *Arsenious Acid**.

191. A solution of arsenious acid in water is of use for discovering the presence of sulphuretted hydrogen gas, and hydrosulphurets in general, with which it produces a yellow pre-

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* Commonly called *white arsenic*. See Sulphuretted Hydrogen as a test for the presence of this substance.

cipitate; and with the salts of lead it produces a white precipitate. It is occasionally used as a standard of comparison, to confirm or invalidate the action of other tests, when employed for the discovery of arsenic, particularly in cases where collateral circumstances render the phenomena of the usual tests doubtful. Example:—

192. Add a little of the solution of arsenious acid to half a test-tubeful of distilled water, and no alteration of colour will take place; but on adding to the fluid, water impregnated with sulphuretted hydrogen gas, a bright yellow precipitate will be produced, which is sulphuret of arsenic.

XXXI. *Muriate of Gold.*—(See Note C.)

193. It is chiefly of use for detecting the presence of tin, with the solutions of which, when the tin is at a *minimum* of oxidation, it produces a purple, or purplish brown precipitate*; hence muriate of gold, and protomuriate of tin, are reciprocally tests for each other. See ***Protomuriate of Tin.*** Muriate of

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* Used by porcelain painters, and is commonly called the *purple powder of Cassius.*

gold has also been recommended as a test for albumen: it throws down a dense flocculent precipitate from a solution containing $\frac{1}{1000}$ part of this substance; but corrosive sublimate is a better test for detecting this substance, because it effects no change in solutions containing jelly, or animal gelatine, and mucus: whereas muriate of gold appears to have a slight action on these bodies.

XXXII. *Sulphate of Copper**.

194. This salt may be employed for discovering arsenic, with which it produces a bright yellowish green precipitate, provided a very small quantity of a carbonated alkali has previously been added to the fluid in which the arsenic is suspected. Water impregnated with sulphuretted hydrogen gas produces with this salt a dark brown precipitate, which is a sulpuret of copper. Example:—

195. Add a small quantity of solution of arsenious acid, to half a wine-glassful of distilled water, in which previously a grain of carbonate of potash has been dissolved; then add a few drops of the above test: a green

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* This salt is a *bisulphate*. It is vulgarly called *blue vitriol*.

flocculent precipitate will instantly fall down. This substance, after being dried, is to be tested with the black flux. See *Black Flux*.

To identify arsenic, when this is one of the tests employed for detecting it, Dr. Henry very properly advises to perform, at the time of making the experiment, similar comparative experiments with what is actually known to be arsenic; because the proportions of sulphate of copper and carbonated alkali employed, have considerable influence on the distinct exhibition of the effect. Those which answer best are, one of arsenic, three of carbonate of potash (common salt of tartar), and five of sulphate of copper. For instance, if a solution of one grain of arsenic, and three grains of potash, in two drachms of water, are mingled with another solution of five grains of sulphate of copper in the same quantity of water, the whole becomes converted into a beautiful grass green mixture, from which a copious precipitate of the same hue slowly subsides, leaving the supernatant liquor transparent, and nearly colourless. When the same materials, with the omission of the arsenic, are employed in the like manner, a delicate sky blue mixture results, so different from the former as not to admit of the possibility of a mistake. In this way $\frac{1}{40}$th of a grain of arsenic diffused through 60 grains of water, afforded to Dr. Bostock, by the addition of sulphate of copper and carbonate of potash, in proper proportions, a distinct yellowish green precipitate. See "Edinburgh Medical and Surgical Journal," vol. v. 166. In employing this test, it is necessary to view the fluid by reflected, and not by transmitted light, and to perform the experiments by daylight. To render the effect more apparent, a sheet of white paper may be placed behind the glass or test tube in which the mixed fluids are contained.

XXXIII. *Muriate of Lime*

196. Is of some use, as an auxiliary test, for discovering the presence of alkaline carbonates, all of which decompose this salt, and produce with it carbonate of lime. It is further useful in the analysis of vegetable substances, for detecting the presence of oxalic, malic, and tartaric acid, with which it produces white crystalline precipitates, which are highly insoluble in water, but readily soluble in dilute

nitric acid, and the precise nature of these may then be further examined with less difficulty, so as to discriminate which particular vegetable acid enters into composition.

197. Muriate of lime evaporated to dryness becomes *chloride* of calcium*: this substance is employed also to strengthen spirits of wine, because the affinity of alcohol for water is so strong, that it cannot be entirely freed from it by simple distillation; but by chloride of calcium this may readily be effected. For this purpose, one part of the chloride rendered perfectly dry by having been exposed to a red heat, and powdered after it has become cold, is put into the retort or still; over this, three parts of highly rectified spirit are to be poured, and the mixture well agitated: by distillation with a very gentle heat, about two-thirds of the spirit will then be obtained in the state of perfectly pure alcohol.

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* Muriates by evaporation to dryness become chlorides, by the decomposition of the muriatic acid and the metallic oxide: the hydrogen of the former unites with the oxygen of the latter, and water is formed and evaporated, and the chlorine of the acid forms a chloride by uniting with the metallic base of the salt. This change does not take place when muriate of ammonia is evaporated to dryness, because that salt has a non-metallic base. See note, p. 44.

XXXIV. *Benzoate of Ammonia.*

198. Benzoate of ammonia is an excellent test for separating iron from manganese when together in one solution. It is necessary, when employed for this purpose, that the solution containing the two oxides should be rendered previously neutral, with accuracy, by the admixture of ammonia, or any other alkali; and then the benzoate of ammonia may be added, till no more precipitate falls down. This precipitate is benzoate of iron, for all the manganese remains in the solution.

It may however happen, that after having precipitated the iron from the solution containing several kinds of earths and metallic oxides, that part of the benzoate added, exists in the solution in excess; in that case it ought to be destroyed by boiling the solution with some acid, to obviate any confusion which might happen to be produced by the benzoic acid, on the continuation of the analysis.

199. Benzoate of ammonia not only separates iron from manganese, but it will also detach this metal from all earthy salts, and from nickel,

cobalt, zinc, and many other metals, none of which are precipitated by this test, when properly applied; that is to say, if the following circumstances be attended to. Let the solution of iron, which ought to be in the state of peroxide, be rendered perfectly neutral by the admixture of ammonia, and dilute it considerably with distilled water. Then let fall into the fluid, drop by drop, the solution of benzoate of ammonia, till no further precipitate appears.

Throw the mass on a filter; wash the insoluble residue with cold water, and dry the precipitate at a temperature of 212°. The benzoate of iron thus obtained, contains 25 per cent. of red oxide of iron, and 75 of benzoic acid, which corresponds with

1 atom of benzoic acid ...... = 120
1 atom of peroxide of iron ... = 40
160

If the benzoate of iron be digested for about 12 hours in liquid ammonia, it becomes completely decomposed; the red oxide of iron falls down to the bottom of the vessel, and benzoate of ammonia remains in solution. We are indebted to Berzelius for this test.

Its utility must be obvious to all who are employed in analytical labours; because the complete separation of manganese from iron, has hitherto been attended with peculiar difficulty.

XXXV. *Water impregnated with Sulphuretted Hydrogen Gas*—(See Note D).

200. This fluid precipitates several of the metals from their solutions in acids, and produces with most of them dark coloured precipitates; and as it affects none of the earths, with the exception of zirconia and alumina, it affords us a very valuable agent in analysis. And besides this, some metals may at once be recognized by the colour of the precipitate which they afford with this fluid. For example: with zinc, this test produces a white precipitate; with the salts of antimony, a bright orange coloured one; arsenic is precipitated yellow; tin, chocolate brown; gold, a dark purple; platinum, reddish brown, or nearly black. The solutions of lead, silver, mercury, copper, and bismuth, are precipitated of a dark brown, or black colour. The colours of the precipitates are, however, very

liable to variation, from the state of the combination. And particularly the degree of oxidizement of the metal in the solution has a material influence on the colour of the precipitates.

201. It seems doubtful whether sulphuretted hydrogen has the power to combine with the oxides of the common metals; for, on adding it in a combined or uncombined state to a solution of any of their salts, it becomes decomposed, as does also the metallic oxide, the following change taking place: the hydrogen of the sulphuretted hydrogen unites with the oxygen of the oxide, forming water; and the sulphur, combining with the metal, forms a sulphuret.

It is also doubtful whether sulphuretted hydrogen combines with any pure metal.

With alkalies, alkaline earths, and magnesia, sulphuretted hydrogen forms salts which are soluble: these salts are called *hydrosulphurets*, or *hydrosulphates*.

202. Sometimes too, a small portion of sulphuric acid is formed at the same time, which renders the play of affinities still more complex. Some of the metallic solutions afford no precipitate with sulphuretted hydrogen,

or at least the precipitate is re-dissolved by a slight excess of acid. The metals which afford no precipitate are those chiefly which have a great affinity for oxygen, and which decompose water; namely, iron, cobalt, nickel, manganese, uranium, titanium, and cerium. But some of these metallic solutions become more or less deeply coloured by this test. Thus, if liquid sulphuretted hydrogen be added to a weak solution of red sulphate of iron, the metal becomes reduced immediately to the state of the green or less oxygenized sulphate, and no actual metallic compound falls down; but sulphur is merely precipitated. This test is usually employed for detecting the presence of lead when contained in water, which has passed through leaden pipes, or been kept in leaden vessels. Some bad wines contain acetate of lead.

203. The *hydrosulphurets* (particularly *hydrosulphuret of ammonia)* are sometimes employed as tests. See Table of precipitates from metallic solutions, at the end of the work. Examples:—

204. Dissolve one or two grains of sulphate of zinc (white vitriol) in half a test-tubeful of distilled water, and add to the solution liquid

sulphuretted hydrogen: the zinc will become precipitated in the form of a *white* gelatinous sediment, which is a sulphuret of zinc.

205. Dissolve a few grains of tartrate of antimony and potash (tartar emetic) in a test-tubeful of distilled water; and drop into the solution, gradually, liquid sulphuretted hydrogen: a bright *orange* coloured precipitate will be obtained.

206. Add a small quantity of the solution of arsenious acid to half a test-tubeful of distilled water, and add to the mixture liquid sulphuretted hydrogen: a *yellow* precipitate will immediately be produced.

207. But we must not infer from the colour of the precipitate that arsenic is present, because other substances produce a *yellow* precipitate when this test is applied to their solutions. But if the precipitate, when tested with the black flux (see *Black Flux*) give the metallic sublimate, in every particular answering to arsenic, then the presence of that substance is proved beyond doubt.

Instead of applying this test, as above, to a solution suspected to contain arsenic, it is best to pass sulphuretted hydrogen gas through the solution, and then to boil it, for the purpose of expelling the excess of sulphuretted hydrogen: by this means, we effectually obtain the desired precipitate, if arsenic be present; whereas, we only sometimes obtain a yellow *fluid*, instead of a yellow *precipitate*, when the test is applied in the liquid form. To whatever suspected fluid this test is applied, care must be taken that it contain no free alkali, otherwise the sulphuret will be dissolved. This may be guarded against by neutralizing the alkali with acetic acid.

208. Let fall a few drops of protomuriate of tin into half a wine-glassful of distilled water; and add to the mixture liquid sulphuretted hydrogen: a *chocolate brown* precipitate will be produced.

209. Mix a few drops of muriate of gold with half a test-tubeful of distilled water; and add to the mixture liquid sulphuretted hydrogen: a dark *brown* precipitate will fall down, which is sulphuret of gold, and which is composed of 80.65 gold, and 19.35 sulphur; or 1 atom gold $=200+3$ atoms sulphur $=48$. When exposed to heat, it gives up its sulphur, and the residue is metallic gold.

210. Add to half a test-tubeful of distilled water ten or twenty drops of muriate of plati-

num; and drop into the mixture liquid sulphuretted hydrogen: a *black* precipitate will take place, which becomes reddish brown, with an excess of the test. It is, according to Berzelius, a perfect sulphuret of platinum; but Vauquelin describes it as a *hydrosulphuretted oxide of platinum*.

XXXVI. *Wine Test.*

211. This test is nothing else but water impregnated with sulphuretted hydrogen gas, combined with a small portion of muriatic or any other weak acid. It is employed chiefly for readily distinguishing iron from lead in wine. By adding this test to wine, or any other liquid suspected to contain lead, the liquor, if iron only be present, will remain transparent, and no precipitate will be formed; but if it contain the minutest portion of lead, the test will occasion a black muddy precipitate (which is sulphuret of lead), because the weak acid, combined with the sulphuretted hydrogen, is not capable of dissolving sulphuret of lead; and this precipitate, when fused before the blowpipe, with a minute portion of lime, or fine iron filings, on a charcoal support, then yields a globule of

metallic lead. This test, however, is not discriminative; because iron, dissolved in acetic, or in any other vegetable acid, is also precipitated by it. It likewise yields a black precipitate with solutions of iron in general, provided a minute portion of acetate of potash be added to the fluid prior to the addition of the test liquor.

XXXVII. *Tincture of Galls.*

212. This is an excellent test for detecting the presence of iron. It produces with this metal a violet or black precipitate, whether the iron be held in solution by carbonic acid, or by any other acid. If the iron be dissolved in carbonic acid, as is often the case in mineral waters, the solution, after having been concentrated by boiling, is no longer tinged of a violet or black colour; but if it be held in solution by any other acid, the test still continues to produce a black precipitate. When the quantity of iron is exceedingly small, as is in general the case in chalybeate waters, tincture of galls does not actually produce a sensible precipitate, but only a slight purple tinge. A neat way of applying this test, in cases where the quantity of iron is

very small, consists in suspending a slice of gall-nut, by a silken string, in the water to be examined. The iron, in order to afford a purple or black precipitate with tincture of galls, must be in the state of peroxide, for if it be in the state of protoxide, the effect will not be instantaneous, but will only take place after leaving the mixture to stand some time in contact with the air, so as for it to absorb oxygen.

The action of this test is influenced by the presence of other bodies. For example: if alkalies and earthy carbonates are present, it then produces with iron a violet colour. If neutral alkaline salts are present, the colour is deepened, or of a dark purple. The presence of sulphate of lime renders the colour of the precipitate at first whitish, and afterwards black; and carbonate of lime produces the same effect: a dark purple colour indicates other alkaline salts; purplish red denotes sulphuretted hydrogen. Mr. Phillips has shewn, that carbonate of lime has a considerable effect on the production of colour, by the action of tincture of galls on salts of iron. When the iron is in a low degree of oxidizement, it rather heightens the colour;

while, when it is at the maximum of oxidizement, it diminishes it so much, that if the iron be present in a very minute quantity, it may even not be capable of being detected by this test. He has thus been able to explain a fact before inexplicable, which had given rise to various opinions with regard to the hot waters of Bath, namely, that when taken immediately from the spring, and while hot, they give indication of a small quantity of iron, on application of the gall test; while, when they have cooled under exposure to the air, so that the iron becomes more oxidized, they appear, from the same test, to contain none, though no iron is deposited during the cooling.

213. Tincture of galls produces with the solutions of osmium a vivid blue colour. With the solutions of tellurium it affords a yellow precipitate; with solutions of mercury, an orange-coloured precipitate. Silver is precipitated of a yellow brown; uranium, brown; but the colour of the precipitates of these metals is, upon the whole, exceedingly variable, according to the combination or state of existence of the metal, and its degree of oxidizement. Examples:—

214. Impregnate a quantity of distilled

water with carbonic acid gas; shake it up for a few minutes with a small quantity of iron filings: let the mixture stand for about twenty-four hours, and then decant, or filter it. Take half a wine-glassful of this chalybeate water, and add to it a few drops of tincture of galls: the mixture will assume a violet colour, and a black precipitate will become deposited, composed of gallic acid, tannin, and oxide of iron.

215. Take another portion of the same chalybeate water, concentrate it by boiling to about one half of its bulk, and when it is become cold, filter it: a brown precipitate (carbonate of iron) will fall down. The remaining clear fluid will no longer be altered by tincture of galls, which shews that the iron was combined with an excess of carbonic acid, which held it dissolved in the water.

216. Add to two or three ounces of distilled water five or six drops of sulphuric acid, together with a small quantity of iron filings; shake the mixture for a few minutes, and let it stand till it is become perfectly clear; or it may be filtered, after having stood eight or ten hours.

To one half of this clear solution of iron add a few drops of tincture of galls: a violet colour, which speedily darkens, will immediately appear.

Boil the other half of the fluid till it is concentrated to about one-half of its original bulk: a brown powder will separate from the solution during the process. When the fluid is cold, filter it, and examine it again by adding to it a few drops of tincture of galls, which will still occasion a violet or black colour, because the iron is combined with a mineral acid. A minute quantity of sulphate of iron, dissolved in distilled water, will give the same results.

The black or violet-coloured precipitate which this test produces with the solutions of iron, is a combination of oxide of iron with the gallic acid and tannin contained in the tincture of galls: it is called *tannogallate of iron*. In order that the iron may produce immediately a black precipitate, it must be, as just observed, in the state of red or peroxide; for the less oxidized iron does not form instantly a black precipitate with these bodies; but the tendency of the oxide of iron in the green sulphate, to receive a larger proportion of oxygen into the combination, is, however, such, that it is difficult to prevent a black precipitate from being obtained. A few moments exposure to the asmosphere, or the action of the oxygen, even of the air contained in the upper part of the test-tube, is sufficient to communicate a violet tint. The brown precipitate, which is produced when a solution of green sulphate of iron is boiled, is owing to part of the protoxide of iron passing to the state of peroxide, and combining with a portion of acid; it is in the form of a brown powder, and, according to Berzelius, is a sulphate of the peroxide with *excess of base*, or a *subpersulphate* of iron. It consists of

1 atom sulph. acid		= 40
4 atoms peroxide of iron	40 × 4	= 160
6 atoms water	9 × 6	= 54
		254

217. The effects of a sympathetic ink may be obtained by writing on paper with a dilute solution of green sulphate of iron. When the writing is dry no letters are visible; but if a feather, or sponge, moistened with tincture of galls, be passed over the paper, the writing will instantly become visible, and assume a black colour.

XXXVIII. *Sulphate of Copper and Ammonia; or, Ammoniacal Sulphate of Copper.*—(See Note E.)

218. This test, which is of a very fine azure blue colour, has long been applied for discovering arsenic when contained in a liquid. It produces with it a yellowish green precipitate, which, after being separated from the supernatant fluid, dried, and tested with the black flux (see *black flux*), yields metallic arsenic. The precipitate is not soluble in water, nor in a solution of arsenious acid, unless added largely in excess; but it is soluble in liquid ammonia, and in nitric and most other acids. This test is now considered as very objectionable, as it has been proved, by Dr. Christison, to produce a greenish precipitate with certain animal and vegetable infusions which do not contain arsenic; and which, as merely relates to colour, might be mistaken for the precipitate occasioned by the same test applied to a solution which does contain arsenic. On the other hand, when arsenious acid has been added, in a small quantity, to tea, porter, and other mixed fluids, this test occasions no precipitate, the arsenite of copper being soluble

in tannin, and in some other vegetable as well as animal principles. Examples :—

219. Into half a wine-glassful of distilled water let fall a few drops of the solution of arsenious acid, and add to it a few drops of solution of sulphate of copper and ammonia : a yellowish, or pea-green precipitate will ensue, which, if collected and dried, will diffuse the peculiar garlic-like odour which characterises arsenic when heated with combustible bodies. (See *black flux*).

220. Divide the whole of the fluid, together with the above precipitate, into four parts, and add to one a little distilled water only; to the second, a few drops of solution of arsenious acid; to the third, liquid ammonia; and to the fourth, acetic, nitric, or any other acid. On the addition of water, no alteration will be perceived, any more than from the re-solution of arsenious acid ; but if the latter be added in great quantity, the precipitate becomes re-dissolved ; a few drops of liquid ammonia will also immediately dissolve the precipitate, and a blue transparent fluid will be obtained ; and a little nitric acid added to the fourth part, will, in a like manner, dis-

solve the precipitate, and form with it a colourless solution.

XXXIX. *Borate of Soda**,

221. Or common *borax*, when deprived by fusion of its water of crystallization, becomes a vitreous transparent substance (*glass of borax*), an excellent flux for all earthy substances and metallic oxides, and is employed as such in the blowpipe assays.

It likewise renders an essential service in the operation of analyzing argillaceous minerals. These substances, which are but feebly acted on when fused with alkalies, yield readily to glass of borax. Corundum, and the hardest gems, may be subdued by fusion, by means of this salt.

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* This salt is, according to Dr. Thomson, composed of

2 atoms boracic acid..............24 × 2 = 48
1 atom soda.................................. = 32
80

It is, therefore, strictly speaking, a *biborate*. Its crystals contain 8 atoms of water. It is called usually *sub-borate of soda*, as if it were a subsalt, merely on account of its action on vegetable colours.

XL. *Protomuriate of Tin.*

222. This is a delicate test for platinum, with the solutions of which it produces an orange-coloured precipitate. It is also used as a test for detecting gold, with the solutions of which it affords a purple-coloured precipitate, well known by the name of *purple precipitate of Cassius*, and used to give a red colour to porcelain and glass. Protomuriate of tin has likewise been recommended as a test for detecting albumen, which it precipitates from its solution, but less actively than corrosive sublimate; for water containing $\frac{1}{200}$ of albumen is not altered by this test immediately, but only after the mixture has been suffered to stand some hours. With the neutral salts of palladium this test gives a dark brown precipitate; but if added to excess, the liquor remains transparent, and of a fine emerald green colour. It also produces a dark brown precipitate with a solution of corrosive sublimate. It is absolutely essential that the test be fresh prepared; or, at least, the tin which it contains should be at a *minimum* of oxidation; for the *permuriate* of tin does not throw down precipitates from metallic solutions; and as

protomuriate of tin has a strong tendency to acquire a further proportion of oxygen, it should therefore be preserved in a well stopped bottle. Examples:—

223. Mix a drop of muriate of platinum with a wine-glassful of distilled water, and add to the mixture a drop or two of protomuriate of tin: a dense orange-coloured precipitate will fall down.

224. Add to a wine-glassful of distilled water one drop of muriate of gold, and let fall into this fluid a few drops of protomuriate of tin: a purple-coloured precipitate will be obtained, consisting of peroxide of tin and protoxide of gold.

The colour and quantity of the precipitate is extremely various, from circumstances not easily appreciated. Its production is owing to the strong attraction of the tin for oxygen, and the large quantity of that principle with which it is disposed to combine. When the two solutions are mixed, the protoxide of tin attracts part of the oxygen of the oxide of gold: the two oxides, thus brought to states of existence different from those in which they were present in the separate solutions, are no longer soluble, and are precipitated in combination. This theory also points out the circumstances required to be attended to in the process, to obtain the precipitate uniformly: the whole depends on having the solution of tin at the minimum of oxidizement; and hence it must be used newly prepared, as otherwise the tin passes to too highly an oxidized state, and the effect of the test is lost.

The colour of the precipitate approaches more to a violet, as the protomuriate of tin bears a larger proportion to that of gold; and the colour communicated by this precipitate to porcelain has the same variable character. When the muriate of gold is in excess, the precipitate is more of a rose-colour. A violet-coloured precipitate M. Oberkampf found to contain 60 per cent. of oxide of tin, and 40 of metallic gold; and a fine purple-coloured precipitate, contained 20½ per cent. of tin, and 79½ of gold. From the experiments of M. Duportal, it appears that the degree of dilution influences much the quantity of the precipitate; so that when a very weak solution of muriate of gold and muriate of tin are employed, one part of gold will produce as much as 5½ parts of purple precipitate.

225. Let fall into a test-tube, half filled with distilled water, one drop of a solution of corrosive sublimate; and add to the mixture a drop of protomuriate of tin: a dark brown precipitate will instantly be produced.

XLI. *Solution of Ammonia.*

226. Solution of caustic ammonia is chiefly employed in analytical experiments, for discovering copper and nickel, with the solutions of which, when added in excess, it produces a clear sapphire-blue colour.

To discriminate to which of these metals the blue colour be owing, it is only necessary that the ammoniacal solution be saturated in excess with sulphuric or nitric acid, and then immersing in it a slip or bar of zinc or iron; these metals will precipitate copper, if the colour be owing to that metal; but with nickel they produce no effect. A mud-coloured precipitate, indeed, is not unfrequently deposited from a solution of *common* nickel, but this precipitate is for the most part arsenic and iron, with which nickel, purified in the usual way, always abounds; and when all the arsenic, capable of precipitation by this method, has fallen down, no further digestion with zinc will produce the least effect. The solution of oxide of nickel in ammonia, is decomposed, according to Mr. Phillips, by the addition of soda or potash; and he has pointed out this as affording a certain and easy method of obtaining, what is otherwise very difficult, cobalt free from nickel; the oxide of the former, when dissolved in ammonia, being very slowly and sparingly precipitated by potash, while that of the latter is precipitated immediately and largely. He ascribes these decompositions to the two alkalies combining, and thus weakening the affinity of either to the metallic oxide.—(See Note F.)

227. Ammonia produces with zinc a white precipitate, which again becomes dissolved by a more copious admixture of the test. Liquid ammonia renders great services to the practical analyst, by enabling him to discriminate, in many cases, saline compounds with a base of lime, from those of magnesia; because it precipitates the salts of magnesia *partially*, but not the salts of lime; at least the latter are not precipitated when lime alone is present. Certain precautions are however necessary in the application of this substance; be-

cause, although magnesia cannot be precipitated entirely from many of its solutions by ammonia, yet, if alumina be present, its precipitation is complete. Thus, Chevenix found, that on adding an excess of ammonia to a solution of muriate of magnesia, mixed with a large proportion of muriate of alumina, nothing remained in the solution but muriate of ammonia: the two earths were precipitated in combination, and the affinity of the alumina to the magnesia had so much aided the decomposition, as to render it complete; and this affinity between the two earths, was even sufficient to resist the action which potash is capable of exerting on alumina. And further; if in the examination of a liquid (for instance, a mineral water) containing carbonic acid, either in a free state, or combined with magnesia, liquid ammonia be employed, it will take part of the excess of the carbonic acid from the magnesia, and the carbonate of ammonia will then throw down carbonate of lime; and if salts of alumina be present, they will likewise be affected.

228. It is of the greatest importance to be aware of the remarkable property which this re-agent possesses of forming triple salts with

earths of metallic oxides, as is the case when sulphate of magnesia, sulphate of lime, and sulphate of iron, occur together. In such a case, for example, the excess of acid (if any) must first be neutralized by ammonia; if succinate of ammonia be then added, the iron, if in a high state of oxidation, will become precipitated (see *succinate of ammonia*), and the earths remain untouched.

Or, the solution may be evaporated to dryness, and then exposed to a dull red heat for at least one hour. By this means the sulphate of iron becomes decomposed, its oxide of iron is left behind, and the sulphate of lime will be rendered insoluble, whilst the sulphate of magnesia is not altered. If the mass be then digested in water, the sulphate of magnesia becomes dissolved.

If sulphate of iron, and sulphate of magnesia, are alone present in a fluid, the insoluble residue will of course be oxide of iron.

Sulphate of lime, and sulphate of magnesia, may also be separated by the following methods: If the quantity of sulphate of magnesia is comparatively small with regard to the sulphate of lime, liquid ammonia, when added to the solution, will separate a portion of the magnesia (but not all), and the sulphate of lime will not be acted on, provided the mixture be kept for some hours in a well corked bottle, to prevent its absorbing carbonic acid from the atmosphere. But as it is more commonly required to separate sulphate of lime from a larger quantity of sulphate of magnesia, advantage may be taken of the very difficult solubility of the former, and the ready solubility of the latter. The mixed solutions, therefore, should be concentrated highly by evaporation ; when, after some hours repose, most of the sulphate of lime will separate alone, and may be removed. The solution may then be evaporated to dryness, and strongly heated, and next pulverized and digested with three or four times its weight of cold water, by which the whole of the sulphate of magnesia will be dissolved, and what little sulphate of lime may remain, after the first process, will be left untouched. The solution may then be boiled with carbonate of potash, to decompose the sulphate of magnesia, and the resulting carbonate, when washed, dried, and ignited at a red heat, will yield pure magnesia.

229. Solution of ammonia may also be employed as an useful re-agent, to separate oxide of iron from oxide of manganese. For this fact we

are indebted to Mr. Hatchett; his method is as follows: Pour into the solution of the mineral in muriatic acid, diluted with water, liquid ammonia, till the mixture slightly restores the blue colour of litmus paper, reddened by vinegar: the oxide of iron will thus be separated, and remain on the filter upon which the liquor is thrown, and the oxide of manganese will pass through it in a state of solution, combined with muriatic acid. To obtain it from this solution, it is only necessary to evaporate the fluid to dryness, and then expose the residue to a red heat, to expel the muriate of ammonia; and then wash it on a filter.

230. Solution of ammonia is known to be perfectly deprived of carbonic acid, or fit to be used as a test, when it gives no effervescence with acids, no cloudiness on mixture with strong alcohol, and particularly when it does not alter the transparency of a solution of pure lime, calcareous spar, or Carrara marble, in nitric, muriatic, or acetic acid. This last, which is a most delicate test, should be made in a well corked bottle; for though pure ammonia will not precipitate lime, carbonated ammonia will do it very readily; and the alkali, if exposed to the air, will speedily absorb

from it sufficient carbonic acid to render this test fallacious. Besides this, it should yield no precipitate with oxalic acid. If muriate of ammonia is accidentally mixed with the solution of ammonia in the process of distillation, the presence of the muriatic acid is thus detected: saturate part of the liquor with distilled vinegar, and add to it a few drops of nitrate of silver: a white precipitate will then indicate the muriatic acid, for nitrate of silver is not clouded by pure acetate of ammonia. Examples:—

231. Add three or four drops of a solution of sulphate of copper to half a test-tubeful of distilled water: no change will take place: but if a few drops of solution of ammonia be added in excess, the mixture will assume a fine sapphire blue colour, and thus indicate the presence of copper. This experiment may be pleasingly varied in the following manner.

232. Write on paper with a solution of sulphate of copper: the characters or writing will be of a green colour (or, when the solution is dilute, the letters will be invisible); but if the paper be held over the surface of solution of ammonia, contained in a glass or saucer, the writing will assume a beautiful blue

colour, which departs again on removing the paper near a fire, or by suffering it to be exposed to the open air for some time.

233. The presence of copper, when contained in pickles, to which a beautiful green colour has been given, according to the directions of the most popular homicidial cookery books, by boiling them with half-pence, or allowing them to stand for twenty-four hours in copper or brass pans (*see English Housekeeper, by E. Raffald, p.* 352, 354), may thus be detected. It is only necessary to mince the suspected pickles, and to pour solution of ammonia, diluted with an equal bulk of water, over them in a stopped phial: if the pickles contain the minutest quantity of copper, the ammonia will assume a blue colour.

234. Dissolve a few grains of sulphate of zinc (white vitriol) in half a test-tubeful of distilled water, and add solution of ammonia to the liquid drop by drop: a gelatinous precipitate of oxide of zinc will be produced, which disappears again by a more copious admixture of the test, the oxide being soluble in excess of ammonia.

235. Dissolve five or six grains of sulphate of magnesia in half a test tubeful of distilled

water, and add to the fluid, solution of ammonia: part of the magnesia only will be precipitated, the rest remains in solution; and by evaporating the supernatant fluid, a triple salt will be obtained, consisting of sulphuric acid, magnesia, and ammonia.

XLII. *Oxalate of Ammonia.*

236. This salt is a most delicate test for lime, with which it produces a white insoluble precipitate. Its power is very great: one grain of lime may be detected by it in 24.250 of water. It also occasions a cloudiness in fluids containing magnesia; but then its action is comparatively very feeble.

The precipitate, when magnesia is present, does not take place *immediately*, but only after some hours standing; and besides this, the magnesia must be present in considerable quantity; whilst, on the contrary, the minutest portion of lime is immediately affected by this test.

If oxalate of ammonia occasion a white precipitate before, and not after, having boiled the fluid submitted to its action (for instance, a mineral water), the lime is dissolved by an excess of carbonic acid; and if it continue to produce a precipitate in a liquid, which has been concentrated by boiling, we then are convinced that the lime is combined with a fixed acid: from the quantity of the precipitate produced, we are enabled to determine the quantity of lime which the substance contains. To render this test decisive, the following precautions are however necessary:—1. The mineral acids, if any be present, must be previously saturated with an alkali; 2. barytes and strontia, if present, must be previously removed by sulphuric acid.

The quantity of lime contained in the precipitate may be known, by first igniting it with access of air, which converts the oxalate into a carbonate of lime; and by expelling from this last the carbonic acid, by a red heat, in a covered crucible. According to Dr. Marcet, 117 grains of sulphate of lime give 100 of oxalate of lime, dried at 160°. Examples:—

237. Impregnate a small quantity of distilled water with carbonic acid, and shake the water up, for some minutes, with a small portion of powdered white marble, or chalk; suffer it to stand for at least two days, and then filter it.

To one half of this solution add a few drops of solution of oxalate of ammonia: the fluid will immediately become turbid, and, after some time, a white powder (oxalate of lime) will fall to the bottom.

Boil the other half of the liquor over the lamp furnace for a little while: during this process the fluid will become turbid, and a white precipitate (carbonate of lime) will be deposited; and the liquid, after having also been filtered when cold, will now no longer be rendered turbid by the test, because the excess of carbonic acid, which held the lime in solution, being volatilized, the lime becomes precipitated in the form of carbonate of lime.

238. Make a mixture composed of three ounces of distilled water, a few grains of powdered white marble, or chalk, and a few drops of muriatic acid; shake the mixture for five or six minutes, and suffer it to stand till it is become perfectly clear. Pour off half a wine-glassful of the fluid, and add to it a few drops of solution of oxalate of ammonia; the fluid will immediately become turbid, and oxalate of lime will be deposited in the form of a white powder.

Having concentrated, by boiling, another portion of the solution, examine it in a like manner with oxalate of ammonia, and it will also afford a white precipitate; because the acid which holds the lime dissolved cannot be volatilized by heat.

239. Pour a few drops of a solution of oxalate of ammonia into a test-tubeful of lime water, and the same phenomena will take place as in the preceding experiment.

240. Pour a little oxalate of ammonia into a tumbler of common spring water: the water will become milky, and a white precipitate will fall down; because spring or pump water always contains a portion of lime combined either with sulphuric or carbonic acid, or sometimes both sulphate and carbonate of lime are present.

To distinguish whether the precipitate be *carbonate* or *sulphate* of lime, we have only to bear in mind, that the former is precipitated from the water by boiling, while the presence of the latter is shewn by the test both before and after boiling, and is known, also, by its affording a precipitate with *nitrate of barytes*.

241. Dissolve one or two grains of sulphate

of magnesia in a test-tubeful of distilled water, and add to it a few drops of oxalate of ammonia: the solution will not become turbid. This experiment shews, that magnesia does not form a salt of so difficult solution as lime does with oxalic acid, and that, consequently, the presence of magnesia is no material obstacle to the detection of lime by means of this test. If, again, a few more grains of sulphate of magnesia are added to the before-mentioned quantity of water, and if to this several grains of oxalate of ammonia are added, the solution even then does not become turbid, although it be suffered to stand for some days.

242. On account of the great insolubility of oxalate of lime, oxalic acid is readily counteracted, when taken as a poison, by giving a mixture of chalk and water. Next to lime, magnesia is the best antidote we can administer, for neutralizing so deadly an acid.

XLIII. *Triple Prussiate, or Ferrocyanate of Potash.*

243. This is one of the most important tests ever discovered, because it has the valuable property of forming a precipitate with certain

metallic solutions*, and from the colour of the precipitate, the particular metal may, in many cases, be inferred, and its quantity ascertained by easy means.

244. It is chiefly used for detecting iron. If this metal exists in a state of peroxide in any fluid, it produces with this test a Prussian blue precipitate; and when in the state of protoxide, the precipitate is white, but even then it very rapidly assumes a blue colour on mere exposure to the air.

It is not affected by any of the earths. It is a very useful test for the analysis of mineral waters. If a mineral water, taken fresh from the spring, afford a blue precipitate with prussiate of potash, but not after having been concentrated by boiling, it may be inferred, that the iron is present in the water in combination with carbonic acid: and if the test continue to strike a blue colour with the boiled or concentrated water, the acid which held the iron in solution is a mineral acid; the nature of which may be readily discovered by the appropriate tests for acids; namely, by the salts of barytes, or those of silver.

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* See the Table of Precipitates from Metallic Solutions, at the end of the work.

245. It is stated by some authors, that alumina is also precipitated by ferrocyanate of potash: such a statement is erroneous. The error has arisen from the application of an impure test; and many of the contradictory results of mineralogical analyses, by different chemists, are probably to be ascribed to a similar cause. But with barytes, this test produces a *crystalline salt*; and this peculiar character, which the test presents, was regarded as in some measure assimilating barytes with the metals, the solutions of which are so generally precipitated by this test. Meyer and Klaproth observed, however, that no such precipitation from the solutions of barytes takes place *immediately*, unless when the prussiate employed is contaminated with a sulphate, from which it is difficult to obtain it free. Dr. Henry has shewn, that although no *immediate* precipitate is formed on the addition of ferrocyanate of potash to a barytic salt when the ferrocyanate is pure, yet, in a few hours, small crystals are deposited from the liquor, but these crystals consist of ferrocyanate of barytes; which proves, that the salts have, in part, at least, exchanged their principles: and this, as Guyton has re-

marked, is not peculiar to this earth; a similar exchange happens with the salts of other earths, as well as with those of alkalies. Dr. Henry observes, likewise, that the same crystals are formed from barytic water added to the ferrocyanate.

Ferrocyanate of potash is partly decomposed, if kept exposed to light; it should, therefore, be preserved in an opaque bottle. Examples:—

246. To three or four ounces of distilled water, impregnated with carbonic acid gas, or common Seltzer water, add a few iron filings, or iron wire, and let it stand in a corked phial for three or four days, occasionally shaking the mixture; and then filter the solution, which will be an artificial chalybeate aërated water. To one half of it, add a few drops of solution of ferrocyanate of potash: the liquid will become blue, and, some time after, a blue precipitate will be deposited, which is ferrocyanate of iron.

247. Evaporate the other half of the chalybeate aërated water, obtained in the last experiment, to one half of its bulk: a brown powder, of sub-carbonate of iron, will fall down. When the water has become cold,

filter it, and assay it again with ferrocyanate of potash, which will now produce no effect; because the excess of carbonic acid, which held the iron in solution, is volatilized, and the iron thus reduced to a sub-carbonate, is no longer soluble in the water.

248. Shake two or three ounces of distilled water with thirty or forty grains of iron filings, and five or six drops of sulphuric acid, for a few minutes: let the mixture stand for a day or two, and decant or filter it. Or dissolve a few grains of sulphate of iron in half a wine-glassful of distilled water: to one half of either of these clear solutions, add a few drops of a solution of ferrocyanate of potash, and a blue precipitate will be formed.

If the other half of the fluid be evaporated a little, and the same test be added to it, a blue precipitate will nevertheless be produced; because the iron is held in solution by a mineral or fixed acid, which cannot be volatilized by heat.

249. Put into one wine-glass, half filled with distilled water, a few grains of ferrocyanate of potash, and in another glass, containing a like quantity of distilled water, dissolve a grain of green sulphate of iron: pour

the solutions together, when the salts are dissolved, and *a whitish* precipitate will be produced, which will speedily acquire a blue colour.

250. The effect of a sympathetic ink may be obtained by means of this re-agent, namely, writing made on paper with a dilute solution of sulphate of iron, when dry, is invisible; but, by passing a feather or sponge, wetted with a solution of ferrocyanate of potash over the characters, the letters will become visible, and appear of a blue colour. The experiment may be reversed, by writing with prussiate of potash, and rendering the characters visible by solution of sulphate of iron.

251. Dissolve about one drachm of green sulphate of iron in two ounces of water; add to the solution one or two drachms of clean (*not rusty*) iron filings; boil the mixture briskly for about five minutes, and filter the fluid. Add a drop of this solution to a test-tubeful of water, and let fall into the liquor also a few drops of a solution of ferrocyanate of potash, and then cork the tube immediately: a copious *white* precipitate will fall down, which is ferrocyanate of protoxide of iron, which, exposed to air, soon becomes blue;

but, if the tube remains corked, the white colour does not deepen, nor alter, by exposure to light.

The iron in this solution is kept at a *minimum* of oxidizement, by being digested with metallic iron; it yields, therefore, a white precipitate with ferrocyanate of potash.

252. Add a few drops of nitric acid to the solution of sulphate of iron, as prepared in the last experiment, and again test it with ferrocyanate of potash: it will now produce Prussian blue*, because the iron, having received oxygen from the nitric acid, and being in the state of peroxide, yields a blue precipitate with this test.

253. Dissolve a grain of ferrocyanate of potash in half a test-tubeful of distilled water, and add to the solution a drop or two of a solution of sulphate of copper: a *brown* precipitate of ferrocyanate of copper will immediately be produced.

254. Put a grain of sulphate of zinc (white vitriol) into a test-tubeful of distilled water, and add to the solution a few drops of ferro-

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* This precipitate is called *Prussian blue,* from being originally discovered by Diesbach, a colour-manufacturer of Berlin. There has been much discrepancy of opinion amongst chemists respecting the nature of this compound, as regards the proportions of its constituents.

cyanate of potash: a gelatinous *white* precipitate will fall to the bottom, which is ferrocyanate of zinc, and which *again becomes dissolved* by the addition of solution of ammonia.

255. Add a few drops of the solution of protomuriate of tin to a test-tubeful of distilled water, and let fall into the mixture a few drops of ferrocyanate of potash: a very dense *white* gelatinous precipitate, similar to that thrown down in the last experiment, will be produced; which does *not* become re-dissolved by the addition of solution of ammonia: it is ferrocyanate of tin.

256. Let fall a few drops of the solution of nitrate of cobalt into half a wine-glassful of distilled water, and add ferrocyanate of potash to the solution: a pale *olive green* precipitate will be produced, which is ferrocyanate of cobalt.

257. Add to half a test-tubeful of distilled water two or three drops of a solution of muriate of bismuth, previously mixed with a little muriatic acid, to prevent the muriate of bismuth from being decomposed by the water, and drop into the mixture ferrocyanate of potash: a *sulphur yellow* precipitate, of ferrocyanate of bismuth, will be produced.

258. Let three test-tubes be half filled with distilled water; put into the first a drop or two of muriate of platinum; into the second, put a like quantity of muriate of gold; and into the third, a solution of tartrate of potash and antimony. If to either of these solutions ferrocyanate of potash be added, no change will take place, because the metals which form the bases of these salts, are some of those which are not precipitable by this re-agent.

259. Arrange three separate wine-glasses, half filled with distilled water: pour a few drops of a solution of sulphate of magnesia into the first glass, add muriate of lime to the second, and a solution of alum to the third glass. If ferrocyanate of potash be added to these solutions, no change will take place, because the earths contained in these salts are not precipitable by ferrocyanate of potash.

XLIV. *Ferrocyanate of Ammonia.*

260. This re-agent is of use only in the analysis of saline substances. It may happen, for example, that a fluid contains neutral salts with alkaline bases, together with metallic

salts. In this case ferrocyanate of potash cannot be well applied to separate the metallic salts, because it then would be difficult to ascertain whether the alkaline salts were originally present in the solution or not; but if ferrocyanate of ammonia be employed, no ambiguity can result; for the metallic salts need only be precipitated by this test, and the earths by bicarbonate of ammonia, in a temperature of 180°, or upwards, in order to ensure the decomposition of magnesian salts, which this carbonate does not effect in the cold. The liquor may then be separated by filtration, and boiled to dryness, and the dry mass exposed to such a heat as is sufficient to expel the ammoniacal salts. This application of heat will drive off, also, any excess of the ammoniacal carbonate, which might have retained in solution, either yttria, glucina, or zirconia. The alkaline salts may be separated from these earths, by boiling the mixture in water, and filtering and evaporating it. The salts, with bases of fixed alkalies, will remain unvolatilized. By this process, indeed, it will be impossible to ascertain whether ammoniacal salts were originally present; but this may be easily learned, by adding to the salt under examination, before its solution in water, potash; which, if ammonia be contained in the salt, will produce the peculiar smell of that alkali. (See Note G.)

XLV. *Cyanuret of Mercury*[*].

261. This combination of cyanogen with mercury is a delicate test for palladium, which it separates in the form of a yellowish-white precipitate, *cyanuret of palladium*, from all its solutions;—the solution of palladium should be neutral. The precipitate thus formed has the property of detonating when heated. The noise is similar to that occasioned by firing an equal quantity of gunpowder, and, accordingly, the explosion is attended with no marks of violence, unless occasioned by close confinement. The heat requisite for the purpose is barely sufficient to melt bismuth, and the light produced is feeble, and can be seen only in the absence of all other light. By means of this re-agent, Dr. Wollaston has

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[*] This compound was formerly called *Prussiate of Mercury*, from the belief that it consisted of prussic acid and mercury: it is, however, composed of one atom of mercury, and two atoms of cyanogen, and the above name is, therefore, more consistent with its composition. It dissolves in hot and cold water without change.

pointed out a method of obtaining palladium with facility from the ore of platinum. The process is as follows:—Let any quantity of platinum of commerce be dissolved in a sufficient quantity of nitro-muriatic acid, and free the solution as much as possible from its excess of acid (if it contains any) by evaporation, or by the addition of an alkali; this being done, mingle the solution with cyanuret of mercury until no farther cloudiness ensues, taking care to leave the mixture to stand for some minutes. The yellowish-white precipitate which is then deposited is cyanuret of palladium. To obtain the palladium in a pure state, let the precipitate be heated to redness, and palladium will be obtained in a state of purity amounting to about four or five-tenths per cent. upon the quantity of the ore of platinum employed. It is no matter whether the solution of the ore of platinum has been rendered neutral by evaporation of the redundant acid, or saturated by the admixture of potash, soda, ammonia, lime, magnesia, mercury, copper, or iron; or whether the platinum has or has not been precipitated from the solution by muriate of ammonia. The cyanuret of mercury acts equally well in either case ; for cyanuret of mercury Dr. Wollaston found peculiarly adapted to precipitate palladium, exclusively of all other metals, on account of the great affinity of mercury for cyanogen, which in this case prevents the precipitation of iron or copper.

"*The decomposition of muriate of palla-*
"*dium by prussiate of mercury*," Dr. Wollaston observes, "*is not effected solely by the*
"*superior affinity of mercury for muriatic*
"*acid, but is assisted also by the greater affi-*
"*nity of prussic acid for palladium ; for he*
"*observed that* prussiate of palladium *may be*
"*formed by boiling* oxide of palladium *in a*
"*solution of* prussiate of mercury*."

XLVI. *Barytic Water*

262. Is a very effectual test for detecting the presence of free or combined carbonic acid, with which it forms a precipitate, which is soluble with effervescence in dilute nitric or muriatic acid. It is also a most sensible test of sulphuric acid and all its combinations, which it indicates by a precipitate which is

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* In retaining this passage from the last edition of this work, the editor thought it better to let it stand in the Doctor's own words. See note, page 170.

not soluble in water, nor in dilute muriatic or nitric acid.

263. Barytic water may likewise be employed for separating strontia from barytes: this operation is founded on the stronger affinity of barytes, than of the former earth, for acids. Hence, if barytes and strontia be present in the same solution, barytic water may be added, till no further precipitate falls down: the barytes seizes the acid, and the strontia becomes precipitated. The solution of strontia should have no excess of acid, which would prevent the action of the barytic earth. Examples:—

264. Drop barytic water into water impregnated with carbonic acid gas: a copious white precipitate, which is carbonate of barytes, will fall down. Add nitric or muriatic acid to the mixture, and the precipitate will become re-dissolved.

265. Blow the air, respired from the lungs, through barytic water, by means of a quill or glass tube; a white precipitate of carbonate of barytes will fall down, originating from the carbonic acid gas contained in the respired air.

266. Pour some barytic water from one glass vessel into another, repeatedly: it will

speedily become turbid, and a white precipitate will fall down. This shews that carbonic acid gas is contained in the atmosphere, which, combining with the dissolved barytes, forms carbonate of barytes. Hence also, if barytic water be left exposed to the atmosphere, it will soon be covered with a thin white pellicle, which, when broken, will fall to the bottom of the vessel, and be succeeded by another: and this may be continued till the whole of the barytes is separated from the water. The action of barytic water, therefore, resembles that of lime water, as respects carbonic acid.

267. Let fall a single drop of sulphuric acid into a tumbler of distilled water: no alteration will follow; but if a little barytic water be added, a white precipitate of sulphate of barytes will immediately be produced, which is not soluble in any dilute acid.

268. Drop barytic water into a decanter of common spring or pump-water: an immediate cloudiness will ensue, and a white precipitate will gradually fall down, which likewise does not disappear again by the admixture of dilute muriatic or nitric acid; because spring or well-water always contains a minute

quantity of sulphate of lime, or other salts containing sulphuric acid; and this acid joins the barytes, and produces the white insoluble precipitate, or sulphate of barytes.

269. To a solution of a few grains of carbonate of potash, or of soda, in half a wine-glassful of distilled water, add barytic water, which will immediately produce a turbidness; because the barytes separates the carbonic acid from the carbonated alkali, and falls down with it in the state of carbonate of barytes. By adding a sufficient quantity of the solution of barytes, the whole of the carbonic acid may thus be taken away from a carbonated alkali, and the alkali remains perfectly pure, or, at least, free from carbonic and sulphuric acid, the latter being sometimes present.

270. This re-agent may also be employed for purifying rain-water, so as to render it fit for chemical researches. Rain-water, collected from the roofs of houses, (not the first water which is directly received from the gutters at the commencement of a shower, but that which descends after the rain has sufficiently washed the surface of the tiles,) contains seldom any other impurities than a minute portion of sulphate of lime, and a

small quantity of earthy matter mechanically suspended. The latter may be removed by immediate filtration, and the former by carefully adding to it barytic water. This will remove the sulphuric acid, and fall down with it as an insoluble precipitate; the lime, which remains partly dissolved, afterwards likewise falls down by absorbing carbonic acid gas from the atmosphere, or it may be precipitated by adding to the water a portion of water impregnated with carbonic acid gas, which will also destroy any excess of barytic water, if part should have been added in excess. In this manner, the water necessary for chemical experiments may be economically supplied without much trouble, and almost at no expense.

The best way, however, of *collecting* rain-water, for chemical purposes, is by exposing large clean shallow dishes to the atmosphere during a heavy fall of rain: these should be placed in such a manner, that the rain falling on the outside of the dishes cannot wash in any earthy matter by splashing.

271. Barytic water soon spoils by the frequent opening of the bottle containing it: but it may be readily prepared, by dissolving

a small quantity of barytic earth, or hydrate of barytes, in distilled water.

XLVII. *Muriate of Barytes.*

272. This salt is extremely well adapted for discovering the presence of sulphuric acid, either when in a disengaged state, or when combined with other substances in solution. It produces with sulphuric acid (like barytic water) a white precipitate, which requires for its solution 43,000 times its weight of water, and which is also perfectly insoluble in all acids, except the most concentrated; hence, the precipitate obtained by this test, may be collected, washed, and dried, with the greatest facility, and without risk of loss: it is free from smell and taste, and undergoes no change by being heated red-hot, except the loss of water which it may contain. In a very strong fire, or before the blowpipe flame, it melts into an opaque milky globule. From the quantity of the precipitate produced by this re-agent, we may learn the quantity of sulphuric acid which the test has separated from the solution; for 100 parts of the precipitate, after being calcined, contain two-thirds

of barytes, and one-third of acid, very nearly, or, according to

	Barytes.		Acid.
Klaproth	66.55	+	33.45
Mr. A. Aikin	66.04	+	33.96
Mr. J. Thomson	66.96	+	33.04
Berthollet	66.50	+	33.50
Berzelius	65.69	+	34.31

which corresponds with its theoretical composition, viz. 1 atom of acid + 1 atom of base.

273. This test, which forms one of the most important instruments in analysis, is also decomposed like barytic water by carbonated alkalies; but the precipitate is then soluble in dilute muriatic or nitric acid; and may be prevented, by adding to the solution to be assayed, a few drops of muriatic acid. Or, if any excess of carbonated alkali has produced a precipitate of carbonate and sulphate of barytes, the two precipitates may easily be separated by mere digestion in dilute muriatic acid, which removes the carbonate of barytes, but does not touch the sulphate.

274. Concentrated nitric acid also decomposes a concentrated solution of muriate of barytes: the precipitate is *not* crystallized nitrate of barytes, and owing to the more

sparing solubility of the nitrate than of the muriate of barytes in water, as has been supposed by some chemists; but the concentrated nitric acid attracting water from the solution of muriate of barytes occasions it to crystallize. In this case, the precipitate is soluble in water, by which it may be easily distinguished from sulphate and carbonate of barytes. This supposed decomposition of muriate of barytes was first noticed by Mr. Hume. It may serve to guard the young chemist against drawing false conclusions, particularly with regard to the examination of the purity of nitric acid, when examined by means of this test. Examples:—

275. Fill two test-tubes with distilled water, and let fall into one of them a drop of sulphuric acid, and into the other a few drops of solution of muriate of barytes: no change will take place in either of them; but if only a little of the fluid containing the muriate of barytes be poured into the liquid containing the sulphuric acid, a copious white precipitate of sulphate of barytes will take place, which will not become re-dissolved by the admixture of dilute muriatic or nitric acid.

276. Put a grain of sulphate of soda (Glau-

ber's salt) into half a wine-glassful of distilled water, and when dissolved, add to the solution a few drops of solution of muriate of barytes: the same appearance will be perceived as in the last experiment. A like effect will take place if the liquid holds alum, Epsom salt, white vitriol, or any other sulphate, in solution.

277. Dissolve a few grains of carbonate of potash in a wine-glassful of distilled water, and pour half the solution into another glass. Drop into one of the glasses a little muriate of barytes: a white precipitate will fall down, which is carbonate of barytes: it again disappears by the admixture of pure dilute muriatic or nitric acid. Drop into the other glass pure nitric or muriatic acid, in sufficient quantity to saturate the potash of the carbonate which it contains, and then add to the mixture also muriate of barytes, which now will produce a precipitate, which is perfectly insoluble in muriatic or nitric acid; because the free alkali being neutralized by the nitric acid, the precipitate produced by the test can only be occasioned by the presence of sulphuric acid. This is accounted for by the carbonate of potash (or, as it is called, *subcarbo-*

nate of potash, or *salt of tartar*) containing sulphate of potash.

XLVIII. *Acetate of Barytes.*

278. This salt of barytes, the action of which, as a test, is similar to the preceding re-agent, is particularly well adapted for ascertaining the presence of sulphuric acid, when contained in vinegar, and in sulphurous acid. And although it may produce a white precipitate with genuine vinegar, on account of the malic, citric, or tartaric acid, which that fluid may contain, either in a free state, or combined with an alkaline base, yet the precipitate then produced may be distinguished from the precipitate produced by sulphuric acid by merely exposing it to heat, in order to destroy the vegetable acid, so as to convert it into a carbonated alkali. This being done, the residue will dissolve and effervesce with dilute acids. Whereas the precipitate produced by sulphuric acid, when similarly treated, remains virtually insoluble in dilute acids. This test may likewise be employed with advantage for readily ascertaining both the nature and quantity of alkalies

and alkaline sulphates in fluids, when no other sulphates are present, in the manner to be stated presently. Examples :—

279. Add to vinegar a few drops of acetate of barytes : a copious white precipitate will fall down : collect this precipitate, dry it, and expose it to the heat of the blowpipe flame, on a slip of platinum foil, till all the carbonaceous matter is burnt away, and the product has assumed a white or grey colour. Transfer the mass, which is chiefly carbonate of potash, into a test-tube, and pour upon it dilute muriatic or nitric acid, which will instantly dissolve it with effervescence, which therefore shews, that the vinegar was free from sulphuric acid.

Repeat the same experiment with a portion of vinegar, to which a drop of sulphuric acid has been added. The precipitate obtained in this case, which is sulphate of barytes, after having been treated in the same manner with the blowpipe flame, will not be soluble in any dilute acid.

280. Dissolve a little sulphate of soda, or sulphate of potash, in distilled water, and pour into the solution acetate of barytes : a precipitate will take place, which is sulphate of

barytes: decant the supernatant fluid, evaporate it to dryness, and digest the residuum in alcohol: it will dissolve. Evaporate the solution to dryness again, and the dry salt will deliquesce, if it be acetate of potash, but effloresce, if it be acetate of soda. The two alkalies, potash and soda, may thus be distinguished, as well as by *muriate of platinum* and *tartaric acid*, as already mentioned.

XLIX. *Nitrate of Barytes.*

281. This is another salt of barytes, which acts, in every respect, like the combination of barytes with muriatic acid. Instances, however, frequently occur in analytical operations, where the introduction of muriatic acid into the compound would render the analysis embarassing, and in such cases nitrate of barytes is employed more successfully.

L. *Muriate of Alumina.*

282. This test has been recommended by Mr. Kirwan, as indicative of carbonate of magnesia, when present in mineral waters, and which cannot, like carbonate of lime, be totally separated by ebullition, but remains till the whole liquid is evaporated. By adding muriate of alumina to the boiled water, a precipitate of carbonate of alumina is thrown down, if carbonate of magnesia be present; but not otherwise, unless there be an excess of alkali, which may easily be neutralized by an acid.

LI. *Succinate of Soda and Succinate of Ammonia.*

283. These tests are useful re-agents for detecting iron, and for readily ascertaining its quantity, when in a solution; the iron, however, must be in the highest state of oxidation, as the succinates do not act on salts which contain protoxide of iron; and, in applying these tests, it is necessary not to use more than is exactly sufficient for the purpose, because an excess is liable to re-act on

the precipitate. They produce, with the peroxide of iron, a brown precipitate. They are very useful to separate oxide of iron from oxide of manganese.

284. The succinates, however, precipitate also alumina, provided there be no considerable excess of acid in the aluminous solution. Mr. Ekeberg states that succinate of ammonia precipitates glucina, and Klaproth observes that it throws down zirconia. Examples :—

285. Put a few grains of green sulphate of iron into a test-tube; pour upon it five or six drops of nitric acid, and heat the mixture strongly over a lamp till a dry red mass is obtained. Dissolve this mass in distilled water, and having filtered it, drop into it succinate of ammonia, or succinate of soda: the iron contained in the sulphate of iron having become highly oxigenated by the action of the nitric acid, a brown flocculent precipitate, succinate of iron, will be obtained. This precipitate, when heated, first by itself, and afterwards with a little wax, at a low red heat, gives oxide of iron containing 77·77 per cent. of metal. The first heating decomposes the succinic acid, and the second reduces the metal to the state of protoxide.

LII. *Solution of Starch.*

286. A solution of starch in water has of late received a place among the list of chemical re-agents, as a test for detecting iodine. Its action as such was first made known by Professor Stromeyer, of Gottingen. If a solution of starch be added to a liquid containing a very minute quantity of iodine in an uncombined state, it produces with it an indigo-blue colour, and a precipitate, *ioduret of starch*, of the same hue, is slowly thrown down. The delicacy of this test is astonishingly great. It will indicate, according to Stromeyer, $\frac{1}{450000}$ part of iodine in a liquid. Hence iodine and starch are tests for each other, and have been successfully employed as such by M. de Claubray, who detected, by means of starch, not only the presence of iodine in the decoctions of the *fucus saccharinus,* but also its state of existence, or the manner in which this singular substance is combined, in the body of the several varieties of sea-plants which have furnished it. The blue colour produced by the contact of iodine and dissolved starch varies, according as

either the one or the other of the substances predominates. When the two bodies are in due proportion, the colour is a pure intense indigo-blue; but it is black when iodine prevails, and of a reddish blue or violet colour when starch is in excess.

287. When iodine is not present in the fluid, in a free or uncombined state, it is necessary to add to the solution a very minute portion of any acid, in order to disengage the iodine from its combination. Hence, if a solution of starch be dropped into a fluid containing hydriodic acid, or iodic acid, no change takes place; but if an acid be added, so as to disengage the iodine, the starch then instantly shews the presence of this substance by the indigo-blue colour which it assumes.

288. The compound of starch and iodine, or ioduret of starch, is soluble in dilute sulphuric acid, and the liquor is of a fine blue colour; and with concentrated sulphuric acid, a brown compound is obtained, which becomes also blue when diluted with water. The solution of starch should always be added quite cold.

LIII. *Sulphate of Soda, or Sulphate of Potash.*

289. Sulphate of soda, or sulphate of potash, may be employed for detecting the presence of lead, by virtue of one of the constituent parts of these salts, namely, the sulphuric acid, combining with the oxide of lead, and forming with it a white precipitate, *sulphate of lead*, which is insoluble in water and in liquid ammonia, but soluble in dilute nitric acid, when assisted by heat; and which becomes blackened by water impregnated with sulphuretted hydrogen gas. These characters are sufficient to distinguish it, at once, from sulphate of barytes, with which it might otherwise be confounded; because, from what has been stated, this test must also produce a white precipitate with all the salts of barytes and of strontia. Sulphate of soda, or sulphate of potash, is chiefly of use in such cases where sulphuric acid, in an uncombined state, cannot be well applied, as is often the case in the analysis of mineral waters. Dr. T. Thomson considers this test "as the most unequivocal re-agent of lead which we possess;" for by means of it he was enabled

to detect in water the *one-millionth* part of its weight of lead. It may be employed for detecting lead in wines. Example :—

290. Let fall into a test-tubeful of distilled water a drop of solution of acetate of lead, and add to the mixture a few drops of a solution of sulphate of soda, or sulphate of potash : a dense white precipitate will fall down, which is sulphate of lead. Decant the supernatant fluid, pour upon the precipitate dilute nitric acid, and apply a gentle heat : the precipitate will again become re-dissolved. If water, impregnated with sulphuretted hydrogen gas, be added to it it will, become instantly blackened.

LIV. *Carbonate of Ammonia*

291. Is made use of, in combination with phosphate of soda, for detecting and separating magnesia from other earths, when combined with them in solutions*. It is also employed for separating yttria, glucina, and zirconia, from other earths, for they are soluble in a solution of this salt. Copper is detected by this re-agent, by its imparting to the fluid

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* See *Phosphate of Soda*, and *Note*, p. 91.

containing that metal a blue colour, and, like the rest of the carbonated alkalies, it precipitates the solutions of most earthy and all metallic salts; and from the colour of this precipitate, the experienced operator may, in some cases, form a notion of the nature of the precipitate obtained by means of this test.

LV. *Fluate of Ammonia.*

292. This salt has been recommended as a test for lime, with which it produces a white precipitate, *fluate of lime.* But it is not discriminative, because it affects also the salts with a base of magnesia, yttria, glucina, and perhaps alumina: its action upon the whole is much inferior to oxalate of ammonia.

LVI. *Alcohol.*

293. Highly rectified alcohol is of particular use in the analysis of mineral waters. When added to a liquid in large quantities, it precipitates such saline bodies as are soluble in water, and insoluble in alcohol. It is essential, however, that the saline fluid should be as concentrated as possible, and the quan-

tity of alcohol added, should be, at least, double that of the bulk of the fluid on which it is intended to act. Thus sulphate of lime may be precipitated by alcohol from water which contains this salt in the proportion of $\frac{1}{1000}$, provided the specific gravity of the alcohol is below .850; and alkaline sulphates may be precipitated, if the spirit is of a specific gravity, equal to .817. Besides, as alcohol dissolves some of the substances often found in mineral waters, and does not touch others, it enables us to separate these into two classes. Alcohol is also employed for detecting the adulterations of essential oils. Examples:—

294. Dissolve thirty or forty grains of sulphate of magnesia in $\frac{1}{4}$ or $\frac{1}{2}$ oz. of distilled water; put the solution into a test-tube, and add to it two or three times its bulk of alcohol; the mixture will become turbid, and, by degrees, minute crystals of sulphate of magnesia will be deposited at the bottom of the glass. If, instead of sulphate of magnesia, sulphate of soda, sulphate of potash, nitrate of potash, or alum, be employed, the same effect will take place.

295. Mix about five grains of acetate of potash with any quantity of sulphate of pot-

ash; put the mixture into a phial furnished with a stopper, and after pouring some alcohol upon it, set the mixture in a warm place to digest for 24 hours; decant the fluid from the insoluble residue, and evaporate it to dryness. The product will be the acetate of potash, which was added to the spirit; but the sulphate of potash will not have been touched. In a similar manner, different substances may frequently be separated from each other by the mere action of alcohol.

296. Thus the greater number of mineral waters contain some earthy salts, with a fixed acid, which remains in combination after boiling down the water to dryness, and which acid is seldom any other than the sulphuric or muriatic; and the earths, with which the acid is combined, are in general either lime or magnesia. Therefore, only four earthy salts may be expected (not all together, for they would decompose each other), namely, sulphate of lime, muriate of lime, sulphate of magnesia, and muriate of magnesia. Now, of these salts, the sulphates are perfectly insoluble in alcohol, but the muriates are extremely soluble. This, therefore, affords a very convenient way of separating some of

the salts. For this purpose, if we put the dry residue of the water in a phial, and pour on it about five or six parts of alcohol, and let the mixture remain for some hours with frequent agitation, the alcoholic solution can contain only the muriates of lime and magnesia, provided the alcohol has been highly rectified; if not, it will also dissolve a little muriate of soda, if present. The residue, which is not dissolved by the alcohol, may contain the sulphates of lime and magnesia, of which salts the latter is easily soluble in water, but the former with great difficulty, unless assisted by an acid.

297. As many of the volatile or essential oils* are produced only in small quantities,

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* Essential oils, for the most part, are obtained by distilling the part of the plant which affords them with water, from which they separate, either by floating at the top, or sinking to the bottom of it, according to their specific gravity, some being lighter, and some few heavier, than that fluid. Others, such as those of lemon, orange, bergamotte, are obtained by expression. If a piece of lemon or orange peel be pressed between the finger and thumb before the flame of a candle, the essential oil will be forced out, and will take fire.

" There are some essential oils, which are of so delicate a nature as to be impaired or decomposed even by the most careful distillation, such as those which confer odour upon the flowers of jasmine, and of the tuberose. These are only valued as perfumes, and are procured for that purpose by steeping they are consequently high priced, and there is some temptation to adulterate them with fixed oils, to increase the quantity. It is, therefore, of considerable importance to be able to detect such frauds, which may be done in the following manner:—Mix a few drops of oil of almonds, or of olives, with any essential oil, for instance, with oil of lavender, and pour alcohol upon it; the oil of lavender will dissolve in the spirit, and the oil of almonds remains behind undissolved. Decant the alcoholic solution from the oil of almonds, and add distilled water to the former; the water will unite with the alcohol, and by this means the essential oil of lavender will be separated.

298. An additional examination may be the following:—Let a single drop of the oil which is suspected fall on clear paper, and expose it to a gentle heat. If the oil be pure, the whole will be evaporated, and no trace or spot will remain on the paper; but if it has been mixed

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the flowers in some perfectly pure and inodorous fixed oil, which abstracts the odorous principle of the flower, and from which it may be transferred by digesting the oil thus impregnated in alcohol, so as to form a spirituous essence. The same perfumes cannot be obtained either by steeping the flowers in alcohol, or by distilling them either with it or with water."—*Brande's Pharmacy.*

with a fixed oil, a greasy spot will remain behind.

299. When essential or volatile oils are adulterated with alcohol, the fraud is easily detected by mixing a little of the oil with water, which immediately produces a milkiness, by the abstraction of the alcohol from the oil, and its combination with the water. Volatile oils are frequently adulterated with oil of turpentine; but this can only be detected by the peculiar odour of oil of turpentine, which continues for a longer time than the odour of the other volatile oils.

LVII. *Solution of Soap.*

300. A solution of soap in alcohol is of some use, as a test, for ascertaining what is vulgarly called the *hardness* of water; because, when added to pure water, it produces no change, but when dropped into water loaded with earthy or metallic salts, it occasions a milkiness, and a flocculent precipitate is formed. And from the degree of milkiness, and the quantity of the precipitate produced, some notion may be formed of the quality of the water, at least so far as regards its fitness

for the purposes of washing, dyeing, bleaching, boiling ileguminous and cereal seeds, and other purposes of the culinary art and domestic economy, for which water as pure as possible ought to be employed. Examples :—

301. Into a test tube, half filled with distilled water, pour a few drops of a solution of soap in spirit of wine, and no alteration will be produced.

To a like quantity of common pump or spring water add a few drops of solution of soap : a milkiness will instantly ensue, and a flaky precipitate will be deposited if the mixture be left undisturbed for some hours. The milkiness is owing to the presence of earthy salts, which, in pump water, are usually sulphate and carbonate of lime : the alkali of the soap leaves the oil, with which it was chemically combined, and unites with the acid of the earthy salts, which are present in the water, and the oil joins the earth, and produces with it an insoluble precipitate, or earthy soap.

The action of this test is therefore not discriminative, and it can serve only to indicate the presence or absence of those kinds of substances which occasion that quality in water which is usually called *hardness*, and which is chiefly owing to salts with an earthy or metallic base.

302. Having impregnated a small quantity of distilled water with carbonic acid gas, dissolve in it a few grains of white marble or magnesia; and after the liquid is poured off clear from the insoluble residue, add to it a few drops of the solution of soap, and in a like manner a white curdy precipitate will be produced.

303. Dissolve a few grains of sulphate of magnesia, or chloride of calcium, or alum, in half a wine-glassful of distilled water, and add to the mixture a few drops of the solution of soap: the fluid will become milky, and will deposit a white flocculent precipitate.

The same effect will be produced with any other earthy or metallic salt.

304. Mix a drop of a solution of sulphate of iron, or any other metallic salt, with half a wine-glassful of distilled water; and add to it a few drops of a solution of soap: this will, in a like manner, become turbid, and a great number of flakes will be deposited.

LVIII. *Zinc.*

305. Metallic zinc is chiefly employed as a re-agent for separating copper, lead, tin, silver, and tellurium, in a metallic state, from their solutions in acids. It also precipitates lead, tin, copper, and tungsten, from their alkaline solutions; but it is seldom employed for that purpose, because we have better means of effecting the decomposition of these solutions, through the medium of acids. When zinc, or in fact any metal, is employed to separate another metal, in a metallic form, from its solution in an acid, it is essential that the fluid should have a very slight excess of free acid; for otherwise, a portion of the metal is thrown down either in the state of an oxide or as an alloy. Examples :—

306. Add to a wine-glassful of distilled water a small quantity of the solution of acetate of lead, mixed with a few drops of acetic or nitric acid, and immerse in the fluid a slip or piece of zinc: the lead, contained in the solution, will immediately become precipitated upon the zinc, forming a metallic and moss-like appearance, of a dark bluish-grey colour.

The precipitate of lead, which has been long known by the name of the *lead tree*, may be here mentioned. It is accomplished in the following manner:—Into a quart decanter, nearly filled with soft or rain water, put ¾ oz. of acetate of lead (sugar of lead of commerce), reduced to powder, shake the mixture, and suffer it to stand undisturbed for two or three days; then decant the clear fluid from the insoluble residue, if any; reject the latter, and after having rinced the decanter with water, return into it the clear solution. If now a ball of zinc be suspended in the middle of the fluid, by tying it to a thread affixed to the stopper of the bottle, and the vessel be then set in a place where it cannot be disturbed, the zinc soon becomes covered with a moss-like substance of metallic lead, which increases gradually, and shoots out brilliant crystalline plates of metallic lead, which place themselves in a kind of symmetrical arrangement somewhat resembling a tree or shrub.

The zinc has a greater affinity than lead for oxygen; it deprives the oxide of lead of it, which, being thus reduced to the metallic state, can no longer remain in combination with the acetic acid, but becomes precipitated upon the zinc. The theory of voltaic electricity has of late shewn, that this phenomenon, like all other metallic precipitations, is the result of a voltaic action, produced between the bodies brought in contact; namely, when the precipitation of the metallic lead takes place on the surface of the zinc, voltaic electricity is evolved, in consequence of an easily oxidizable metal coming in contact, together with a fluid, with another metal, which is with more difficulty oxidizable. A galvanic circle being thus formed, part of the water of the interposed fluid becomes decomposed, one of its constituent parts, namely, the oxygen, becomes attracted by the metal positively electrified (the zinc), whilst its other constituent part, the hydrogen, is attracted by the metal, negatively electrified (the lead); it there acts in producing the further reduction, by abstracting oxygen from the metallic oxide, dissolved in the acid, and the particles of the reduced metal are gradually deposited at that extremity; and the accretion of the metallic crystals taking place, from the metallic filaments already formed, spread out and arrange themselves somewhat like a shrub or tree.

The theory of the reduction of other metallic precipitates from their solutions, is precisely analogous to this statement.

307. Immerse a bar, or a slip, of laminated zinc in a dilute solution of sulphate of copper, having an excess of acid: a precipitation of metallic copper will immediately take place, and the zinc will become incrusted with a coat of copper. The copper may readily be detached from the zinc: it is advisable to digest it in muriatic acid, which will dissolve any zinc, if part of it should happen to adhere to the copper; and besides, unless there be a considerable excess of acid in the solution, a portion of the copper is always precipitated as an oxide, and which is thus completely removed by the muriatic acid.

308. Add to half a wine-glassful of distilled water eight or ten grains of protomuriate of tin, and immerse in this fluid a slip of zinc: the tin will immediately become precipitated in a metallic state, surrounding the zinc in the form of a spangled moss-like coating.

309. Mr. Sylvester has recommended a galvanic circle, formed of zinc and gold, as an active agent for detecting corrosive sublimate, if applied in the following manner:—

Let a piece of zinc wire*, about three inches long, be twice bent at right angles, so as to resemble the Greek letter Π, so that the two legs of this figure be distant about the diameter of a common gold wedding-ring from each other, and let the two ends of the bent wire be afterwards tied to a ring of this description; then take a plate of glass, not less than three inches square, lay it as nearly horizontal as possible, and on one side drop some sulphuric acid, diluted with about six times its weight of water, till it spreads to the size of a halfpenny. At a little distance from this, towards the other side, drop some of the solution supposed to contain corrosive sublimate, till the edges of the two liquids join together, and let the wire and ring, arranged as above stated, be placed in such a way, that the wire may touch the acid while the gold ring is in contact with the suspected liquid. If the minutest quantity of corrosive sublimate be present in the fluid, the ring in a few minutes will then become covered with metallic mercury on the part which touches the liquid. In this manner, the minutest

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* Iron wire will do as well.

quantity of mercury may be discovered, when present in any liquid.

This test for discovering the presence of mercury has been varied by Dr. Paris, in the following manner, which is more simple: —Place a drop of any liquid supposed to contain corrosive sublimate on a piece of polished gold, and touch it with a slip of zinc, a piece of iron wire, or the point of a penknife, so as to form a galvanic circle, and if mercury be present in the liquid, the part where the zinc or iron wire touches the gold, will be *white*, in consequence of an amalgam of gold and mercury being formed.

LIX. *Iron.*

310. Polished iron wires, bars, or plates, are useful re-agents for precipitating copper, in a metallic state, from its solution in acids. Iron likewise precipitates antimony and tellurium in a metallic form from acid solutions. Example:—

311. Immerse the blade of a knife, a key, or any other piece of polished iron or steel, for a few seconds, in a solution of sulphate of copper, having a slight excess of sulphuric acid: the knife when withdrawn will be co-

vered with a case of metallic copper. To obtain the copper in a pure state, the precipitated metal ought to be digested in dilute muriatic acid.

LX. *Tin.*

312. This metal is useful as a test for detecting the presence of gold, with the solutions of which it produces a purple-coloured precipitate. If a slip or bar of tin, or a piece of tinfoil, be immersed in a solution of muriate of gold, the surface of the tin becomes immediately covered with a deep purple-coloured powder, which becomes gradually diffused through the whole fluid, and imparts to it the colour of red wine. The powder thus produced speedily subsides, and leaves the solution of gold colourless. This powder is similar to the precipitate produced by protomuriate of tin and muriate of gold.— (See Nos. 193 and 222.) Examples :—

313. Add to half a test-tubeful of distilled water a few drops of muriate of gold, and immerse in it a piece of tinfoil: in a short time a violet or purple-coloured precipitate will fall down, which, according to Proust, is a com-

pound of one part of oxide of gold, in a very low state of oxidizement, and three parts of peroxide of tin.

LXI. *Copper*

314. Is used in analytical experiments chiefly as an agent for separating silver in a metallic state from its solutions. When a bar or rod of this metal is immersed in a solution of silver in an acid, it becomes superficially of a blackish colour, and, after a while, the silver is precipitated upon the copper in a metallic state. The whole of the silver is not, however, separated by the copper, for the solution becomes milky on adding to it a solution of common salt or muriatic acid. Still it is a very convenient way of recovering the silver immediately in the metallic state. If the solution has no considerable excess of acid, the latter portion of silver thus precipitated contains a minute portion of copper, but this may be prevented by adding to the fluid a slight excess of nitric acid, or bringing the precipitate again in contact with a solution of nitrate of silver.

This process is followed in the art of

assaying, to recover the silver which has been alloyed with gold, and which, in the operation of *parting*, has been dissolved by nitric acid; plates of copper being put into the solution, so as to precipitate the silver. It is also frequently employed to obtain silver free from other metals with which it has been alloyed. Examples :—

315. Add to half a wine-glassful of distilled water five or ten drops of the solution of nitrate of silver, and immerse in it a polished bar or slip of copper, or a bright farthing. The silver will immediately be precipitated upon the surface of the copper in a brilliant metallic form.

This experiment may be pleasingly varied in the following manner :—

Spread on a plate of glass a few drops of nitrate of silver, diluted with double its quantity of distilled water; place at the bottom of it, flat upon the glass, and in contact with the fluid, a copper wire bent to any figure, and let the whole remain undisturbed in a horizontal position. In a few hours a crystallization of metallic silver will make its appearance upon the glass, next the piece of copper wire, and the arrangement of crystals will extend gradually till the whole quantity of fluid is decomposed.

LXII. *Quicksilver, and Silver Leaf.*

316. Both these metals are useful for discovering minute portions of sulphuretted hydrogen gas, or hydro sulphurets in general, particularly when contained in mineral waters, because the metallic brilliancy of these metals becomes destroyed when they are suffered to be immersed in a fluid, containing sulphur in loose combination. Example:—

317. Fill a phial with water impregnated with sulphuretted hydrogen gas, and add to it a few globules of mercury, free from dust, or a silver leaf: in a short time the metal will lose its metallic splendour; and its surface will become covered with a brown pellicle, which is a combination of sulphur with the metal.

LXIII. *Fluxes for the Blowpipe.*

318. The term flux is applied in chemistry to those substances which are added to minerals, metallic ores, or other bodies, to assist their fusion when exposed to the action of

fire. Thus potash or soda, in a pure state, or as carbonates, are fluxes for flint, and all kinds of siliceous minerals, because when flint is mixed with these bodies in a proper proportion, and heated, these alkalies cause it to melt, and the compound is a vitreous mass: boracic acid and borax are fluxes for clay and argillaceous minerals, &c. These bodies, therefore, act upon refractory substances, in the *dry way*, as water, acids, and other liquids act, which are used to dissolve solids, in the *humid way*. The manner in which each mineral is affected when it is heated with different fluxes; its fusion, more or less quick or slow, easy or difficult, complete or incomplete, liquid or pasty; the kind of mass which results from it,—opaque, transparent, vitreous, or enamelled, scorified or dense and compact; the colour which it principally affects, and which almost always depends on the nature and the proportion of the metallic matters which it contains;—these form so many useful characters employed by analytical mineralogists to discover and distinguish each species of the several compounds; and when the external characters or the sensible properties do not suffice to determine, with accuracy, the kind or species, the action of the fluxes employed with the blowpipe is frequently very useful to that determination, by removing doubts, destroying uncertainties, and explaining the general nature of the mineral.

319. It may easily be imagined that the nature of the products will greatly vary, according to that of the flux, which enters into combination with them; and, accordingly, fluxes are varied in experiments according to the object in view.

The fluxes which are used for blowpipe experiments, and in all laboratory operations in general, are chiefly compound bodies belonging to the class of salts. One of the constituent parts of these bodies frequently acts chemically: thus the alkaline or earthy part of fluxes often combines with the acid which may be attached to a metallic oxide, and which would prevent its reduction to the metallic state, if not separated; whilst others, again, act merely mechanically. And further, many of the metals will retain their oxygen so forcibly, that the application of heat is totally incapable of expelling it, when the object is to obtain the metal. The addition of inflammable matter becomes, therefore, expedient to carry off the oxygen in the form of gas. The oxide to be reduced is, therefore, mixed with a portion of inflammable matter, and is then exposed to an intense heat; and to obtain the reduced metal in a coherent mass, and not in small grains, a substance must be also present which is capable of being readily melted, and of allowing the metal to subside through it, so as to cause the particles to conglomerate and to form a collected button, instead of scattered grains, which would otherwise happen. And it would be extremely laborious to collect together the minute particles, if they were not thus enabled to descend, and permitted to unite at the bottom of the crucible. The action of fluxes are, therefore, in general, both mechanical and chemical.

320. The fluxes, which have obtained the general sanction of chemists, on account of their extensive use, are, *phosphate of soda*, *borax*, and *boracic acid;* besides these, *fluor spar*, *gypsum*, *carbonate of soda*, *nitrate of potash*, and *glass*, are occasionally employed in the blowpipe assay. These bodies are reduced to powder, and mixed up with the sub-

stances upon which they are to act. What is called *white flux* is carbonate of potash, prepared by deflagrating together equal parts of nitrate of potash and bitartrate of potash: the acids in the two salts are decomposed, and by an interchange of affinities there are produced carbonic oxide, carbonic acid, and nitrogen, which escape, while carbonate of potash remains behind. When an oxide is at the same time to be reduced, the flux, called *black flux*, is to be preferred, which is produced by the deflagration of two parts of bitartrate of potash, and one of nitrate of potash: it differs from the former only in containing a little charcoal, in consequence of the excess of the bitartrate. (See Note H.) Soap, likewise, promotes fusion in being converted by the fire into carbonate of soda and charcoal, and, therefore, also acts as a flux, and is frequently employed as such in the laboratory.

LXIV. *Blowpipe, and its Application.*

321. The blowpipe, in chemistry and mineralogy, is an instrument of the greatest utility. It enables us to expose to the action of a most violent heat any substance we may meet with,

in order to ascertain its general nature or qualities, with regard to fire: every effect of the most intense heat of furnaces may instantly be produced by this instrument; and with this advantage, that the process is expeditious, and under the inspection of the operator; whereas we can only conjecture what passes in the centre of a furnace, if the same experiment be made in the laboratory way. The most expensive materials, and the minutest quantity of bodies, may be used, and the whole process, instead of being carried on in an opaque vessel, may instantly be varied under the eye of the observer, and may be seen from beginning to end. Indeed, many advantages may thus be derived from the use of this simple and valuable instrument. Its smallness, which renders it suitable to the pocket, is no inconsiderable recommendation to the travelling mineralogist. It is true, that very little can be determined in these miniature assays concerning the actual quantity of products; but in most cases, a knowledge of the constituents of any mineral substance is a great acquisition, which is thus obtained in a very short time, although the actual quantities of the products discovered are too minute to enable the operator to ascertain their relative proportions.

Thus, for example, if we meet with a species of clay, and wish to know whether it be fit or not for the purpose of making porcelain, the blowpipe assay will decide the question; because, for the purpose of making the finer kinds of pottery and porcelain, it is essential to have a clay, which, *after burning*, remains perfectly white. The appearance of these substances, before burning, can never be depended on, for, though often the whitest clays, before burning, are those which remain white afterwards, it is only in a few districts where clays are found that remain absolutely white: and many white clays are to be found, which, when burnt, become more or less coloured; and, again, many black clays burn perfectly white. The nature of *limestone* may readily be discriminated by means of this instrument. Lime-stone, fit for making mortar and cement, does not melt by itself, but becomes more or less white after being violently heated by the blowpipe flame, and, if suffered to cool, and then mixed with water, becomes hot. This proof is best made by putting the minute portion of the assayed stone on the outside of the hand, and letting a drop of water fall upon it, when a quick heat will be felt on the skin. Siliceous stones never melt alone, but form a glass with borax and soda; argillaceous stones, when pure, do not melt, but become white, and acquire a flinty hardness. Fluor spar becomes phosphorescent, and melts into an opaque white slag; zeolites melt easily, and foam in the flame. From the colour which the substances, called fluxes, acquire, much useful information may be drawn concerning the nature of the mineral under examination. Thus, for example, gold imparts to borax, and phosphate of soda, and boracic acid, a ruby colour; silver tinges these fluxes orange-yellow; copper produces, with the same fluxes, a bluish-green pearl; iron tinges them green, of different intensities and hues; tin produces a white or greyish-white opaque enamel; antimony affords a hyacinth-coloured glass, and flies off partly in white fumes, and a white powder, or oxide of antimony, is deposited on the surface held near the fixed substance. Arsenic, likewise, diffuses white fumes when heated on charcoal, and produces a garlic-like odour; cobalt stains a large quantity of borax intensely blue, and forms with it a blue glass. Oxide of manganese yields with the inner point, or the blue flame, a violet-coloured bead, which, with the interior part of the flame, becomes again colourless, and which may be made alternately to disappear and re-appear at pleasure. These successive changes of colour, which are peculiar to the oxide of manganese, may be shewn in the following manner :—

Melt a small quantity of phosphate of soda, or glass of borax, with the blowpipe flame, upon a piece of charcoal, and add to it a very small portion of black oxide of manganese; melt the mixture together by the inner blue flame: the globule will assume a violet or purple colour. Then fuse it again, and keep it in a melted state for a longer time, the result of which will be, that the violet colour again vanishes. This being effected, melt the colourless globule by the exterior flame of the blowpipe, and the purple colour will re-appear, but becomes, as before, again destroyed by a longer continuance of the heat. The smallest particle of nitre, laid upon the globule, also immediately restores the red colour. If the globule, when colourless, be now melted in a silver spoon, or on an iron plate, or on any metallic support, instead of being on the charcoal, the violet colour returns, and will not be again removed by any continuance of heat, so long as it remains on the metallic support.

322. Some minerals, when exposed to the blowpipe dart, are perfectly infusible by it, others melt with facility; some are partly volatilized, others burn with a flame of a peculiar colour; in some the colour is changed at different temperatures, as in the oxide of manganese; some fuse with intumescence, others decrepitate or exfoliate when urged by the flame, or lose their colour; in some the fusion is partial; sometimes the result is a kind of ashes or powder; in many cases it is a complete vitreous globule, transparent, or opaque, or of various colours; some afford a mere scoria or cinder, others produce an enamel, and some give a mere *frit*. All these gradations of phenomena are so many means of discovering and of estimating the differences, particularly of earthy minerals, and they contribute also to the

knowledge and the determination of the particular species of the individual which affords them.

323. It requires a little art to keep up an uninterrupted blast of the blowpipe with the mouth, which is not easily described, but may readily be acquired by practice. The act of breathing must be carried on through the nostrils, without interruption, and the stress of blowing must be performed merely by the compression of the cheeks upon the air in the mouth. Beginners blow generally too strong, which obliges them to take breath very often. The whole art consists in inspiring the air through the nostrils, whilst the air contained in the mouth is forced out through the blow pipe; so that the action of the nostrils, lungs, and mouth, resemble the action of double bellows; and to accomplish this object, there is no necessity of blowing violently, but only with a moderate and equable force, and then the breath can never fail the operator. This art of blowing properly is, by some, acquired in an instant, while others are a long time in making themselves masters of it. To those who experience any difficulty in the free use of the blowpipe, the following

directions may be of service. First, let the learner accustom himself to breathe freely with the mouth shut; then, in making an expiration, let him transfer the air into the mouth, till the cheeks are moderately inflated, and retaining it there, let him discharge the surplus of the expiration through the nostrils, and then make two or three easy inspirations and expirations through them, without allowing the air in the mouth to escape. When practice has rendered this easy, which may be effected in half an hour, let the nozzle, with the smallest aperture, be fixed on the jet tube of the blowpipe, and introduce the mouthpiece within the lips; then inflate the cheeks by an expiration, and continue breathing easily through the nostrils till nearly the whole of the air has passed out of the mouth through the tube; then renew the air as before, and, after a few days' practice, the muscles of the mouth will be accustomed to this new mode of exertion, and an uniform, uninterrupted stream of air may be kept up for half an hour without any extraordinary fatigue.

324. The best kind of flame for blowing through with the blowpipe, is a thick wax or

tallow candle, with a very large wick, which should be kept snuffed moderately low, and the wick turned a little aside from the pipe: the spirit lamp may also be used; it makes a perfectly clear flame without smoke, but weak in comparison to a thick wax candle: although a wax candle is the most convenient, a thick tallow candle will do very well. The candle should be snuffed rather short, and the wick turned on one side towards the object, so that a part of it may lay horizontally. The stream of air must be blown along this horizontal part, as near as may be without striking the wick. If the flame be ragged and irregular, it is a proof that the hole of the blowpipe nozzle is not round or smooth; and if the flame have a cavity through it, the aperture of the nozzle pipe is too large. When the hole is of a proper figure, and duly proportioned, the flame consists of a neat luminous blue dart or cone, surrounded by another flame of a more faint and indistinct appearance. Too great a flame does not easily yield to the blast, and too small a one produces a weak effect.

325. In using the blowpipe, the following observations should be attended to. The end of the nozzle pipe must be just entered into

the flame, and the current of air will then throw out a cone or dart of flame from the opposite side. If well managed, this dart or cone will be very distinct and well defined. Care must be taken that the stream of air does not strike against any part of the wick, as it would then be disturbed, and split into several parts. The jet or blast of air must be delivered somewhat above the wick; and as, unless the flame was considerable, there will not be sufficient for the stream of air to act upon, for this reason the wick is best to be opened, because it then exposes the largest surface, and produces the greatest flame; the stream of air from the pipe should then be directed through the channel or opening between the wick, so as to produce a cone, the most perfect and brilliant, directed downwards, at an angle of about forty-five degrees.

Its intensity is different, according to the different parts of the flame. The place where this intensity is strongest, is the extremity of the blue point of the flame.

326. Every substance intended to be assayed with the blowpipe should be heated very gradually; the flame should be directed very slowly towards it in the beginning, not

directly upon it, but somewhat above it, and so approaching nearer and nearer with the flame, until it becomes red hot. Whenever any mineral substance is to be tried, we do not immediately begin with the blowpipe, because minerals are not always homogeneous, or of the same kind throughout, although they may appear to the eye to be so. A *magnifier* is, therefore, necessary, to enable us to discover the heterogeneous particles, if there be any; and these ought to be separated, and every part tried by itself, that the effects of two different things examined together, may not be attributed to one alone.

327. The substance upon which the flame acts ought to be proportioned to the size of the flame to which it is exposed. If the aperture of the blowpipe is only of the diameter of a common pin, the substance ought not to be larger than a pepper corn. In order to support the substance, it may be laid upon a piece of close grained well burned charcoal, made of elm or poplar wood. A small shallow hole may be scooped out with a knife on the piece of charcoal, and the substance laid upon it. The charcoal itself kindles all around the hole, and the hole is thus gradually en-

larged; and the heat, too, is kept up around the substance much more uniformly than when a metal support is used. At the same time, however, the chemical effect produced by ignited charcoal should not be forgotten, particularly in the reduction of metallic oxides, and the de-oxygenation of the fixed acids; so that, for example, a small heap of oxide of copper, lead, or tin, heated red-hot on charcoal by the blowpipe, is speedily reduced to a metallic state; hence, also, fragments of tin-stone (tin ore), common lead ore, or galena, ruby copper, &c. are easily reduced when heated on a charcoal support.

328. Very small and brittle substances are apt to be carried away by the current of flame from the piece of charcoal. These may be secured by making a deep cavity in the charcoal, into which the substance is to be put, and covered with another small piece of charcoal, which partly protects it from the flame. Some experiments of reductions are best made by binding two flat pieces of charcoal together, cutting a channel along the piece intended to be uppermost, and making a cavity in the middle of this channel, to contain the matter to be examined. With this contri-

vance the flame may be urged through the channel, between the two pieces of charcoal, and thus violently heats the substance in the cavity, which may be considered as in a closed furnace.

329. Those bodies upon which charcoal acts chemically (but when intended to be exposed to the blowpipe flame, without suffering such changes to take place), may be placed in a small spoon, somewhat less than a quarter of an inch in diameter, made of gold, silver, or platinum. The spoon must, of course, be properly fixed in a wooden handle. Silver or gold spoons are best adapted for fusions with alkaline fluxes, for which those made of platinum are entirely unfit; they have, nevertheless, the capital disadvantage, that they will only bear a dull red heat, without risk of melting; whereas spoons of platinum are perfectly infusible by the blowpipe flame.

330. Small forceps, entirely made of platinum, are also very convenient and useful for easily exposing fragments of stones to the dart of the blowpipe, because these bodies may be held with them, and the forceps cannot be melted nor oxidized, nor do they become too hot to be held by the fingers during trial, on account of

the bad conducting power of the metal of which they are fabricated. They are also convenient for handling or taking out from the melted fluxes the small bead of the product.

331. Flattened platinum wire is another very useful article for exposing fragments of infusible substances to the action of the blowpipe flame. The fragment may easily be secured between a piece of the wire bent round it, and may thus be firmly held in any direction we choose.

332. Platinum foil is likewise very serviceable for exposing to the flame of the blowpipe such substances as readily split, and are dispersed when heated by the blowpipe dart on charcoal, or when held by the forceps, or placed in the spoon, or when secured between platinum wire. Any substance, wrapped up in a piece of this foil, may readily be kept steady during trial; and hence it is best adapted for pulverulent substances. Slender filaments of cyanite or of asbestos may also be employed occasionally.

333. The best blowpipe for chemical and mineralogical purposes, is the *Pocket Blowpipe*, invented by Mr. Pepys, which is sufficiently known, and does not require to be described.

The form of the blowpipe is seen in plate 1, fig. 6. The globular part in the middle is an enlargement in the tube to condense the moisture of the breath. Besides the mouth blowpipe, there are several others; such as the table blowpipe, oxyhydrogen blowpipe, &c. which it is not necessary to describe here. Dr. Wollaston's pocket blowpipe is seen in plate 2, fig. 10, and the manner of applying another form of this instrument may be seen plate 3, fig. 7.

TABLE

SHEWING THE PRINCIPAL CHARACTERS OF THE EARTHS AND METALLIC OXIDES BEFORE THE BLOWPIPE.

[From Mr. Children's translation of "The Use of the Blowpipe in Chemical Analysis, and in the Examination of Minerals: by J. J. Berzelius."]

⁂ ABBREVIATIONS.—O. F. *Oxidating Flame.* R. F. *Reducing Flame.* = parts, *equal Parts of the Assay and Flux.* N. C. *Nitrate of Cobalt.* Fl. *Flaming.* C. *under the Column of either of the Fluxes means that the support is Charcoal.* P. F. *Platinum Foil.* P. W. *Platinum Wire.* A Brace { *refers to the Substances in the first column only, and includes all those which are contained in the space it comprehends.*

ASSAY.	HEATED ALONE ON	
	PLATINUM.	CHARCOAL.
Alkalies		
Baryta	Infusible	Infusible
Hydrate	Bubbles up and fuses	Is absorbed
Carbonate	Fuses readily into a clear glass; enamel-white on cooling	Becomes caustic, and is absorbed
Strontia	Infusible	Infusible
Hydrate	Like baryta	
Carbonate	Fuses with moderate heat at the surface, great brilliancy; tinges strong R. F. red; becomes alkaline	

ASSAY.	HEATED ALONE ON	
	PLATINUM.	CHARCOAL.
Lime	No change	
Carbonate	Becomes caustic and alkaline; emits brilliant white light	
Magnesia	No change	No change
Alumina	No change	No change
Glucina	No change	No change
Yttria	No change	No change
Zirconia	Infusible: emits intense light	Infusible: emits intense light
Silica	No change	No change
Molybdic acid	F. fumes and fuses; brown-yellow on cooling; in R. F. blue; intense heat, brown	Fuses, and is absorbed, and partly reduced
Tungstic acid	R. F. blackens, but not reduced	The same
Oxide of chrome	No change	The same
Antimony		Fuses readily; white fumes, which condense into pearly crystals

ASSAY.	HEATED ALONE ON	
	PLATINUM.	CHARCOAL.
Oxide of Antimony	Fuses readily, and sublimes in white fumes; *precipitated oxide*, burns like tinder into antimonious acid	Fuses readily, and reduces: colours the flame greenish
Antimonious acid		Does not fuse, nor reduce; gives a bright light
Antimonic acid		Whitens; is changed to antimonious acid
Oxide of tellurium	F. fuses and fumes	Fuses, effervesces, and reduces
Oxide of columbium	No change	The same
Oxide of titanium	No change	The same
Oxides of uranium		Peroxide becomes protoxide; blackens, but does not fuse
Oxides of cerium	Protoxide becomes peroxide	Peroxide does not alter
Oxide of manganese		Not fused; becomes brown in a strong heat

Assay.	Heated alone on Platinum.	Heated alone on Charcoal.
Oxide of zinc	Yellow while hot; white when cold; does not fuse, but gives out great light when very hot, and white fumes, which condense like wool	
Oxide of cadmium	F. no change	Soon dissipates; leaves a red or orange-yellow powder on the charcoal
Oxide of iron	O. F. no change	R. F. blackens and becomes magnetic
Oxide of cobalt	No change	The same
Oxide of nickel	No change	The same
Bismuth		Flies off in fumes, and leaves a mark with red, or orange edges, which may be dissipated in R. F. without giving colour to the flame
Oxide of bismuth	F. fuses readily, mass dark-brown, yellowish on cooling. In very intense heat reduces, and perforates the foil.	Instantly reduced

ASSAY.	HEATED ALONE ON	
	PLATINUM.	CHARCOAL.
Oxides of tin	Protoxide takes fire, and burns like tinder into peroxide	R. F. peroxide does not fuse, but reduces in a strong prolonged heat
Oxide of lead	Minium becomes black while hot; at incipient redness, changes to yellow oxide, fusible into orange-coloured glass	Orange glass reduces into a globule of lead
Oxide of copper		O. F. black globule; flows over the charcoal; under surface reduces R. F. reduces; with strong heat gives a bead of metal
Mercury	Instantly reduced	Instantly reduced
Oxide of silver		
Gold		
Platinum		
Iridium		
Rhodium		
Palladium		

	HEATED WITH FLUXES.		
ASSAY.	SODA.	BORAX.	SALT OF PHOSPHORUS.
Alkalies			
Baryta *Hydrate* *Carbonate*	Fuse, and are absorbed by the charcoal	Fuse readily with effervescence into a clear glass, which becomes opaque by Fl.	As with borax, but foam and intumesce; end in a clear glass
Strontia	No action on caustic strontia	Like baryta	Ditto
Hydrate *Carbonate*	= parts, fuses into a clear glass, becomes milky on cooling: in strong heat, bubbles, and absorbed by the charcoal		
Lime	No sensible quantity dissolved	Clear glass; opaque by Fl.	Fuses in large quantity; clear glass
Carbonate		Fuses with effervescence; with more carbonate clear glass; crystallizes on cooling	Fuses with effervescence

	Heated with Fluxes,		
Assay.	Soda.	Borax.	Salt of Phosphorus.
Magnesia	No action	Like lime	Fuses readily; clear glass; saturated with magnesia, opaque on cooling
Alumina	Swells up: forms an infusible compound	Fuses slowly; permanently clear glass	Permanently clear glass
Glucina	No action	Clear glass, with a large proportion of the assay; opaque by Fl.	As with borax
Yttria	Like glucina	Like glucina	Like glucina
Zirconia	Similar to glucina	Like glucina	Like glucina, but dissolves more difficultly
Silica	Fuses with brisk effervescence; clear glass.	Fuses very slowly: permanently clear glass	Very small portion dissolves; clear glass
Molybdic acid	P. W. effervesces, clear glass; becomes milky on cooling. C. fuses, absorbed and reduced	P. W. clear glass in O. F. C. and in R. F. glass becomes dirty-brown, but not opaque	P. W. and in O. F. greenish glass while hot; colourless, cold In R. F. becomes opaque; dull blue while hot; clear and fine green on cooling C. same phenomena

ASSAY.	HEATED WITH FLUXES.		
	SODA.	BORAX.	SALT OF PHOSPHORUS.
Tungstic acid	P. W. dark yellow glass, crystallizes on cooling; opaque white or yellowish C. and R. F. reduced	P. W. and O. F. clear glass; not opaque by Fl. R. F. glass becomes yellow	O. F. yellowish glass R. F. fine blue glass
Oxide of chrome	P. W. and O. F. dark-orange glass; opaque and yellow on cooling. R. F. opaque; glass green on cooling C. absorbed, but not reduced	C. fuses difficultly, glass emerald-green; on P. W. and O. F. the colour flies, and glass becomes brown-yellow; on cooling, assumes a faint-green tinge.	Green glass in both flames
Antimony.........			
Oxide of antimony.........	P. W. fuses; clear colourless glass becomes white on cooling C. is reduced	C. dissolves in large quantity; glass yellowish, hot; almost colourless, cold. If saturated, part reduced and sublimed; strong R. F., the glass becomes opaque and greyish	P. W. and O. F., glass yellowish, hot; colour flies on cooling

Assay.	Heated with Fluxes.		
	Soda.	Borax.	Salt of Phosphorus.
Antimonious acid			
Antimonic acid			
Oxide of tellurium	P. W. colourless glass; white on cooling C. reduced	P. W. clear, colourless glass; white on cooling C. becomes grey and opaque	The same
Oxide of columbium	Combines with effervescence, but not fused or reduced	Colourless, clear glass, becomes opaque by Fl.	Fuses easily; glass, permanently clear
Oxide of titanium	Fuses into a clear dark yellow glass; white or grey-white on cooling, and crystallizes with evolution of great heat C. not reducible	P. W. fuses, easily; glass, colourless; becomes milk-white by Fl. R. F. glass assumes a dark amethyst colour, but transparent In large quantity on C. and R. F. glass, dull-yellow; when cold, deep blue.	O. F. clear, colourless glass R. F. and on C. glass, yellowish, hot; on cooling, first red, then very fine bluish-violet

Assay.	Heated with Fluxes.		
	Soda.	Borax.	Salt of Phosphorus.
Oxides of uranium ………	C. brown yellow; not fused	P. W. dark-yellow glass; in R. F. becomes dirty-green	P. W. and O. F. clear yellow glass; cold, straw yellow, slightly green C. and R. F. fine green glass
Oxides of cerium…………	C. not fused, soda, absorbed; white or grey-white protoxide remains on the surface	O. F. fine red, or deep orange-yellow glass; colour flies on cooling; cold yellowish tint. Enamel white by Fl. In R. F. loses its colour	O. F. fine red glass; colourless when cold, and quite limpid
Oxide of manganese ……	P. F. fuses, green glass, clear; cold, bluish-green C. not reduced	O. F. clear, amethyst colour glass; colour flies in R. F.	The same, but colour not so deep. In fusion in O. F. boils and gives off gas; in R. F. fuses quietly
Oxide of zinc ……………	C. not fused, but reduced, with flame; white fumes, which cover the charcoal	O. F. fuses easily, clear glass becomes milky by Fl.	Nearly the same

Assay.	Heated with Fluxes.		
	Soda.	Borax.	Salt of Phosphorus.
Oxide of Cadmium ………	P. W. not fused C. reduced, sublimes, and leaves a circular yellowish mark	P. W. yellowish glass, colour flies on cooling; on C. glass bubbles, cadmium reduced, sublimes, and leaves yellow oxide	Dissolves in large quantity, clear glass; on cooling, milk white
Oxide of iron ……………	C. absorbed and reduced; not fused	O. F. dull red glass becomes clear and yellowish, or colourless by cooling C. and R. F. bottle-green glass, or bluish-green	Similar to borax
Oxide of cobalt ……… …	P. W. pale-red by transmitted light; grey, cold	Fuses readily, deep-blue glass	The same, the colour appears violet by candle-light
Oxide of nickel …………	C. absorbed and reduced; not fused	O. F. orange-yellow, or reddish glass; becomes yellow, or nearly colourless, on cooling.	As with borax, but the colour flies almost wholly on cooling

ASSAY.	HEATED WITH FLUXES.		
	SODA.	BORAX.	SALT OF PHOSPHORUS.
Bismuth			
Oxide of bismuth............		O. F. colourless glass R. F. partly reduced, muddy greyish glass	O. F. yellowish brown glass, hot; colourless, but not quite clear, cold R. F. clear and colourless glass hot; opaque and greyish-black, cold
Oxides of tin	P. W. effervesces, tumefied, infusible mass C. readily reduced	Fuses with great difficulty; permanently clear glass.	As with borax
Oxide of lead	P. W. clear glass becomes yellowish and opaque on cooling C. instantly reduced	P. W. clear glass, yellow, hot; on cooling, colourless C. flows over the surface and reduces	Clear colourless glass

ASSAY.	HEATED WITH FLUXES.		
	SODA	BORAX.	SALT OF PHOSPHORUS.
Oxide of copper	P. W. fine green glass, hot; on cooling, colourless and opaque C. absorbed and reduced	O. F. fine green glass, which in R. F. becomes colourless, hot; but cinnabar-red and opaque when solid	O. F. similar to borax; R. F. glass usually red, opaque, and like an enamel
Mercury			
Oxide of silver		O. F. glass becomes milky, or opaline on cooling R. F. greyish	O. F. yellowish glass viewed by transmitted light by day, by candle-light reddish. R. F. greyish
Gold			
Platinum			
Iridium			
Rhodium			
Palladium			

ASSAY.	WITH OTHER RE-AGENTS.	REMARKS.
Alkalies		*The alkalies* are not readily distinguishable by the blowpipe. *Lithia* leaves a dull yellow stain, when heated to redness on platinum foil. *Ammonia* may be known by heating the assay with soda: it gives off a pungent vapour, which turns the yellow colour of moistened turmeric paper brown
Baryta	N. C.; a globule of different shades of red; colour flies on cooling	
Hydrate		
Carbonate		
Strontia	N. C. exhibit a black, or greyish-black colour; do not fuse	
Hydrate		
Carbonate		
Lime	N. C. black or dark-grey mass, infusible.	
Carbonate		
Magnesia	N. C.; flesh colour when quite cold.	
Alumina	N. C.; fine blue glass, with strong heat when cold	The blue colour is only distinctly seen by day-light
Glucina	N. C.; black or dark grey mass	

ASSAY.	WITH OTHER RE-AGENTS.	REMARKS.
Yttria		
Zirconia		
Silica	N. C. ; blue glass when perfectly fused	The part not perfectly fused with nitrate of cobalt, has a reddish-blue disagreeable colour
Molybdic acid		In the inclined glass tube, fuses, gives off vapour, which condenses partly on the tube as a white powder, partly on the assay in brilliant pale-yellow crystals
Tungstic acid		If tungstic acid contain iron, the glass with salt of phosphorus is blood-red in R. F. Tin makes it green or blue
Oxide of chrome		
Antimony		Antimony does not sublime at the fusing point of glass. On charcoal, when red, ignition continues spontaneously. In a tube open at both ends, it gives off white fumes
Oxide of antimony *Antimonious acid* *Antimonic acid*		The oxide and acids of antimony behave alike with the fluxes

Assay.	With other Re-agents.	Remarks.
Oxide of tellurium		Metallic tellurium heated in a glass matrass, first gives off vapour, and then a grey metallic sublimate of tellurium. In a tube, open at both ends, emits abundant fumes, which condense in a white fusible powder
Oxide of columbium		
Oxide of titanium	N. C. black, or greyish black	For the rest of the phenomena, see the original work
Oxides of uranium		
Oxides of cerium		
Oxide of manganese		A very minute portion of manganese gives a green glass with soda
Oxide of zinc		
Oxide of cadmium		
Oxide of iron		The reduction of iron from the peroxide to protoxide is facilitated by tin
Oxide of cobalt	With carbonate of potash, black glass when cold	
Oxide of nickel		

ASSAY.	WITH OTHER RE-AGENTS.	REMARKS.
Bismuth		In a glass matrass does not sublime at the fusing point of glass. In an open tube scarcely gives off any fumes; the metal becomes covered with a dull-brown fused oxide, of a slight yellowish tint, when cold
Oxide of bismuth		
Oxides of tin		
Oxide of lead		
Oxide of copper		
Mercury		All the compounds of mercury are volatile; mixed with tin or iron filings, and heated in a glass tube, metallic mercury distils over
Oxide of silver		These metals have no action on the fluxes, which can only serve to detect the foreign metals they may be combined with. They are best examined by cupellation with lead
Gold		
Platina		
Iridium		
Rhodium............ ..		
Palladium		

PART II.

ANALYSIS OF MINERAL WATERS*.

The analysis of mineral waters has always been considered as a difficult operation. Numerous methods are employed to discover their ingredients and estimate their quantities, many of which are liable to errors. This diversity of method itself is a source of discordant results; and to those not familiar with such researches, it presents the difficulty often of determining what process is best adapted to discover a particular composition. Hence the advantage of a general formula, if this could be given, applicable to the analysis of all waters. Dr. Murray has suggested a process which appears to admit of very gene-

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* For this method of analyzing mineral waters we are indebted to J. Murray, M.D.—See Transactions of the Royal Society of Edinburgh, vol. II. p. 255.

ral application : this method is simple ; not difficult of execution, nor liable to any sources of error but what may be easily obviated. The principles on which this method is founded, and the details of the process itself, form the subject of the following observations.

Two methods of analysis have been employed for discovering the composition of mineral waters—what may be called the *direct method*, in which, by evaporation, aided by the subsequent application of solvents, or sometimes by precipitants, certain compound salts are obtained ; and what may be called the *indirect method*, in which, by the use of re-agents, the principles of these salts, that is, the acids and bases of which they are formed, are discovered, and their quantities estimated, whence the particular salts, and their proportions, may be inferred.

Chemists have always considered the former of these methods as affording the most certain and essential information : they have not neglected the latter ; but they have usually employed it as subordinate to the other. The salts procured by evaporation have been uniformly considered as the real ingredients, and nothing more was required, it was therefore imagined, for the accuracy of the analysis, than the obtaining them pure, and estimating their quantities with precision. On the contrary, in obtaining the elements merely, no information, it was believed, was gained with regard to the real composition; for it still remained to be determined in what mode they were combined; and this, it was supposed, could be inferred only from the compounds actually obtained. This method, therefore, when employed with a view to estimate quantities, has been had recourse to only to obviate particular difficulties attending the execution of the other, or to give greater accuracy to the proportions, or, at farthest, when the composition is very simple, consisting chiefly of one genus of salts.

Another circumstance contributed to lead to a preference of the *direct* mode of analysis —the uncertainty attending the determination of the proportions of the elements of compound salts. This uncertainty was such, that, even from the most exact determination of the absolute quantities of the acids and bases existing in a mineral water, it would have been difficult, or nearly impracticable, to assign the precise composition and the real proportions of the compound salts; and hence the necessity of employing the *direct* method of obtaining them. The present state of science leads to other views.

If the conclusion were just, that the salts obtained by evaporation, or any analogous process, from a mineral water, are its real ingredients, no doubt could remain of the superiority of the *direct* method of analysis, and even of the absolute necessity of employing it. But no illustrations are required to prove that this conclusion is not necessarily true. The concentration, by the evaporation, must in many cases change the state of combination, and the salts obtained are hence frequently products of the operation, and not original ingredients. Whether they are so or not, and what the real composition is, must be determined on other grounds than on their being actually obtained; and no more information is gained, therefore, with regard to that composition, by their being procured, than by their elements being discovered; for when these are known, and their quantities are determined, we can, according to the principle from which the actual modes of combination are inferred, whatever this may be, assign with equal facility the quantities of the binary compounds they form.

The accuracy with which the proportions of the constituent principles of the greater number of the compound salts are now determined, enables us also to do this with as much precision as by obtaining the compounds themselves; and if any error should exist in the estimation of these proportions, the prosecution of these researches could not fail soon to discover it.

The mode of determining the composition of a mineral water, by discovering the acids and bases which it contains, admits, in general, of greater facility of execution, and more accuracy, than the mode of determining it by obtaining insulated the compound salts. Nothing is more difficult than to effect the entire separation of salts by crystallization, aided even by the usual methods of the action of alcohol, either as a solvent, or a precipitant, or by the action of water as a solvent, at different temperatures: in many cases it cannot be completely attained, and the analysis must be deficient in accuracy. No such difficulty is attached to the other method. The principles being discovered, and their quantities estimated in general from their precipitation in insoluble compounds, their entire separation is easily effected. Nothing is easier, for example, than to estimate the total quantity of sulphuric acid by precipitation by barytes (see page 177), or of lime by precipitation by oxalate of ammonia (see page 156). And this method has one peculiar advantage with regard to accuracy, that if any error is committed in the estimation of any of the principles, it is discovered in the subsequent step of inferring the binary combinations, since, if all the elements do not bear that due proportion to each other which is necessary to produce the state of neutralization, the excess or deficiency becomes apparent, and of course the error is detected. The *indirect* method, then, has every advantage over the other, both in accuracy and facility of execution.

Another advantage is derived from these views, if they are just—that of precluding the discussion of questions which otherwise fall to be considered, and which must often be of difficult determination, if they are even capable of being determined. From the state or combination being liable to be influenced by evaporation, or any other analytical operation, by which the salts existing in a mineral water are attempted to be procured, discordant results will often be obtained, according to the methods employed; the proportions at least will be different, and sometimes even products will be found by one method which are not by another. In a water which is of complicated composition, this will more peculiarly be the case. The Cheltenham waters, for example, have, in different analyses, afforded results considerably different; and, on the supposition of the salts procured being the real ingredients, this diversity must be ascribed to inaccuracy, and ample room for discussion with regard to this subject is introduced. In like manner, it has often been a subject of controversy, whether sea-water contains sulphate of soda with sulphate of magnesia. All such discussions, however, are superfluous. The salts procured are not necessarily the real ingredients, but in part, at least, are products of the operation, liable, therefore, to be obtained or not, or to be obtained in different proportions, according to the method employed. And all that can be done with precision is to estimate the elements, and then to exhibit their binary combinations, according to whatever may be the most probable view of the real composition.

Mineral waters have been arranged under the four classes of *carbonated*, *sulphureous*, *chalybeate*, and *saline*. But all of them are either *saline*, or may be reduced under this division. From waters of the first class, the *carbonic acid** which is in excess is expelled by heat, and its quantity is estimated. *Sulphuretted hydrogen** is in like manner expelled or decomposed; and iron may be detected by its particular tests (see pages 136, 184), and removed by appropriate methods. In all these cases the water remains, with any saline impregnation which it has, and of course is essentially the same in the subsequent steps of its analysis as a water purely saline; the precaution only being observed of these principles being removed, and of no new ingredient being introduced, by the methods employed.

The salts usually contained in mineral

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* Besides *carbonic acid*, and *sulphuretted hydrogen* gases, mineral waters are also found to contain *oxygen* and *azote*. To ascertain the gaseous products of water is not at all times necessary; but the method of doing this, if desirable, may be seen by referring to *Brande's Chemistry*, or *Henry's Chemistry*, article *Mineral Waters*, or to *Thenard's Analysis, as translated by Children*.

waters are *carbonates*, *sulphates*, and *muriates*, of *lime*, of *magnesia*, and of *soda*. In proceeding to the analysis, a general knowledge is of course first to be gained of the probable composition by the application of the usual tests; the presence of sulphuric and carbonic acids being detected by barytes (see pages 172, 177, 178); of muriatic acid by nitrate of silver (see pages 72, 88, 90); of lime by oxalic acid (see page 60); of magnesia by ammonia (see page 149); and of any alkaline neutral salt by evaporation. It will also be of advantage to obtain the products of evaporation, and ascertain their quantities, without any minute attention to precision, the object being merely, by these previous steps, to facilitate the more accurate analysis.

Supposing this to be done, and supposing the composition of the water to be of the most complicated kind, that is, that by the indications from tests, or by evaporation, it has afforded carbonates, sulphates, and muriates of lime, magnesia, and soda, the following is the general process to be followed to ascertain the ingredients, and their proportions:—

1. Reduce the water by evaporation, as far

as can be done without occasioning any sensible precipitation or crystallization; this, by the concentration, rendering the operation of the re-agents to be employed more certain and complete. It also removes any free carbonic acid.

2. Add to the water thus concentrated a saturated solution of muriate of barytes (see page 177), as long as any precipitation is produced, taking care to avoid adding an excess. By a previous experiment, let it be ascertained whether this precipitate effervesces or not with diluted muriatic acid, and whether it is entirely dissolved. If it is, the precipitate is of course carbonate of barytes, the weight of which, when it is dried, gives the quantity of carbonic acid; 100 grains containing 22 of acid. If it do not effervesce, it is sulphate of barytes, the weight of which, in like manner, gives the quantity of sulphuric acid; 100 grains dried at a low red heat, containing about 34 of acid (see page 178). If it effervesce, and is partially dissolved, it consists both of carbonate and sulphate. To ascertain the proportions of these, let the precipitate be dried at a heat a little inferior to redness, and weighed; then submit it to the action of dilute

muriatic acid; after this wash it with water, and dry it by a similar heat, its weight will give the quantity of sulphate, and the loss of weight that of carbonate of barytes.

By this operation the carbonic and sulphuric acids are entirely removed, and the whole salts in the water are converted into muriates. It remains, therefore, first to discover and estimate the quantities of the bases present, and then, to complete the analysis, to find the quantity of muriatic acid originally contained.

3. Add to the clear liquor a saturated solution of oxalate of ammonia (see page 156), as long as any turbid appearance is produced. The lime will be thrown down in the state of oxalate. The precipitate being washed, may be dried; but as it cannot be exposed to a red heat without decomposition, it can scarcely be brought to any uniform state of dryness with sufficient accuracy to admit of the quantity of lime being estimated from its weight. It is, therefore, to be calcined with a low red heat, by which it is converted into carbonate of lime, 100 grains of which are equivalent to 56 of lime. But as a portion of carbonic acid may be expelled if the heat is raised too

high, or a little water retained if it is not high enough, it is proper to convert it into sulphate, by adding sulphuric acid to a slight excess, and then exposing to a full red heat. The dry sulphate of lime will remain, 100 grains of which contain, according to Dr. Murray, 41.5 of lime.

The only source of error to which this step of the analysis is liable, is that which will arise if more barytes has been used in the first operation than was necessary to precipitate the sulphuric and carbonic acids. It will be thrown down in the state of oxalate of barytes, and be converted into carbonate and sulphate, and thus give the apparent proportion of lime too large.—This is obviated, of course, by taking care to avoid using an excess of barytes. To render the operation of the oxalate of ammonia as perfect as possible in precipitating the lime, the water should be considerably reduced by evaporation, taking care to avoid any separation of any of its ingredients.

4. The next step is to precipitate the magnesia. With regard to this there is some difficulty, particularly as connected with the design of the present formula. The principle

on which it is founded is, first, to remove all the acids but the muriatic; and, secondly, to remove the bases, or otherwise estimate their quantities. The lime and the magnesia may be removed by precipitation; the soda cannot. The process, therefore, must be so conducted as to leave it at the end in the state of *muriate of soda* *. Hence it is necessary either to remove any new product, introduced in the previous steps of the analysis, or if any such remain, to be able to estimate its quantity with precision. In decomposing the muriate of lime by oxalate of ammonia (see page 156), muriate of ammonia is substituted, which can be afterwards dissipated by heat. The object, therefore, is to decompose the muriate of magnesia, and remove the magnesia, either by some similar method, or, if not, by some other in which the muriate substituted can be accurately estimated; and to attain one or other of these conditions, gives rise to the difficulty alluded to.

The decomposition of the magnesian salt by ammonia would have the former advantage, as the muriate of ammonia would be ex-

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* The reader is apprized that the editor thought best to let the term *muriate of soda* stand throughout as in the original paper.

pelled at the end of the process by heat; but this decomposition, it is well known, is only partial. Carbonate of ammonia causes a more abundant precipitation of magnesia, but still its action is likewise partial, a ternary soluble salt being formed after a certain quantity has been added. It seemed probable that this might be obviated by adding the carbonate of ammonia as long as it occasioned any precipitation, then evaporating the clear liquor to dryness, expelling the muriate of ammonia, and any excess of ammonia, by heat, re-dissolving, and again adding the carbonate of ammonia to decompose the remaining magnesian salt. Dr. Murray, proceeding in this way, found that a copious precipitation took place on the second addition, and even on the fourth a small quantity of precipitate was thrown down. But the decomposition, after all, was not perfect, for the quantity of magnesia obtained was not equal to what was procured by other methods.

Carbonate of soda or potash has been usually employed to precipitate magnesia from its saline combinations. The precipitation, however, is only partial, unless an excess of the precipitant be employed (and even then, perhaps, is not altogether complete); and as this excess cannot easily be estimated, it introduces a source of error in estimating the quantity of muriate of soda at the end of the operation, against which it is not easy to guard.

The method proposed by Dr. Wollaston, of precipitating magnesia from its solution, by first adding bicarbonate of ammonia, and then phosphate of soda (see page 91), so as to form the insoluble phosphate of ammonia and magnesia, is one much more perfect; the whole of the magnesia appears to be precipitated; and as a method, therefore, of determining the quantity of this base, it is, probably, unexceptionable. It does not, however, altogether accord with the object of the present formula. The soda of the phosphate of soda serves to neutralize the muriatic acid of the muriate of magnesia; a quantity of muriate of soda is of course formed, which remains with the muriate of soda of the water, and the amount of which, therefore, it is necessary to determine with accuracy. This may be done from the quantity of phosphate of magnesia obtained giving the equivalent portion of muriate of soda, either by means of the equivalents of the acids or of the bases. But still this renders the method somewhat complicated; and it may be liable to some error, if any excess of phosphate of soda be added, (which, in order to precipitate the magnesia entirely, it may be difficult to avoid) this excess remaining with the muriate of soda, and rendering the estimate of it incorrect. And independent of these circumstances, it would be preferable to give uniformity to the operation, by employing some method by which the product in this, as well as in the previous steps, is removed, at the end of the analysis, leaving only the muriate of soda.

It seemed probable that this might be attained by employing phosphoric acid with the bicarbonate of ammonia to form the triple phosphate of ammonia and magnesia, such an excess of ammonia being used as should both be sufficient for the constitution of this compound, and for the neutralization of the muriatic acid of the muriate of magnesia; muriate of ammonia would thus be substituted, the same as in the preceding step of precipitating the lime, which at the end would be expelled by heat, leaving muriate of soda alone. Dr. Murray accordingly found, that when this variation of the process was employed, the clear liquor, after the precipitation, was not affected by the addition either of phosphate of soda with ammonia, or of carbonate of soda—a proof that the separation of the magnesia had been complete. To establish its accuracy with more certainty, the following experiments were also made.

Twenty grains of pure rock salt, which had been exposed to a red heat, and 10 grains of crystallized muriate of magnesia, were dissolved in an ounce of water, at the temperature of 100°. The phosphate of soda and bicarbonate of ammonia were then employed to precipitate the magnesia in the mode proposed by Dr. Wollaston (see page 91); that is, a solution of the ammoniacal carbonate was first added, and afterwards a solution of phosphate of soda, as long as any precipitation was produced, taking care to preserve in the liquor a slight excess of the ammonia. The precipitate, being washed and dried, afforded, after exposure to a red heat for an hour, 5.4 grains of phosphate of magnesia, equivalent to 2.15 of magnesia. The clear liquor being evaporated, muriate of soda was obtained, which, after exposure to a red heat, weighed 25.7 grains.

Phosphate of magnesia being composed of 39.7 of magnesia, with 60.3 of phosphoric acid, 5.4 grains of it are equivalent to 6.4 grains of muriate of soda, and this deducted from the quantity obtained 25.7, leaves 19.3 as the quantity originally dissolved.

A solution perfectly the same was prepared, and a solution of carbonate of ammonia was added to it as before. A strong solution of phosphoric acid was then dropped in, as long as any precipitation was produced, observing the precaution of having always an excess of ammoniacal carbonate in the liquor. The precipitate, being washed and dried, afforded, after exposure to a red heat, 5.5 grains of phosphate of magnesia, equivalent to 2.19 of magnesia. The clear liquor being evaporated, and the dry matter being exposed to a heat gradually raised to redness, weighed, when cold, exactly 20 grains.

In both experiments the quantity of muriate of soda is accurately obtained, or as nearly so as can be expected. They correspond, too, as nearly as can be looked for, even in a repetition of the same experiment, in the quantity of magnesia which they indicate. To ascertain how far this corresponded with the real quantity, Dr. Murray converted 10 grains of the crystallized muriate of magnesia into sulphate, by the addition of sulphuric acid, and exposed it to a low red heat; the product weighed 6.4 grains, equivalent to 2.13 of magnesia. This may be regarded as a perfect coincidence, and as establishing the accuracy of the other results.

According to the result of this last experiment, 100 grains of crystallized muriate of magnesia would give 64 of real sulphate of magnesia, composed of 21.3 of magnesia, and 42.7 of sulphuric acid. This quantity of sulphuric acid is equivalent to 29.4 of muriatic acid. Hence 100 grains of this salt crystallized, consist of 21.3 magnesia, 29.4 muriatic acid, and 49.3 of water.

It thus appears that phosphoric acid with an excess of ammonia may be employed to precipitate magnesia from its saline combinations; and in a process, such as the present, it has the advantage that the muriate of ammonia formed can be afterwards volatilized by heat, and the quantity of any residual ingredient can of course be easily ascertained. Neutral phosphate of ammonia would also have this advantage: but it does not succeed, phosphate of magnesia not being sufficiently insoluble. On adding a solution of phosphate of ammonia to a solution of sulphate of magnesia, the mixture became turbid in a minute or two, and in a short time a precipitate in crystalline grains formed at the bottom and sides; but it was not considerable, and did not increase. Phosphate of ammonia, however, with an excess of ammonia, or with the previous addition of carbonate of ammonia, may be employed with the same effect as phosphoric acid. In applying the phosphoric acid to this purpose under any of these forms, it is necessary to be careful that it be entirely free from any impregnation of lime.

There is one other advantage which this method has, that if even a slight excess of phosphoric acid be added, the error it can introduce must be extremely trivial; for the effect of it will be only to decompose a small portion of the original muriate of soda; and as the difference is very inconsiderable in the proportion in which phosphoric and muriatic acids combine with soda, any difference of weight which may arise from this substitution, to any extent to which it can be supposed to happen, may be neglected as of no importance.

For the sake of comparison, and to ascertain the accuracy of different methods, Dr. Murray submitted a similar solution of muriate of magnesia and muriate of soda to analysis by carbonate of ammonia. To the saline liquor, heated to 100°, a solution, prepared by dissolving carbonate of ammonia in water of pure ammonia, was added until it was in excess. A precipitation rather copious took place; the precipitate being collected on a filter, the clear liquor was evaporated to dryness, and the saline matter was exposed to heat, while any vapours exhaled. Being re-dissolved, a small portion remained undissolved; and on again adding carbonate of ammonia to the clear liquor, precipitation took place, rather less abundant than at first. This was repeated for a third, and even for a fourth time, after which the liquor was not rendered turbid. Being evaporated, the muriate of soda obtained, after exposure to a red heat, weighed 20.5 grains. The whole precipitate washed, being heated with sulphuric acid, afforded of dry sulphate of magnesia 4.8 grains, a quantity inferior to that obtained by the other methods, evidently owing to the less perfect action of the ammoniacal carbonate as a precipitant. A similar deficiency in the proportion of magnesia was found in the analysis of sea-water by carbonate of ammonia, as has been already stated; while, on the other hand, in its analysis by phosphate of soda and bicarbonate of ammonia, a larger quantity of muriate of soda was obtained than by the other methods, probably from the difficulty of avoiding an excess of phosphate of soda in precipitating the magnesia.

To apply this method, then, to the present formula: add to the clear liquor poured off after the precipitation of the oxalate of lime, heated to 100°, and, if necessary, reduced by evaporation, a solution of carbonate of ammonia; immediately drop in a strong solution of phosphoric acid, or phosphate of ammonia, continuing this addition with fresh portions, if necessary, of carbonate of ammonia, so as to preserve an excess of ammonia in the liquor as long as any precipitation is produced. Let the precipitate be washed; when dried by a heat not exceeding 100°, it is the phosphate of ammonia and magnesia, containing 0.19 of this earth; but it is better, for the sake of accuracy, to convert it into phosphate of magnesia by calcination for an hour at a red heat: 100 grains, then, contain 40 of magnesia.

5. Evaporate the liquor remaining after the preceding operations to dryness, and expose the dry mass to heat as long as any vapours exhale, raising it towards the end to redness. The residual matter is muriate of soda, 100 grains of which are equivalent to 53.3 of soda, and 46.7 of muriatic acid. It is not, however, necessarily to be considered as the quantity of muriate of soda contained in the water; for a portion of soda may have been present above that combined with muriatic acid, united, for example, with portions of sulphuric or carbonic acid; and, from the nature of the analysis, this, in the progress of it, or rather in the first step, that of the removal of these acids by the muriate of barytes, would be combined with muriatic acid. It does not, therefore, give the original quantity of that acid, but it gives the quantity of soda, since no portion of this base has been abstracted, and none introduced.

6. The quantity of muriatic acid may have been either greater or less than that in the muriate of soda obtained. If the quantity of soda existing in the water exceeded what the

proportion of muriatic acid could neutralize, this excess of soda being combined with sulphuric or carbonic acid, then, in the removal of these acids by muriate of barytes, muriatic acid would be substituted, which would remain in the state of muriate of soda; and if the quantity considered as an original ingredient were estimated from the quantity of this salt obtained, it would be stated too high. Or if, on the other hand, more muriatic acid existed in the water than what the soda present could neutralize, the excess being combined with the other bases, lime or magnesia, then, as in the process by which these earths are precipitated, this portion of the acid would be combined with ammonia, and afterwards dissipated by heat in the state of muriate of ammonia: if the original quantity were inferred from the weight of the muriate of soda obtained, it would be stated too low.

To find the real quantity, therefore, another step is necessary. The quantities of bases and of acids procured (taking the quantity of muriatic acid existing in the muriate of soda obtained) being combined according to the known proportions of their binary combinations, if any portion of muriatic acid has been abstracted, the bases will be in excess, and the quantity of this acid necessary to produce neutralization will be the quantity lost; or, on the other hand, if any portion of muriatic acid has been introduced, and remains beyond that originally contained in the water, this quantity will be in excess above what is necessary to produce neutralization.—The simple rule, therefore, is to combine the elements obtained by the analysis, in binary combinations, according to the known proportions in which they unite; the excess or deficiency of muriatic acid will then appear; and the amount of the excess being subtracted from the quantity of muriatic acid contained in the muriate of soda obtained, or the amount of the deficit being added to that quantity, the real quantity of muriatic acid will be evident.

There is one deficiency, however, in this method: if any error has been introduced in any previous step of the analysis, either in the estimation of the bases or of the acids, this error will be concealed by the kind of compensation that is made for it, by thus adapting the proportion of muriatic acid to the results, such as they are obtained; and at the same time an incorrect estimate will be made of the quantity of muriatic acid itself. When any error, therefore, can be supposed to exist, or, independent of this, to insure perfect accuracy, it may be proper to estimate directly the quantity of muriatic acid in a given portion of the water, by abstracting any sulphuric or carbonic acid by nitrate of barytes, and then precipitating the muriatic acid by nitrate of silver, or nitrate of lead. The real quantity will thus be determined with perfect precision, and the result will form a check on the other steps of the analysis, as it will lead to the detection of any error in the estimate of the other ingredients; for, when the quantity is thus found, the quantities of these must bear that proportion to the muriatic acid, which will correspond with the state of neutralization.

Thus by these methods the different acids and the different bases are discovered, and their quantities determined. To complete the analysis, it remains to infer the state of combination in which they exist. It will probably be admitted that this must be done on a different principle from that on which the composition of mineral waters has hitherto been inferred. The compounds which may be obtained by direct analysis cannot be considered as being necessarily the real ingredients; and to state them as such, would often convey a wrong idea of the real composition. There are two views according to which the state of combination in a saline solution may be inferred, and in conformity to which, therefore, the composition of a mineral water may be assigned. It may be supposed that the acids and bases are in simultaneous combinations; or if they be in binary combinations, the most probable conclusion with regard to this is, that the combinations are those which form the most soluble compounds; their separation in less soluble compounds, on evaporation, arising from the influence of the force of cohesion. In either of these cases the propriety of first stating, as the results of analysis, the quantities of acids and bases obtained, is obvious. On the one supposition, that of their existing in simultaneous combination, it is all that is to be done. On the other supposition, the statement affords the grounds on which the proportions of the binary compounds are inferred; and there can be no impropriety in adding the composition conformably to the products of evaporation. The results of the analysis of a mineral water may always be stated, then, in these three modes: 1. The quantities of the acids and bases. 2. The quantities of the binary compounds, as inferred from the principle that the most soluble compounds are the ingredients; which will have at the same time the advantage of exhibiting the most active composition which can be assigned, and hence of best accounting for any medicinal powers the waters may possess. 3. The quantities of the binary compounds, such as they are obtained by evaporation, or any other direct analytical operation. The results will thus be presented under every point of view.

It is obvious that this process, thus far described by Dr. Murray, has been adapted to the most complicated composition which usually occurs, and that it may of course be modified according to the ingredients. If no lime, for example, is present, then the oxalate of ammonia is not employed; and in like manner with regard to the others. It has also been supposed that the usual and obvious precautions be observed, such as not adding an excess of any of the precipitants, and bringing the products to an uniform state of dryness, &c.

With regard to other ingredients, either not saline, or more rarely present, it will in general be preferable, when their presence has been indicated by the employment of tests, or by results occurring in the analysis itself, not to combine the investigation to discover them with the general process above described, but to operate on separate portions of the water, and to make the necessary allowance for their quantities in estimating the other ingredients. The quantity of iron, for example, in a given portion of the water, may be found by the most appropriate method. Silica will be discovered by the gelatinous consistence it gives on evaporation, and by forming a residue insoluble in acids, but soluble in a solution of potash. Alumina may be discovered in the preliminary application of tests, by the water giving a precipitate with carbonate of ammonia, which is not soluble, or is only partially soluble in weak distilled vinegar, but is dissolved by boiling in a solution of potash; or by its precipitation from the water (sufficiently evaporated) by succinate of soda; or in conducting the process itself, it will remain in solution after the precipitation of the lime by the oxalic acid, and be detected by the turbid appearance produced on the addition of the carbonate of ammonia, previous to the addition of the phosphoric acid to discover the magnesia. Its quantity may then be estimated from its precipitation by carbonate of ammonia, or by other methods usually employed. Silica will also be precipitated in the same stage of the process; its separation from the alumina may be effected by submitting the precipitates, thoroughly dried, to the action of diluted sulphuric acid. Potash, when present, which is very seldom to be looked for, will remain at the end in the state of muriate of potash. Muriate of platinum (see page 119) will detect its presence, and the muriate of potash may be separated by crystallization from the muriate of soda.

There is another mode in which part of the analysis may be conducted, which, although perhaps a little less accurate than that which forms the preceding formula, is simple and easy of execution, and which may hence occasionally be admitted as a variation of the process; the outline of which, therefore, may briefly be stated.

The water being partially evaporated, and the sulphuric and carbonic acids, if they are present, being removed by the addition of muriate of barytes, and the conversion of the whole salts into muriates effected in the manner already described, the liquor may be evaporated to dryness, avoiding an excess of heat, by which the muriate of magnesia, if present, might be decomposed; then add to the dry mass six times its weight of rectified alcohol (of the specific gravity of at least .835), and agitate them occasionally during 24 hours, without applying heat. The muriates of lime and magnesia will thus be dissolved, while any muriate of soda will remain undissolved. To remove the former more completely, when the solution is poured off, add to the residue about twice its weight of the same alcohol, and allow them to stand for some hours, agitating frequently. And when this liquor is poured off, wash the undissolved matter with a small portion of alcohol, which add to the former liquors.

Although muriate of soda by itself is insoluble, or nearly so, in alcohol of this strength, yet, when submitted to its action along with muriate of lime or of magnesia, a little of it is dissolved. To guard against error from this, therefore, evaporate or distil the alcoholic solution to dryness, and submit the dry mass again to the action of alcohol in smaller quantity than before: any muriate of soda which had been dissolved will now remain undissolved, and may be added to the other portion; or at least any quantity of it dissolved must be extremely minute. A slight trace of muriate of lime, or of magnesia, may adhere to the muriate of soda; but when a sufficient quantity of alcohol has been employed, the quantity is scarcely appreciable; and the trivial errors from these two circumstances counteract each other, and so far serve to give the result more nearly accurate.

Evaporate the alcohol of the solution, or draw it off by distillation. To the solid matter add sulphuric acid, so as to expel the whole of the muriatic acid; and expose the residue to a heat approaching to redness, to remove any excess of sulphuric acid. By lixiviation with a small portion of water, the sulphate of magnesia will be dissolved, the sulphate of lime remaining undissolved, and the quantities of each, after exposure to a low red heat, will give the proportions of lime and magnesia. The quantity of soda will be found from the weight of muriate of soda heated to redness;

and the quantities of the acids will be determined in the same manner as in the general formula.

This method is equally proper to discover other ingredients which are more rarely present in mineral waters. Thus alumina will remain in the state of sulphate of alumina, along with the sulphate of magnesia, and may be detected, by precipitation, by bicarbonate of ammonia. Silica will remain with the muriate of soda, after the action of the alcohol, and will be obtained on dissolving that salt in water: and iron will be discovered by the colour it will give to the concentrated liquors, or the dry residues, in one or other of the steps of the operation.

Such is the method of examining mineral waters recommended by Dr. Murray. A similar process may be applied to the analysis of earthy minerals. When they are of such a composition as to be dissolved entirely, or nearly so, by an acid, that is, when they consist chiefly of lime, magnesia, and alumina, its direct application is sufficiently obvious; when they require the previous action of an alkali from the predominance of siliceous earth, on this being separated, the excess of alkali may be neutralized by muriatic acid; and the remaining steps of the analysis may be prosecuted with any modification which the peculiar composition will require. As the proportions of the ingredients are capable of being estimated with so much precision, it may be employed with more peculiar advantage where a small quantity only of the mineral can be submitted to analysis; and when it is employed, such a quantity only, 10 grains, for example, ought to be made the subject of experiment.

It will be advisable for the young chemist to analyze some mineral waters, for the sake of experiment, whose composition is pretty well ascertained, and then compare the results of his analyses with those of such chemists as have received sanction. Tables of the composition of the most celebrated mineral waters may be found in the works of Henry, Brande, &c. &c.

ANALYSIS OF EARTHS AND STONES.

Those indurated masses, more or less coherent, of which the solid part of our earth is composed, are called Stones. They may be considered as *salts*, or a mixture of earths either chemically or mechanically united with each other.

The acids found in stones are chiefly the sulphuric, carbonic, phosphoric, fluoric, boracic, arsenic, and tungstic. The bases are silica, alumina, lime, barytes, strontia, magnesia, and, in some rare cases, yttria, glucina, zirconia. Oxide of iron is a common constituent of stones: it gives colour to most of them. In some rare instances oxides of manganese, copper, chromium, and nickel, are found in stones, as well as other substances, which, in a general view of the subject, the memory is not easily charged with, but which present themselves on the application of tests.

Apparatus for Analyzing Stones.

To analyze a stone or earth, it is first necessary to reduce it to an impalpable powder; for that purpose two kinds of mortars are necessary. The first of these is of steel, usually called the *diamond mortar* (see plate 2, fig. 5), because it is employed for pounding diamonds. It consists of three pieces of polished steel. The first of these constitutes the bottom of the mortar: it is a circular piece of steel, about an inch thick; the top is flat and polished, only it has a circular ring raised a little above it, and the flat circular space within this ring is about an inch and a quarter in diameter. The second piece is a hollow cylinder of steel, of such a size as to fill exactly the circular space within the ring of the first piece, to which it is fitted by grinding. This cylinder is about two inches high, and the diameter within is about an inch. The third piece is a solid steel cylinder, of the same length as the hollow cylinder, into which it is fitted by grinding, and it has a bulb on the top. The stone, previously broken into small pieces, is reduced to a pretty fine powder in this mortar. A little of it is put into the hollow cylinder, the solid cylinder is fitted in, and, by a blow with a hammer, it is smartly struck against the bottom part. By this blow the fragment is crushed, the pieces of the mortar are now removed, and the powder which lay on the bottom piece is carefully poured into a glass capsule. By proceeding in this way the stone is reduced to a coarse powder.

To convert this into an impalpable powder an agate mortar is employed. Plate 2, fig. 7, exhibits an outline of this mortar: *a* is a section of it, *b* a profile of it, and *e* the pestle, which is also of agate. They are about three inches in diameter, and about an inch and a half or two inches thick. These mortars are sufficiently hard for grinding in them the hardest stony bodies. But when the mineral to be pounded is very hard, as sapphire, spinell, &c. a portion of the mortar is always ground down at the same time. It is necessary to keep an account of the portion. This is done by weighing the mortar before and at the end of the process. The loss of weight which it has sustained is the portion of the mortar which has been ground down and mixed with the mineral to be analyzed. As agate mortars are composed almost entirely of silica, we have only to subtract from the weight of silica which we obtain from the mineral, the quantity which has been rubbed from the mortar. The remainder will be the silica really contained in the mineral. Suppose that, while pounding a mineral in the mortar, the mortar undergoes a loss of twenty grains, and that we obtain forty grains of silica by the subsequent analysis; it is obvious that the mineral will really contain only twenty grains of silica, the other twenty grains having been rubbed off the mortar.

To pound the mineral successfully in an agate mortar, some precautions must be taken. We must put only a small quantity (not more than a few grains in weight) into the mortar at once. The pounding is performed by rubbing the pestle against the bottom of the mortar; and we must continue the friction till all feeling of grittiness has disappeared, and till the powdered mineral adheres together in the form of a cake. As it is of the utmost consequence not to lose a particle of the mineral during the pounding, the mortar must be placed upon a sheet of clean paper, and we must be careful not to drive any of the mineral out of the mortar by incautious pounding. When the whole mineral is reduced to powder, we must weigh it again. If the operation of pounding has been properly performed, the powder should be equal to the weight of the mineral and of the portion rubbed off the mortar added together.

When the mineral is reduced to an impalpable powder, the next step of the process is usually to mix with it twice or thrice its weight of caustic potash, or carbonate of soda, according to circumstances, and to expose the mixture to a red heat for an hour, in a silver crucible, about two inches in height.

This crucible must be inclosed within a common clay or black-lead crucible, and care must be taken not to expose it to a heat sufficient to melt the silver. There is little risk of this in a common fire, if we do not urge it with bellows.

When the mixture of alkali and stone has been exposed for an hour to a red heat, we must take it off the fire, and allow it to cool. Upon inspecting this hot matter, we are enabled, from the appearance which it assumes, to draw some conclusions respecting the constitution of the mineral. If the mixture has melted completely, we may be sure that the mineral either consists entirely of silica, or at least contains a considerable proportion of that earth. If it has not melted, the probability is, that a great deal of alumina is present in the mineral. If the mixture while hot has a brownish-red colour, but becomes green on cooling, we may be sure that iron is present. Grass-green indicates manganese, and yellowish-green chromium.

The next set of vessels required are dishes, into which the mixture is to be put after being softened with water, in order to be dissolved in muriatic acid, and afterwards evaporated to dryness, or nearly so, upon a sand bath. The most convenient vessels for this purpose are those made of green glass (plate 1, fig. 10) or of porcelain: the latter are shaped somewhat like a saucer, only they have a spout at one side, for the convenience of pouring out their contents, and they have no circular rim round the bottom.

Now let us suppose a stone to be presented for analysis. The first step of the process is to drop a fragment of it into muriatic acid. If it should effervesce in the acid and dissolve, we may infer that it is an earthy carbonate; but if not sensibly acted on by the acid, the process of analysis will be more complicated.

Simple Stones.

Great pains should be taken in selecting the specimen for analysis. It should be as pure as possible, and should be selected for the purpose by a skilful mineralogist. The chemist, before he begins the analysis, should ascertain the specific gravity of the specimen, and write down a mineralogical description of it from actual observation. This serves as a kind of testimony of the nature of the mineral, after it has been destroyed by the analysis.

The quantity taken for analysis may be about 50 grains. When more than this is employed, the analysis becomes very tedious: the time is shortened in proportion to the smallness of the quantity examined. If we work upon a grain or two only, we may ascertain the nature of the constituents in an hour or two; but 50 grains enable us to determine the weight of each constituent with sufficient exactness, while the quantity is so great as to render it unlikely that any one of the constituents should be overlooked, without our perceiving the oversight.

The first step of the analysis is the reduction of the mineral to an impalpable powder, in the way described. We then weigh out fifty grains of it, mix it with twice or thrice its weight of carbonate of soda, or pure potash, and expose it for an hour to a red heat in a platinum crucible. When the mineral contains a great proportion of silica, carbonate of soda answers just as well as caustic potash, while it is much cheaper.

When the crucible is removed from the fire, and has become cold, we must wipe it quite clean on the outside with a cloth, and then placing it in the middle of a Wedgwood evaporating dish, fill the crucible with distilled water. After standing some hours covered with water, the mixture at the bottom of the crucible will be partly softened. Stir it up with a platinum spatula; pour off the water, containing all the softened part of the mixture, into the Wedgwood dish; fill up the crucible with distilled water again, and let it stand some hours, as before. In this way we must proceed, till the whole of the mixture has been washed out of the crucible.

Muriatic acid must now be poured into the watery liquid in the Wedgwood dish: an effervescence takes place, because the alkali has absorbed carbonic acid during the preceding process, which is driven off as it dissolves in the muriatic acid. We continue to add muriatic acid till all effervescence has ceased, and till the whole of the matter has been dissolved.

Some minerals which contain little silica and a great deal of alumina, will not be rendered quite soluble by heating them with an alkali. In such cases a portion of insoluble matter remains, upon which the muriatic acid has no action. This is a portion of the mineral in its original state. To render it soluble we must repeat the heating with an alkali, softening with water, and adding muriatic acid till we obtain a complete solution. Five or six repetitions of these processes may in some cases be requisite. With such minerals it is better to employ borax, or phosphoric acid, than potash or soda. We shall then obtain a complete solution by one process, which will greatly diminish the risk of error. If we employ too little alkali, it may happen that we do not obtain a complete solution in muriatic acid, even when the mineral contains a sufficient quantity of silica. The insoluble matter in such a case will be pure silica, and will readily enter into fusion when heated with a new portion of alkali.

Let us suppose the muriatic acid solution accomplished, the next step in the process is to evaporate this solution upon a lamp furnace (plate 1, fig. 4). Place the Wedgwood dish upon one of the rings of the lamp furnace, and expose it to a heat sufficient to cause it to evaporate; but care must be taken not to raise the heat so high as to cause the liquid to boil, for in such a case a portion of it would be driven out of the dish and lost. When the solution is considerably concentrated by evaporation, it loses its liquid form, and assumes that of a jelly, at least if it contain any considerable portion of silica. As soon as this change has taken place we must stir it with a platinum spatula, and continue the agitation till the liquid is evaporated nearly to dryness. If this be neglected, it is apt to sputter up, and part of it to be driven out of the vessel. Besides, the portion next the bottom is apt to be overheated, and some of the earthy salts might run some hazard of being decomposed. The evaporation requires not to be carried farther than the gelatinizing of the silica, if our sole object be merely to obtain the whole of that substance ; for when silica is reduced to the state of a stiff jelly, it is no longer soluble in water.

Upon the gelatinous mass thus obtained distilled water is to be poured; the Wedgwood dish is to be put again upon the lamp furnace; and the whole stirred about occasionally with the spatula, till the water has become almost boiling hot. The whole is now to be poured upon a filter. The silica having been rendered insoluble by the evaporation of the muriatic acid liquid to dryness, will remain upon the filter; but all the other constituents of the mineral, being in the state of muriates, will be dissolved in the water, and in that state will pass through the filter. Distilled water must now be poured upon the filter to wash the silica clean, and we must continue to do so till it passes through quite tasteless, and is incapable of rendering a solution of common salt milky. The filter is now to be dried, and then accurately weighed. We then put the silica into a platinum crucible, the weight of which has been previously noted. Wipe the filter quite clean with a cloth, and weigh it again. The difference of weight gives the quantity of silica collected on the filter. Let this weight be a. By weighing the platinum crucible containing the silica, we find the quantity of it which we have collected in that vessel. Let it be b. Expose the platinum crucible for half an hour to a red heat, and weigh it again as soon as it has become cold. The weight of the silica will be diminished; because it will, by the heat, be deprived of the whole water with which it was impregnated when weighed upon the filter. Let its new weight be c. Let the weight of the whole silica, supposing it had been exposed to a red heat, be x. We have $b : c :: a : x$ and $x = \frac{a \times c.}{b}$

Having thus obtained the silica in a separate state, the next step of the process is to separate and weigh the alumina. For this purpose we must pour carbonate of soda into the aqueous solution which has passed through the filter, till we throw down the whole of the constituents of the mineral that were united to the muriatic acid. This precipitate is to be edulcorated, and, while still moist, a quantity of caustic potash ley is to be poured over it, and the whole boiled for half an hour in a glass flask. The alumina, if any be present, will be dissolved in the ley, while the other substances will remain undissolved: allow them to fall to the bottom. Decant off the potash ley; wash the residual powder clean with water, and add the liquid to the potash ley. Pour a solution of muriate of ammonia into the potash till the liquid acquires a pretty strong smell of ammonia: the alumina will precipitate in white flocks. Continue to add muriate of ammonia as long as any precipitate appears. The alumina thus separated must be washed, dried, and exposed to a red heat, and weighed.

Potash ley is capable of dissolving not merely alumina, but glucina also. The white powder thus precipitated by muriate of ammonia, may therefore be glucina as well as alumina. To determine this point we must dissolve it in sulphuric acid by the assistance of heat. If any portion remain undissolved, it must be considered as silica, and be added to the quantity of that substance found previously. Into the sulphuric acid solution we must pour a quantity of sulphate or muriate of potash, previously dissolved in water, and set the liquid aside for a few days. If the earth was alumina we shall find a number of crystals of alum deposited at the bottom of the vessel. If it was glucina, no such deposit will have taken place. When all the crystals of alum that can be obtained have been deposited, we must wipe them dry and weigh them. The alumina which they contain, is equivalent to $\frac{10.86}{100}$ or 0.1086 of the weight of the crystals. If this weight be equal to the whole of the earth originally dissolved in the sulphuric acid, we may conclude that the whole of that earth was alumina; but if there be a deficiency, the probability is that some glucina was also present. This will be found in the sulphuric acid solution, from which it may be precipitated by an alkaline carbonate. We may be certain that this precipitate is glucina if we find it soluble in solution of carbonate of ammonia; if it form sweet-tasted salts with acids; and if it be precipitated white from acids by ferrocyanate of potash, and yellow by infusion of nut-galls.

If yttria be suspected in the matter which remained undissolved after the action of the potash ley, we may digest it in solution of carbonate of ammonia, which will dissolve that earth, but will leave all the other ingredients untouched. And the yttria may be obtained pure by evaporating the solution of carbonate of ammonia to dryness, and exposing the residue to a red heat.

The residue of the mineral thus deprived of the silica, alumina, glucina, and yttria, may still consist of lime, magnesia, oxide of iron, oxide of manganese, and in some rare cases oxide of chromium and oxide of nickel. It is always proper to determine, by means of tests, which of these bodies are present, and which absent; because the mode of the analysis must vary with the number and nature of the ingredients. If, for example, nothing were present but lime and oxide of iron, we should dissolve the whole in muriatic acid, precipitate the iron by means of ammonia, and the lime by means of oxalate of ammonia. If the residue consisted of lime, magnesia, and oxide of iron, we should dissolve it in dilute sulphuric acid, evaporate the solution to dryness at as low a heat as possible; water, mixed with a little alcohol, would dissolve the sulphates of magnesia and iron, but would leave the sulphate of lime. This last sulphate, being heated to redness and weighed, would give us the lime contained in the mineral, which will amount to $\frac{3.625}{8.625}$ or 0.42 of the sulphates. The iron may be precipitated from the liquid solution by means of benzoate of ammonia. The precipitate being washed, dried, exposed to a red heat, and weighed, will be red oxide of iron. Nine-tenths of its weight are equivalent to the black oxide of iron which existed in the mineral. The magnesia may now be precipitated by potash and weighed.

If besides these three ingredients oxide of manganese be likewise present, the very same method of proceeding will answer; only, after having separated the iron by means of benzoate of ammonia, we must pour a little hydrosulphuret of potash or ammonia into the liquid which still contains the magnesia and manganese: by this addition the manganese will be precipitated. If it be heated to redness for some time in an open vessel, its weight will indicate peroxide of manganese. To convert it into protoxide of manganese we must multiply the weight of peroxide by $\frac{9}{11}$ or 0.818.

The chromium, when present, is indicated by protonitrate of mercury forming a red precipitate. When this metal is suspected in the mineral subjected to analysis, from the peculiar green or red colour which it has, we must employ nitric acid, instead of muriatic, to form the original solution. After the silica is separated, and the liquid deprived of its excess of acid by the requisite evaporation, we may precipitate the chromium by means of protonitrate of mercury. The precipitate being dried, exposed to a red heat, and weighed, will give the quantity of protoxide of chromium. If the chromium was present in the state of chromic acid, to obtain its weight we must multiply the weight of the green oxide by 1.3.

Nickel has hitherto been found in one stony mineral only—the chrysoprase, which consists chiefly of silica, and has an apple-green colour. In this mineral it is associated with iron and lime. After the separation of the silica and alumina, the iron may be precipitated by ammonia, and when it is separated, we may throw down the nickel by hydrosulphuret of potash. Nothing will remain but the lime, which may be thrown down by an alkaline carbonate, or by oxalate of ammonia.

After having thus obtained all the constituents of the mineral in a separate state, and determined the weight of each, the next step is to add all these weights together. If they amount to the weight of the portion of mineral analyzed, we have reason to conclude that the analysis has been rightly performed; but if there be a deficiency, we have either committed an error, or the mineral contains some ingredient which we have overlooked.

As water occurs very frequently in minerals, we must in the first place endeavour to discover whether the deficiency be not owing to a portion of that substance, which we have not reckoned. For this purpose we must take a determinate weight of the mineral (fifty grains for example), and expose it for an hour to a strong red heat in a platinum crucible. The heat will drive off the water, if any be present, and the deficiency of weight, after the mineral has been allowed to cool, will indicate the quantity of water which has been driven off.

If the mineral contain no water, or if the quantity which it contains be insufficient to make up the deficiency between the original weight of the stone, and the weight of the constituents which we have obtained, it may probably contain an alkali; for three different alkalies have been found in stones, namely, potash, soda, and lithia. To detect the latter alkaline ingredient we must make a second analysis of the mineral, but we must conduct it in a different way. Fifty grains of the stone, reduced to a fine powder, must be mixed with four times its weight of nitrate of barytes, or three times its weight of carbonate of barytes. This mixture must be exposed for two hours to a strong red heat in a platinum crucible. If nitrate of barytes be employed, it will enter into fusion at a comparatively low heat. Of course, if the mixture were exposed suddenly to a strong red heat, it would swell greatly, and a portion of it would probably be driven out of the crucible and lost. To prevent this we must raise the heat gradually, and not bring it to the utmost degree of intensity till the nitrate of barytes has had time to lose most of its acid.

The fused mass is to be taken from the fire, allowed to cool, softened with water, and dissolved in muriatic acid, precisely in the way described at the commencement of this section. Into the muriatic acid solution a quantity of sulphuric acid is to be poured, capable of decomposing all the muriates, and converting them into sulphates. The liquid becomes immediately milky, in consequence of the precipitation of the sulphate of barytes. Separate the precipitate by the filter. Then pour an excess of carbonate of ammonia into the liquid, and boil the whole for some minutes. All the earths and metallic oxides will be precipitated, and nothing will remain in the solution but the sulphate of ammonia, and the sulphate of the alkali contained in the mineral, if any such exist in it. Evaporate the liquid to dryness, and expose the dry mass to a red heat in a platinum crucible. The sulphate of ammonia will be sublimed, and nothing will remain but the alkaline sulphate derived from the mineral. Weigh this sulphate, then dissolve it in water, and crystallize the salt. It will be easy, from the shape of the crystals, and the properties of the salt, to determine whether it be sulphate of potash, sulphate of soda, or sulphate of lithia. The composition of all these sulphates being known, we may easily deduce from the weight of the sulphate previously ascertained, how much potash, soda, or lithia, the mineral contained.

If no alkali can be detected in the mineral, it may contain *fluoric acid*, which constitutes an ingredient of the topaz, and of some other analogous minerals. To ascertain whether any of this acid be present, mix a portion of the mineral reduced to fine powder with sulphuric acid, and expose the mixture to heat in a glass vessel. If the glass be corroded, and if the vessel acquire a smell similar to that of muriatic acid, we may conclude that fluoric acid is present. To determine its quantity we must make a new analysis of the mineral. Fifty grains of it are to be fused with an alkali, softened with water, dissolved in muriatic acid, and the silica separated by the method described at the beginning of this section. The remaining liquid is to be precipitated by carbonate of potash, and being filtered, and exactly neutralized, is next to be precipitated by means of lime-water. The precipitate is *fluor spar*. It must be exposed to a red heat. 26.32 *per cent.* of its weight indicates the fluoric acid, if we consider fluor spar as a fluate of lime. But if we consider fluor spar to be a compound of fluorine and calcium, according to the hypothesis of Ampére and Davy, in that case the fluorine will amount to 47.37 *per cent.* of the fluor spar obtained.

Carbonates.

As the carbonic acid cannot be conveniently collected and weighed, we are under the necessity of adopting a different method for the analysis of carbonates. Provide a phial with two mouths. To one of these mouths let a stopper be fitted: the other must remain open. Pour into this phial a quantity of concentrated nitric acid, recently heated, to deprive it of the nitrous acid which the smoking acids of the shops always contain. Put into the mouth of the phial a plug of cotton-wool, and balance it accurately upon the scales of a good beam. Suppose the carbonate to be subjected to analysis be calcareous spar or common limestone. Break the mineral into small pieces, of such a size that they can conveniently pass through the mouth of the phial; but let there be no powder. Into the same scale that contains the phial with the nitric acid, put fifty grains of these pieces, and counterpoise them exactly by fifty grains weight put into the opposite scale.

The nitric acid must have been poured into the phial through the mouth furnished with a glass stopper: as soon as it is poured in, the mouth must be wiped with a piece of paper, and the stopper put in its place. Remove the cotton plug, and with a pair of forceps lift up the pieces of calcareous spar, and put them one after the other into the phial through the open mouth: then replace the cotton plug. The pieces will immediately begin to dissolve with effervescence, owing to the escape of the carbonic acid gas, and in proportion to its escape the weight will diminish, and the opposite scale will preponderate. When the solution is completed, or when the effervescence is at an end, remove the phial from the balance; place it upon a table; take out the glass stopper and the cotton plug; then introduce through one of the mouths of the phial a small glass tube, and plunge it nearly, but not quite, as low as the surface of the nitric acid. Apply the mouth to the other end of the tube, and blow air gently through it for about a minute. Then draw in air through it into the mouth for about another minute. This will remove the carbonic acid gas which is usually floating in the empty part of the phial, and materially affects the weight. Put the glass stopper and the cotton plug again in their places. Put the phial on the same scale of the balance where it was before, and add weights till the equilibrium is restored. These weights are equivalent to the weight of the carbonic acid which made its escape during the solution of the mineral in the nitric acid.

By the same method may the quantity of carbonic acid present in carbonate of strontia, carbonate of barytes, carbonate of magnesia, carbonate of iron, magnesian limestone, and, indeed, in all the carbonates, be ascertained. When carbonate of barytes is analyzed in this way, we must dilute the nitric acid with water, otherwise the solution does not succeed. This renders the result not quite so accurate as it would otherwise be; for when the nitric acid is very weak, it is capable of retaining a portion of the carbonic acid in solution. We may, indeed, determine the bulk of the quantity thus held in solution, by putting the liquid into a small flask, or retort, furnished with a bent tube, passing into a mercurial trough. By carefully heating the liquid, we can drive off the carbonic acid gas, and measure its bulk in a glass jar standing inverted over the mercury. But such an experiment must be made with great caution, lest we drive over nitric acid, which would act upon the mercury, and produce nitrous gas, the evolution of which would disturb all our estimates.

The weight of carbonic acid in the carbonates being determined, we can ascertain that of the earthy bodies dissolved in the nitric acid, by the rules already laid down in a preceding part of this article. If there be any portion which refuses to dissolve in the nitric acid, we must carefully wash it, and dry it, and then heat it with thrice its weight of carbonate of soda. The fused mass may be analyzed precisely in the way described at the beginning of this section.

One hundred parts of the earthy carbonates contain respectively, when quite pure, the following proportions of carbonic acid :—

Carbonate of Magnesia ..	52.38	carbonic acid.
Lime	44.00	
Strontia	29.73	
Barytes	22.00	

Knowing these proportions, we may easily deduce from the weight of carbonic acid, obtained from any native carbonate subjected to analysis, the degree of its purity with very little trouble.

We might lay down here rules for analyzing the other earthy salts, as sulphates, phosphates, tungstates, &c. which occur ready formed in the earth; but such details would swell this article to too great a length.

ANALYSIS OF SOILS.

The following abstract for determining the composition of a soil, is copied from a memoir presented by Sir Humphry Davy to the Board of Agriculture.

1. *Utility of investigation relating to the Analysis of Soils.*—The methods of improving lands are immediately connected with the knowledge of the chemical nature of soils, and experiments on their composition appear capable of many useful applications.

The importance of this subject has been already felt by some very able cultivators of science: many useful facts and observations, with regard to it, have been furnished by Mr. Young: it has been examined by Lord Dundonald, in his treatise on the Connexion of Chemistry with Agriculture, and by Mr. Kirwan, in his excellent Essay on Manures;

but the inquiry is still far from being exhausted, and new methods of elucidating it are almost continually offered, in consequence of the rapid progress of chemical discovery.

In the following pages I shall have the honour of laying before the Board an account of those modes of analyzing soils which appear most precise and simple, and most likely to be useful to the practical farmer: they are founded partly upon the labours of the gentlemen whose names have been just mentioned, and partly upon some later improvements.

The substances which are found in soils are certain mixtures or combinations of some of the primitive earths, animal or vegetable matter, in a decomposing state, certain saline compounds, and the oxide of iron. These bodies always retain water, and exist in very different proportions in different lands; and the end of analytical experiments is the detection of their quantities, and mode of union.

2. *Mode of collecting Soils for Analysis.*—In cases when the general nature of the soil of a field is to be ascertained, specimens of it should be taken from different places, two or three inches below the surface, and examined as to the similarity of their properties. It

sometimes happens, that, upon plains, the whole of the upper stratum of the land is of the same kind, and, in this case, one analysis will be sufficient; but, in valleys, and near the beds of rivers, there are very great differences, and it now and then occurs, that one part of a field is calcareous, and another part siliceous: and, in this case, and in analogous cases, the portions different from each other should be separately submitted to experiment.

Soils, when collected, if they cannot be immediately examined, should be preserved in phials quite filled with them, and closed with ground glass stoppers.

The quantity of soil most convenient for a perfect analysis is from two to four hundred grains. It should be collected in dry weather, and exposed to the atmosphere till it becomes dry to the touch.

The specific gravity of a soil, or the relation of its weight to that of water, may be ascertained by introducing into a phial, which will contain a known quantity of water, equal volumes of water and of soil; and this may be easily done by pouring in water till it is half full, and then adding the soil till the fluid rises to the mouth; the difference between the weight of the soil and that of the water will give the result. Thus, if the bottle contains four hundred grains of water, and gains two hundred grains when half filled with water and half with soil, the specific gravity of the soil will be 2; that is, it will be twice as heavy as water; and if it gained one hundred and sixty-five grains, its specific gravity would be 1825, water being 1000.

It is of importance that the specific gravity of a soil should be known, as it affords an indication of the quantity of animal and vegetable matter it contains, these substances being always most abundant in the lighter soils.

The other physical properties of soils should likewise be examined before the analysis is made, as they denote to a certain extent their composition, and serve as guides in directing the experiments. Thus siliceous soils are generally rough to the touch, and scratch glass when rubbed upon it; argillaceous soils adhere strongly to the tongue, and emit a strong earthy smell when breathed on; and calcareous soils are soft, and much less adhesive than argillaceous soils.

3. *Mode of ascertaining the quantity of Water of Absorption in Soils.*—Soils, though as

dry as they can be made by continued exposure to the air, in all cases still contain a considerable quantity of water, which adheres with great obstinacy to the earths and animal and vegetable matter, and can only be driven off from them by a considerable degree of heat. The first process of analysis is, to free the given weight of soil from as much of this water as possible, without in other respects affecting its composition; and this may be done by heating it for ten or twelve minutes over a spirit lamp, in a basin of porcelain (fig. 4, pl. 1,) to a temperature equal to 300° Fahrenheit*; and in case a thermometer is not used, the proper degree may be easily ascertained by keeping a piece of wood in contact with the bottom of the dish: as long as the colour of the wood remains unaltered, the heat is not too high; but when the wood begins to be charred, the process must be stopped. A small quantity of water will perhaps remain in the soil even after this operation, but it always affords useful comparative

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* In several experiments, in which this process has been carried on by distillation, I have found the water that came over pure, and no sensible quantity of other volatile matter was produced.

results; and if a higher temperature were employed, the vegetable or animal matter would undergo decomposition, and, in consequence, the experiment be wholly unsatisfactory.

The loss of weight in the process should be carefully noted; and when in 400 grains of soil it reaches as high as 50, the soil may be considered as in the greatest degree absorbent, and retentive of water, and will generally be found to contain much vegetable or animal matter, or a large proportion of aluminous earth. When the loss is only from 20 to 10, the land may be considered as only slightly absorbent and retentive, and the siliceous earth as most abundant.

4. *Of the separation of Stones, Gravel, and Vegetable Fibres, from Soils.*—None of the loose stones, gravel, or large vegetable fibres, should be divided from the pure soil till after the water is drawn off; for these bodies are themselves often highly absorbent and retentive, and, in consequence, influence the fertility of the land. The next process, however, after that of heating, should be their separation, which may be easily accomplished by the sieve, after the soil has been gently bruised in a mortar. The weights of the

vegetable fibres or wood, and of the gravel and stones, should be separately noted down, and the nature of the last ascertained; if calcareous, they will effervesce with acids; if siliceous, they will be sufficiently hard to scratch glass; and if of the common argillaceous class of stones, they will be soft, easily scratched with a knife, and incapable of effervescing with acids.

5. *Separation of the Sand and Clay, or Loam, from each other.*—The greater number of soils, besides gravel and stones, contain larger or smaller proportions of sand of different degrees of fineness; and it is a necessary operation, the next in the process of analysis, to detach them from the parts in the state of more minute division, such as clay, loam, marl, and vegetable and animal matter, and the matter soluble in water. This may be effected in a way sufficiently accurate, by boiling the soil in three or four times its weight of water, and when the texture of the soil is broken down, and the water cool, by agitating the parts together, and then suffering them to rest. In this case, the coarse sand will generally separate in a minute, and the finer in two or three minutes, whilst the

minutely divided earthy, animal, or vegetable matter, will remain in a state of mechanical suspension for a much longer time; so that, by pouring the water from the bottom of the vessel (fig. 14, pl. 1,) after one, two, or three minutes, the sand will be principally separated from the other substances, which, with the water containing them, must be poured into a filter, and after the water has passed through, collected, dried, and weighed: the sand must likewise be weighed, and their respective quantities noted down. The water of lixiviation must be preserved, as it will be found to contain the saline matter, and the soluble animal and vegetable matters, if any exist in the soil.

6. *Examination of the Sand.*—By the process of washing and filtration, the soil is separated into two portions, the most important of which is generally the finely divided matter. A minute analysis of the sand is seldom or never necessary, and its nature may be detected in the same manner as that of the stones and gravel. It is always either siliceous sand or calcareous sand, or a mixture of both. If it consist wholly of carbonate of lime, it will be rapidly soluble in muriatic

acid, with effervescence; but if it consist partly of this substance, and partly of siliceous matter, the respective quantities may be ascertained by weighing the residuum after the action of the acid, which must be applied till the mixture has acquired a sour taste, and has ceased to effervesce. This residuum is the siliceous part: it must be washed, dried, and heated strongly in a crucible; the difference between the weight of it and the weight of the whole indicates the proportion of calcareous sand.

7. *Examination of the finely divided Matter of Soils; and mode of detecting Mild Lime and Magnesia.*—The finely divided matter of the soil is usually very compound in its nature; it sometimes contains all the four primitive earths of soils, as well as animal and vegetable matter; and to ascertain the proportions of these with tolerable accuracy is the most difficult part of the subject.

The first process to be performed, in this part of the analysis, is the exposure of the fine matter of the soil to the action of muriatic acid. This substance should be poured upon the earthy matter in an evaporating basin, in a quantity equal to twice the weight of the earthy matter, but diluted with double its volume of water. The mixture should be often stirred, and suffered to remain for an hour, or an hour and a half, before it is examined.

If any carbonate of lime or of magnesia exist in the soil, they will have been dissolved in this time by the acid, which sometimes takes up likewise a little oxide of iron, but very seldom any alumina.

The fluid should be passed through a filter; the solid matter collected, washed with rain water, dried at a moderate heat, and weighed. Its loss will denote the quantity of solid matter taken up. The washings must be added to the solutions, which, if not sour to the taste, must be made so by the addition of fresh acid, when a little solution of prussiate of potash* and iron must be mixed with the whole. If a blue precipitate occurs, it denotes the presence of oxide of iron, and the solution of the prussiate must be dropped in till no further effect is produced. To ascertain its quantity, it must be collected in the same manner as other solid precipitates, and heated red: the result is oxide of iron,

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* Ferrocyanate of potash.

which may be mixed with a little oxide of manganese.

Into the fluid, freed from oxide of iron, a solution of neutralized carbonate of potash must be poured till all effervescence ceases in it, and till its taste and smell indicate a considerable excess of alkaline salt.

The precipitate that falls down is carbonate of lime; it must be collected on the filter, and dried at a heat below that of redness.

The remaining fluid must be boiled for a quarter of an hour, when the magnesia, if any exist, will be precipitated from it, combined with carbonic acid; and its quantity is to be ascertained in the same manner as that of the carbonate of lime.

If any minute proportion of alumina should, from peculiar circumstances, be dissolved by the acid, it will be found in the precipitate with the carbonate of lime, and it may be separated from it by boiling for a few minutes with caustic potash, sufficient to cover the solid matter. This substance dissolves alumina, without acting upon carbonate of lime.

Should the finely-divided soil be sufficiently calcareous to effervesce very strongly with acids, a very simple method may be adopted for ascertaining the quantity of carbonate of lime, and one sufficiently accurate in all common cases.

Carbonate of lime, in all its states, contains a determinate proportion of carbonic acid, *i. e.* about 43 per cent. so that when the quantity of this elastic fluid, given out by any soil during the solution of its calcareous matter in an acid, is known, either in weight or measure, the quantity of carbonate of lime may be easily discovered.

When the process by diminution of weight is employed, two parts of the acid and one part of the matter of the soil must be weighed in two separate bottles, and very slowly mixed together till the effervescence ceases: the difference between their weight before and after the experiment denotes the quantity of carbonic acid lost; for every four grains and a quarter of which, ten grains of carbonate of lime must be estimated.

The best method of collecting the carbonic acid, so as to discover its volume, is by the pneumatic apparatus, the construction and application of which is described at the end of this paper. The estimation is, for every ounce measure of carbonic acid, two grains of carbonate of lime.

8. *Mode of ascertaining the quantity of insoluble finely-divided Animal and Vegetable Matter.*—After the fine matter of the soil has been acted upon by muriatic acid, the next process is to ascertain the quantity of finely-divided insoluble animal and vegetable matter that it contains.

This may be done with sufficient precision, by heating it to strong ignition in a crucible, over a common fire, till no blackness remains in the mass. It should be often stirred with a metallic wire, so as to expose new surfaces continually to the air: the loss of weight that it undergoes denotes the quantity of the substance that it contains destructible by air and fire.

It is not possible, without very refined and difficult experiments, to ascertain whether this substance is wholly animal or vegetable matter, or a mixture of both. When the smell emitted during the incineration is similar to that of burnt feathers, it is a certain indication of some animal matter; and a copious blue flame at the time of ignition almost always denotes a considerable proportion of vegetable matter. In cases when the experiment is needed to be very quickly performed, the destruction of the decomposable substances may be assisted by the agency of nitrate of ammonia, which, at the time of ignition, may be thrown gradually upon the heated mass, in the quantity of twenty grains for every hundred of residual soil. It accelerates the dissipation of the animal and vegetable matter, which it causes to be converted into elastic fluids; and it is itself at the same time decomposed and lost.

9. *Mode of separating Argillaceous and Siliceous Matter, and Oxide of Iron.*—The substances remaining after the decomposition of the vegetable and animal matter are generally minute particles of earthy matter, containing usually alumina and silica with combined oxide of iron, or of manganese.

To separate these from each other, the solid matter should be boiled for two or three hours with sulphuric acid, diluted with four times its weight of water; the quantity of the acid should be regulated by the quantity of solid residuum to be acted on, allowing for every hundred grains two drachms, or one hundred and twenty grains of acid.

The substance remaining after the action of the acid, may be considered as siliceous; and it must be separated, and its weight ascertained, after washing and drying in the usual manner. The alumina and the oxide of iron and manganese, if any exist, are all dissolved by the sulphuric acid; they may be separated by succinate of ammonia, added to excess, which throws down the oxide of iron; and by soap-ley, or potash, which will dissolve the alumina, but not the oxide of manganese: the weights of the oxides ascertained after they have been heated to redness, will denote their quantities.

Should any magnesia and lime have escaped solution in the muriatic acid, they will be found in the sulphuric acid: this, however, is scarcely ever the case; but the process for detecting them and ascertaining their quantities, is the same in both instances.

The method of analysis by sulphuric acid is sufficiently precise for all usual experiments; but if very great accuracy be an object, dry carbonate of potash must be employed as the agent, and the residuum of the incineration (8) must be heated red for half an hour, with four times its weight of this substance, in a crucible of silver, or of well baked porcelain. The mass obtained must be dissolved in muriatic acid, and the solution evaporated till it is nearly solid; distilled water must then be added, by which the oxide of iron and all the earths, except silica, will be dissolved in combination as muriates. The silica, after the usual process of lixiviation, must be heated red; the other substances may be separated in the same manner as from the muriatic and sulphuric solutions.

This process is the one usually employed by chemical philosophers for the analysis of stones.

10. *Mode of discovering Soluble and Animal and Vegetable Matter, and Saline Substances.*—If any saline matter, or soluble vegetable or animal matter, is suspected in the soil, it will be found in the water of lixiviation used for separating the sand.

This water must be evaporated to dryness in an appropriate dish, at a heat below its boiling point.

If the solid matter obtained is of a brown colour and inflammable, it may be considered as partly vegetable extract. If its smell, when exposed to heat, be like that of burnt feathers, it contains animal or albuminous matter; if it be white, crystalline, and not destructible by heat, it may be considered as principally saline matter.

Nitrate of potash (nitre), or nitrate of lime, is indicated in this saline matter, by its scintillating with a burning coal. Sulphate of magnesia may be detected by its bitter taste; and sulphate of potash produces no alteration in solution of carbonate of ammonia, but precipitates solution of muriate of barytes.

11. *Mode of detecting Sulphate of Lime (Gypsum) and Phosphate of Lime in Soils.*— Should sulphate or phosphate of lime be suspected in the entire soil, the detection of them requires a particular process upon it. A given weight of it, for instance, four hundred grains, must be heated red for half an hour in a crucible, mixed with one-third of powdered charcoal. The mixture must be boiled for a quarter of an hour in a half pint of water, and the fluid collected through the filter, and exposed for some days to the atmosphere in an open vessel. If any notable quantity of sulphate of lime (*gypsum*) existed in the soil, a white precipitate will gradually form in the

fluid, and the weight of it will indicate the proportion.

Phosphate of lime, if any exist, may be separated from the soil after the process for gypsum. Muriatic acid must be digested upon the soil, in quantity more than sufficient to saturate the soluble earths : the solution must be evaporated, and water poured upon the solid matter. This fluid will dissolve the compounds of earths with the muriatic acid, and leave the phosphate of lime untouched.

12. *Statement of Results and Products.*—When the examination of a soil is completed, the products should be numerically arranged, and their quantities added together ; and if they nearly equal the original quantity of soil, the analysis may be considered as accurate. It must, however, be noticed, that when phosphate or sulphate of lime are discovered by the independent process (11), a correction must be made for the general process, by subtracting a sum equal to their weight from the quantity of carbonate of lime obtained by precipitation from the muriatic acid.

In arranging the products, the form should be in the order of the experiments by which they were obtained.

Thus I (*Sir H. Davy*) obtained from 400 grains of a good siliceous sandy soil, from a hop garden, near Tunbridge, Kent—

		Grains.
Of water of absorption		19
Of loose stone and gravel, principally siliceous		53
Of undecomposed vegetable fibres		14
Of fine siliceous sand		212
Of minutely divided matter, separated by agitation and filtration, and consisting of		
Carbonate of lime	19	
Carbonate of magnesia	3	
Matter destructible by heat, principally vegetable	15	
Silica	21	
Alumina	13	
Oxide of iron	5	
Soluble matter, principally common salt and vegetable extract	3	
Gypsum	2	
		81
Amount of all the products		379
Loss		21

The loss in this analysis is not more than usually occurs, and it depends upon the impossibility of collecting the whole quantities of the different precipitates, and upon the presence of more moisture than is accounted for in the water of absorption, and which is lost in the different processes.

13. *This general Method of Analysis may, in many cases, be much simplified.*—When

the experimenter is become acquainted with the use of the different instruments, the properties of the re-agents, and the relations between the external and chemical qualities of soils, he will seldom find it necessary to perform, in any one case, all the processes that have been described. When his soil, for instance, contains no notable proportion of calcareous matter, the action of the muriatic acid (7) may be omitted. In examining peat soils, he will principally have to attend to the operation by fire and air (8); and in the analysis of chalks and loams, he will be often able to omit the experiment by sulphuric acid (9).

In the first trials that are made by persons unacquainted with chemistry, they must not expect much precision of result. Many difficulties will be met with; but in overcoming them the most useful kind of practical knowledge will be obtained; and nothing is so instructive in experimental science as the detection of mistakes. The correct analyst ought to be well grounded in general chemical information; but perhaps there is no better mode of gaining it, than that of attempting original investigations. In pursuing his experiments, he will be continually obliged to learn from books the history of the substances he is employing or acting upon; and his theoretical ideas will be more valuable in being connected with practical operations, and acquired for the purpose of discovery.

14. *On the Improvement of Soils, as connected with the principle of their Composition.*—In cases where a barren soil is examined with a view to its improvement, it ought always, if possible, to be compared with an extremely fertile soil in the same neighbourhood, and in a similar situation: the difference given by their analysis would indicate the methods of cultivation; and thus the plan of improvement would be founded upon accurate scientific principles.

If the fertile soil contained a large quantity of sand in proportion to the barren soil, the process of amelioration would depend simply upon a supply of this substance; and the method would be equally simple with regard to soils deficient in clay or calcareous matter.

In the application of clay, sand, loam, marl, or chalk, to lands, there are no particular chemical principles to be observed; but when quick-lime is used, great care must be taken that it is not obtained from the magnesian limestone; for in this case, as has been shewn by Mr. Tennant, it is exceedingly injurious to land *. The magnesian limestone may be distinguished from the common limestone by its greater hardness, and by the length of time that it requires for its solution in acids; and it may be analyzed by the process of carbonate of lime and magnesia, 7.

When the analytical comparison indicates an excess of vegetable matter as the cause of sterility, it may be destroyed by much pulverization and exposure to air, by paring and burning, or the agency of lately-made quicklime; and the defect of animal and vegetable matter must be supplied by animal or vegetable manure.

15.—*Sterile Soils in different climates and situations must differ in composition.*—The general indications of fertility and barrenness, as found by chemical experiments, necessarily must differ in different climates, and under different circumstances. The power of soils to absorb moisture, a principle essential to

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* Philosoph. Trans. for 1799, p. 305. This limestone is found abundantly in Yorkshire, Derbyshire, and Somersetshire.

their productiveness, ought to be much greater in warm and dry countries than in cold and moist ones ; and the quantity of fine aluminous earth they contain, larger. Soils, likewise, that are situated on declivities, ought to be more absorbent than those in the same climate on plains or in valleys *. The productiveness of soils must likewise be influenced by the nature of the subsoil, or the earthy or stony strata on which they rest ; and this circumstance ought to be particularly attended to in considering their chemical nature, and the system of improvement. Thus a sandy soil may sometimes owe its fertility to the power of the subsoil to retain water ; and an absorbent clayey soil may occasionally be prevented from being barren, in a moist climate, by the influence of a substratum of sand or gravel.

16.—*Of the chemical composition of fertile Corn soils in this climate.*—Those soils that are most productive of corn contain always certain proportions of aluminous and calcareous earth in a finely-divided state, and a certain quantity of vegetable or animal matter.

The quantity of calcareous earth is, how-

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* Kirwan, Trans. Irish Academy, vol. v. p. 175.

ever, very various, and, in some cases, exceedingly small. An excellent wheat soil, from the neighhourhood of West Drayton, Middlesex, gave three parts in five of siliceous sand; and the finely-divided matter consisted of

Carbonate of lime	28
Silica	32
Alumina	29
Animal or vegetable matter and moisture	11

This soil was very coherent in texture. In all cases the constituent parts of the soil which give tenacity and coherence are the finely-divided matters; and they possess the power of giving those qualities in the highest degree when they contain much alumina.

Vegetable or animal matters, when finely divided, not only give coherence, but likewise softness and penetrability; but neither they nor any other part of the soil must be in too great proportion; and a soil is unproductive if it consist entirely of impalpable matters.

Pure alumina or silica, pure carbonate of lime or carbonate of magnesia, are incapable of supporting healthy vegetation.

No soil is fertile that contains as much as

19 parts out of 20 of any of the constituents that have been mentioned.

17.—*Of the composition of Soils proper for Bulbous Roots and for Trees.*—In general, bulbous roots require a soil much more sandy, and less absorbent, than the grasses. A very good turnip soil from Holkham, Norfolk, afforded eight parts out of nine of siliceous sand; and the finely-divided matter consisted of—

Carbonate of lime	63
Silica	15
Alumina	11
Oxide of iron	3
Vegetable and saline matter	5
Moisture	3

Plants and trees, the roots of which are fibrous and hard, and capable of penetrating deep into the earth, will vegetate to advantage in almost all common soils which are moderately dry, and which do not contain a very great excess of vegetable matter.

I (*Sir H. Davy*) found the soil taken from a field at Sheffield Place, in Sussex, remarkable for producing flourishing oaks, to consist of six parts of sand, and one part of clay and finely-divided matter; and one hundred parts of the entire soil, submitted to analysis, produced—

Water	3 parts.
Silica	54
Alumina	28
Carbonate of lime	3
Oxide of iron	5
Decomposing vegetable matter	4
Loss	3

18.—*Advantage of Improvement made by changing the Composition of earthy Parts of Soils.*—From the great difference of the causes that influence the productiveness of lands, it is obvious, that, in the present state of science, no certain system can be devised for their improvement, independent of experiment; but there are few cases in which the labour of analytical trials will not be amply repaid by the certainty with which they denote the best methods of amelioration; and this will particularly happen when the defect of composition is found in the proportions of the primitive earths.

In supplying animal or vegetable manure, a temporary food only is provided for plants, which is in all cases exhausted by means of a certain number of crops: but when a soil is rendered of the best possible constitution and texture, with regard to its earthy parts, its fertility may be considered as permanently established. It becomes capable of attracting a very large portion of vegetable nourishment from the atmosphere, and of producing its crops with comparatively little labour and expense.

Description of the Apparatus for the Analysis of Soils.—Fig. 1, Plate 2, *a, b, c, d, e, f,* represent the different parts of the apparatus required for measuring the quantity of elastic fluid given out during the action of an acid on calcareous soils; *a* represents the bottle for containing the soil; *b*, the bottle containing the acid, furnished with a stop-cock; *c*, the tube connected with a flaccid bladder; *f*, the graduated measure; *f, e*, the bottle for containing the bladder *d*. When this instrument is used, a given quantity of soil is introduced into *a*; *b* is filled with muriatic acid, diluted with an equal quantity of water; and the stop-cock being closed, is connected with the upper orifice of *a*, which is ground to receive it. The tube *c* is introduced in the lower orifice of *a*, and the bladder connected with it placed in its flaccid state in *e f*, which is filled with water. The graduated measure *f* is placed under the spout of *f e*. When the stop-cock of *b* is turned, the acid flows into *a*, and acts upon the soil; the elastic fluid generated passes through *c* into the bladder *d*, and displaces a quantity of water in *e f* equal to its bulk, and this water flows through the tube or spout into the graduated measure *f*, the water in which gives, by its volume, the indication of the proportion of carbonic acid disengaged from the soil; for every ounce measure of which, two grains of carbonate of lime may be estimated.

ANALYSIS OF MARLS.

THE name of *marl* is given to a mixture chiefly composed of carbonate of lime and clay, in which the carbonate considerably exceeds the other ingredients. In agriculture, the following varieties are chiefly distinguished; viz.

Common marl, which includes not only the earthy marl, which is commonly of a yellowish-grey colour, composed of more or less cohesive dusty particles, soiling a little the finger, and rather rough to the touch; and,

Stone marl, or indurated marl, is usually of a smoky-grey, or bluish colour; or sometimes of an ochre-yellow, or brownish-red. It has a slaty texture; it readily disintegrates by exposure to the air and weather, and frequently contains shells. Either the earthy or the indurated, abounding with shells, is called *shell marl.*

All marls are useful in agriculture only in proportion to the quantity of calcareous earth they contain: unless they contain more than 30 per cent of lime, they are of no value to the farmer.

From what has been stated already on the analysis of soils, the analysis of marls becomes obvious. Of all the modes of trial, the one best suited to the unlearned farmer is to observe how much carbonic acid the marl gives out, and this he may ascertain by dissolving a little of it in dilute muriatic acid, and observing what portion of its weight it loses by the escape of the carbonic acid. Thus, if an ounce of marl lose 40 grains, he may conclude that the ounce contained only 100 grains of calcareous earth, and that it would be his interest to pay five times as much for a load of lime as he must pay for a load of marl at the same distance.

Process I.—To find the composition of marl, pour a few ounces of dilute muriatic acid into a flask, place it in a scale, and let it be balanced.

II.—Then reduce a few ounces of dry marl to powder, and let it be carefully and gradually put into the flask, until after repeated additions no further effervescence ensues.

III.—Let the remainder of the powdered marl be weighed, by which means the quantity projected will be known.

IV.—Let the balance be then restored. The difference of weight between the quantity projected, and that requisite to restore the equilibrium, will shew the weight of the carbonic acid gas lost during effervescence.

If the loss amount to 13 per cent. of the quantity of marl projected, or from 13 to 33 grains per cent. the marl analyzed is calcareous marl, that is to say, marl rich in calcareous earth.

Marls in which clay abounds (clayey or argillaceous marls) seldom lose more than 8 or 10 per cent. of their weight by this treatment. The presence of argillaceous earths in marls may likewise be discovered by drying them, after being washed well: when being kneaded together, dried, and burnt, the mass will harden, so as to form a brick.

Sandy marls usually lose the same quantity of carbonic acid, and frequently still less.

ANALYSIS OF ORES.

ANALYSIS OF ORES OF GOLD.

Gold, the most precious of all metals, is hitherto found only in the state of an alloy, combined with silver, copper, and tellurium.

The analysis of ores of gold is very simple; the chief difficulty arising from the minute portion of the precious metal contained in the greatest part even of those ores which are called very rich.

Process I.—Take a portion of the ore, freed as much as possible from its matrix or stony matter, and reduce it to an impalpable powder*.

II.—Transfer the powder into a Florence

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* If sulphur should be present in any ore to be submitted to analysis in the humid way, that is, by acids and other liquid agents, it will prevent their action, and must, therefore, be previously got rid of. This may be accomplished by roast-

flask (fig. 5, pl. 1), cover it with nitro-muriatic acid, and digest it at a gentle heat for a few hours. Decant the fluid, and repeat the digestions until the residue is of a pure white colour. Let it be washed, and add the washings to the nitro-muriatic solution.

III. — Transfer the fluid obtained in the foregoing process into a glass basin (see the stand, fig. 4, pl. 1), and evaporate it slowly, over a lamp, to dryness.

IV.—Pour upon the residue obtained in the last process as much boiling distilled water as is sufficient to dissolve it, and filter the solution through paper placed in a funnel.

V.—Having done this, add a solution of protosulphate of iron to the solution, till no further change of colour ensues, and then suffer the whole to stand undisturbed for some days; the gold will now be precipitated, and found at the bottom of the vessel, in the state of a brown powder.—(See page 121.)

VI.—Decant the fluid from this powder carefully; collect the latter, which is metallic gold, by putting it upon a filter, and, when

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ing the ore in a muffle, or by mixing it with twice or thrice its weight of nitre, and putting it in a red-hot crucible, and then washing off the alkali with boiling water.

perfectly dry, fuse it into a mass with a small portion of nitre.

If the gold exists in the ore alloyed with a small portion of silver, as in the ores called yellow native gold, a white powder will be seen floating in the nitro-muriatic solution: 100 parts of this powder, which is *chloride of silver*, when separated by the filter, and perfectly dried, contain 75.34 parts of silver, which may be obtained from it, as shall be noticed more fully under the article *Silver Ores*.

The presence of silver may also be detected by exposing the insoluble residue (Process II.) to the rays of the sun: the mass will acquire a purplish tint if it contain silver.

If the ore contained copper, a polished cylinder of iron or zinc, after having been immersed in the nitro-muriatic solution, will be covered with copper. In this case the solution should have a very slight excess of acid. (See Note I.)

When gold is found interspersed amongst sand, or earthy substances, in the state of particles so minute as not to be distinguished by the naked eye, we may examine such substances in the following manner:—

Process I. — Diffuse the finely levigated sand or earth through a large quantity of water in a cylindrical glass vessel (fig. 14, pl. 1,) and frequently decant the fluid, *immediately* after stirring it each time; by that means, the lighter particles of sand, or earth, as well as other substances, remaining longer suspended, may be washed away by the water, whilst the more ponderable particles of gold fall to the bottom with great rapidity.

II.—But as it would be difficult to separate completely the gold thus by mere ablution with water, let the last portion of sand which has been repeatedly washed be put into a flask (fig. 5, pl. 1,) cover it with nitro-muriatic acid, and digest it by heat for at least one hour; dilute the fluid with water, and separate the gold by a solution of proto-sulphate of iron, as directed, pages 121 & 335.

ANALYSIS OF ORES OF SILVER.

The ores of silver are more numerous than those of gold. Mineralogists have divided them into different genera, according to their mineralizing substance, which with the metal forms the ore.

Analysis of Native Silver.

Process I.—Take one part of the ore previously comminuted, affuse upon it, in a Florence flask (fig. 5, pl. 1,) three or four parts of nitric acid, and apply a gentle heat; repeat this operation till a new addition of nitric acid does not produce any further action upon the residue from which the acid solution has been decanted; having done this, mix the different nitric solutions, pour over the insoluble residue a small quantity of water at a time, till this fluid runs off tasteless, and mix the water used for washing with the first obtained solutions.

II.—Add to the fluid obtained in the first process common salt, dissolved in water, in small quantities at a time, till no further precipitate ensues; collect this precipitate, pour water over it so as to wash it thoroughly; then suffer it to dry. When perfectly dry, 100 parts contain 75.34 of silver, which may be obtained from it in the manner directed page 74.

Analysis of Plumbiferous Native Silver.

In this ore the silver exists alloyed with lead, and sometimes also with iron.

Process I.—Proceed as in the former Process I. page 338, and immerse in the solution of the ore in nitric acid a polished copper cylinder: the silver will be precipitated in a metallic state. It may be fused into a button, without any addition, and its weight ascertained. It is essential that the solution of the ore should have a slight excess of acid.

II.—To the fluid from which the silver has been obtained, add a solution of sulphate of soda in water. If a white precipitate ensue, it is a proof that lead was present in the ore. Its quantity may be determined by the weight of this precipitate; 100 parts, when perfectly dry, indicate 68.42 of metallic lead.

III.—The presence of iron may be discovered by dropping into the solution ferrocyanate of potash, or tincture of galls.

Analysis of Bismuthic Silver Ore.

Process I.—Digest the ore repeatedly in dilute nitric acid, till this fluid exercises no further action upon it.

II.—Pour the nitric solution into a large quantity of water; a precipitate falls down, which is oxide of bismuth: 100 parts of it, when dry, indicate 90 of bismuth.

III.--Evaporate the fluid to at least one-third of the original bulk, and drop into it muriatic acid. Collect the precipitate which falls down; wash and dry it.

IV.—The precipitate now left is chloride of silver: let it be digested in nitric acid, decant the fluid, and mingle it with a large quantity of distilled water. If a precipitate should ensue, it is a portion of oxide of bismuth, which escaped the action of the water in Process II. Let it be dried, and added to that obtained before.

V.—The remaining fluid may next be assayed for lead: concentrate it, therefore, by evaporation, to dryness; dissolve the residue in a sufficient quantity of water, and drop into it sulphuric acid. A precipitate will appear if lead be present: let it be collected and dried, and the quantity of lead determined, as stated page 339, Process II.

VI.—The solution from which the lead is

separated may then be examined for iron: for that purpose add to it liquid ammonia till the odour of the latter considerably predominates. A brown precipitate falls down, if iron was contained in the ore.

VII.—If the ore contained copper, the fluid has now a blue colour. It may be saturated with sulphuric acid, in excess: a cylinder of iron will precipitate the copper.

VIII.—The residue may be digested repeatedly in muriatic acid at a boiling heat, and assayed for lead by sulphuric acid. If a precipitate ensue, it is sulphate of lead, which is to be added to that obtained before. The residue now left, if any, is merely the matrix of the ore.

ANALYSIS OF COPPER ORES.

Analysis of Vitreous Copper Ore, or Common Sulphuret of Copper.

Process I.—Digest one part of the pulverized ore repeatedly in three times its weight of dilute nitric acid, till it extracts no more copper, which may be known by dropping into the solution liquid ammonia in excess: if the fluid does not acquire a blue colour it contains no copper.

II. Evaporate this solution to dryness, redissolve the mass in concentrated nitric acid; repeat this process for several times successively.

III.—Boil the dry mass in eight times its weight of water: a brown powder becomes separated, which is the iron that was contained in the ore; collect it on a filter; wash, dry, and ignite it.

IV.—Mingle with the fluid from which the iron has been separated, solution of potash, till no further precipitate ensues, and boil it for a few minutes; collect the precipitate, and dry it in a red heat; 100 parts contain 80 of copper.

The ores called purple, yellow, and black copper ores, may be analyzed in a similar manner.

Grey copper ore contains, besides copper, sulphur and iron; also silver, lead, and antimony: it may be analyzed in a like manner; the silver may be separated by common salt; but as lead is also separated by this substance, the precipitate must be digested in liquid ammonia; this dissolves the chloride of silver, and leaves that of lead: by subtracting the weight which the precipitate has lost by this treatment, the quantity of both metals will be found. If antimony be present, it will be separated from the remaining solution by a copious affusion of water: the precipitate remains insoluble in that fluid.

Dr. Fordyce has given the following general process for analyzing all copper ores, with a view to ascertain the quantity of copper.

Process I.—Take 100 grains of the pulverized ore, digest it repeatedly in one ounce of nitro-muriatic acid, composed of equal parts of nitric and muriatic acids, till all the copper is extracted, which may be known as directed already.

II.—The different solutions are then to be mingled, precipitated by the addition of carbonate of potash, and the precipitate collected on a filter.

III.—This precipitate must be re-dissolved in a sufficient quantity of dilute sulphuric acid, and the solution precipitated by a cylinder of zinc.

Such are the modes of analyzing the most valuable ores of copper.—On considering the different proceedings, it will be seen that the totality of the examination is exceedingly simple, and may be shortly stated, thus:—

The ore is repeatedly digested in nitric acid till all the copper and other metals are extracted, and then the copper is precipitated, either in the metallic form or in the state of an oxide, from which the quantity of the metal may be inferred.

The presence of silver is detected by muriate of soda, or muriatic acid, which separates the silver in the state of chloride, and leaves the copper. The presence of lead may be detected by adding to the obtained solution sulphate of soda, which precipitates the lead in the form of sulphate of lead. The presence of antimony may be detected by decomposing the solution of the ore by an alkali, and then digesting the oxide with concentrated nitric acid, which dissolves the oxide of copper, and leaves the oxide of antimony. Iron is separated by supersaturating the solution with ammonia, which dissolves the copper, and leaves the oxide of iron; or else, by immersing a polished cylinder of zinc, which separates the copper, and leaves the iron in solution. Tin, if any be present, may be separated by immersing in the solution a cylinder of pure tin, which separates the copper only. Arsenic may be separated by acetate or nitrate of lead, which separates the arsenic in the form of arseniate of lead, and leaves the copper; 100 parts of it are equal to 35.63 of arsenic acid. To get rid of the excess of lead, if any should remain, let sulphate of soda be added, which will separate this metal. If nickel should be present, it is always in combination with iron. Let liquid ammonia be added to the solution; the copper and the iron, and likewise the nickel, will be separated. To separate the copper, add muriatic acid in excess, and then immerse in the solution a cylinder of zinc or iron; the copper will then be precipitated, and the nickel left in solution.

ANALYSIS OF ORES OF LEAD.

Analysis of Sulphuret of Lead.

Process I.—Let one part of the ore, finely powdered, be digested in a flask with six of dilute nitric acid, and repeat this process for several times successively. During this process a great part of the sulphur will become separated in the form of a light powder, partly floating on the top of the fluid, and partly subsiding to the bottom.

II.—Add to the obtained solution, previously evaporated to a small compass, muriatic acid, till no further cloudiness appears; suffer the mixture to stand undisturbed till the precipitate is fairly deposited; then decant the fluid, separate the precipitate, and wash it repeatedly, by pouring alcohol over it.

III.—The obtained precipitate consists of chloride of lead, and also of chloride of silver, if the latter metal was contained in the ore.

IV.—To separate these two metals, digest the precipitate in liquid ammonia; the chloride of silver will be dissolved, and the chloride of lead left behind: or the chloride of lead may be separated by boiling the precipitate in 24 parts of water, which dissolves the chloride of lead, and leaves the chloride of silver: or the solution of the chloride of lead may still more easily be effected by digesting it in dilute nitric acid, which dissolves it readily, but does not touch the chloride of silver.

V.—Mingle the ammoniacal solution of silver with nitric acid, heat it for a few minutes, and precipitate the silver by a cylinder of copper.

VI.—To ascertain the quantity of lead obtained in process IV., mix the chloride of lead with half its weight of black flux; put the mixture into a crucible, and expose it to a red heat for half an hour; the lead will be reduced to a metallic state. Or this process may be omitted, and the quantity of lead ascertained, by merely weighing the precipitate, dried at a dull red heat: 100 parts of it contain 74.28 of metallic lead.

The chloride of lead may also be reduced, by immersing in the aqueous solution of it, obtained in experiment IV., a cylinder of iron, which precipitates the lead in a metallic state.

VII.—To find the quantity of silver, proceed as directed in the analysis of silver ores.

To assay the ore for iron and copper, let the solutions from which the lead and silver have been separated, be mingled with liquid ammonia in excess: a brown precipitate falls down, which is oxide of iron. The presence of copper may be known by the solution acquiring a blue colour by the addition of ammonia; it may be separated by immersing in the fluid, after having been neutralized by sulphuric acid, a cylinder of zinc; or in the form of an oxide, by boiling it with potash.

Analysis of Antimonial Sulphuret of Lead.

This ore is a triple compound, containing lead, antimony, and copper, with a minute portion of iron. It was thus analyzed by Mr. Hatchett:

Process I.—Two hundred grains of the ore, finely pulverized, were put into a matrass, with two ounces of muriatic acid, heated, and nitric acid added to it, drop by drop, till the whole moderately effervesced. It was then gently heated for an hour, and a green solution was obtained, on the surface of which floated a quantity of sulphur, which was collected and digested with muriatic acid, and lastly washed and dried. It weighed 34 grains, and burned away in a porcelain cup, leaving merely a stain.

II.—The nitric solution, together with the muriatic acid in which the sulphur had been digested, was evaporated and mixed with six pints of boiling distilled water, which it rendered instantly milky, after which it was filtered. The white precipitate obtained, when dried, weighed 63 grains, and was oxide of antimony.

III.—The liquor, with the washings, was found to deposit, on cooling, crystallized chloride of lead : it was, therefore, evaporated nearly to dryness, and a few drops of sulphuric acid added, to separate, in the form of a sulphate of lead, what little of that metal remained in solution.

IV.—The residue was then re-dissolved in boiling water, and decomposed by sulphate of soda. The sulphate of lead produced, being added to that obtained before (process III.) when dried, weighed 120.20 grains.

V.—The fluid, which was now bluish-green, acquired a deep blue colour by ammonia, and a small quantity of oxide of iron was separated, which, when dried and heated with wax, became magnetic, and weighed 2.40 grains.

VI.—The fluid was next evaporated nearly to dryness, boiled with a strong solution of potash till nearly dry, and, on washing it with water, the black oxide of copper obtained weighed 32 grains.

In this analysis the metals are to be estimated as in their metallic state, this being the form in which they exist in the sulphurets, and hence, for the 63 grains of oxide of antimony, 48.46 of metallic antimony are to be put down; and for 120.20 of sulphate of lead, Mr. Hatchett estimates 85.24 of metallic lead; and the 32 grains of black oxide are equal to 25.60 of metallic copper.

Analysis of Carbonate of Lead.

This ore may be analyzed in the following manner:

Process I.—Let 100 grains of the ore be dissolved in a weighed quantity of dilute nitric acid, and note down the loss of weight, which gives the quantity of carbonic acid.

II.—In the filtered solution immerse a cylinder of zinc, which precipitates the lead in a metallic state; or add solution of sulphate of soda. The remaining fluid may be examined for iron and copper, as stated before.

A specimen of carbonate of lead was analyzed by Klaproth in the following way:

One hundred grains of finely pulverized ore were dissolved in 200 grains of nitric acid, diluted with 300 of water, and the loss of weight by the effervescence noted, which amounted to 16 grains : it was carbonic acid. The nitric solution was then diluted, and a cylinder of zinc immersed in it, which precipitated the lead in the metallic state. When dried, it weighed 77 grains, which are equal to 82.5 of oxide, as it is in this state that the lead exists in the ore.

ANALYSIS OF ORES OF TIN.

Analysis of Native Oxide of Tin, or Tin-Stone.

Process I.—Take one part of the ore, reduce it to an impalpable powder, triturate it with four times its weight of potash moistened with water, and, lastly, boil the mass in a silver vessel in eight parts of water; evaporate the whole to dryness, and moderately ignite it for at least half an hour.

II.--Pour water upon the mass, boil the mixture for about a quarter of an hour, and filter the fluid.

III.— Take the residue left on the filter, if any, mix it again with a like quantity of potash, dissolved in a sufficient quantity of water, evaporate to dryness, and proceed as above.

IV.—Put the solutions, thus obtained, together, and add muriatic acid till no more precipitate falls down; suffer the mixture to stand undisturbed till the precipitate has subsided, in order to collect it on a filter: it is oxide of tin.

V.—Dissolve this precipitate in muriatic acid, in excess; precipitate it again by the addition of carbonate of soda; collect the precipitate on a filter; wash it, by pouring water over it repeatedly, and suffer it to dry.

VI.—Let the precipitate be again dissolved in muriatic acid, assisted by a gentle heat (the insoluble part, if any, consists of silica), dilute the solution with two or three parts of water, and immerse in it a cylinder of zinc: leave the whole undisturbed for some days, and all the tin that was contained in the ore will now be deposited round the cylinder of zinc, in a metallic state. It may be formed into a button, by melting it in a crucible, taking care to cover it with charcoal powder.

Analysis of Sulphuret of Tin.

In this ore tin exists, mineralized by sulphur, and associated with copper; its analysis may be accomplished in the following manner:

Process I.—Let one part of finely pulverized ore be repeatedly digested in six of nitro-muriatic acid, composed of two parts of muriatic acid, and one of nitric acid, till it dissolves no more, and decant the fluid.

II.—Add to this solution carbonate of potash, till no further precipitate ensues: collect the precipitate on a filter.

III.—Re-dissolve this precipitate in muriatic acid, diluted with three or four parts of water, and suspend in this solution a cylinder of tin, whose weight is known. If copper was contained in the ore, it will be precipitated in a metallic state on the tin cylinder; but, in order to be certain that it is not contaminated with tin, let the precipitated metal be re-dissolved by heat, in concentrated nitric acid: if a white powder remains, it is a portion of oxide of tin.

IV.—As in the foregoing process, the tin employed for precipitating the copper is acted upon by the muriatic acid; immerse in the solution from which the copper has been separated a cylinder of zinc; the whole of the tin will be again precipitated on the cylinder of zinc: let it be dried, and its weight ascertained, when melted into a mass. From this quantity of tin subtract now that portion which proceeds from the cylinder of tin employed for precipitating the copper; the remainder will give the true quantity of metal contained in the ore.

ANALYSIS OF ORES OF IRON.

Analysis of Magnetic Iron Ore, or Common Magnetic Oxide of Iron.

This ore contains, besides oxide of iron, a small portion of silica and alumina. It is not only attracted by the magnet, but it possesses itself polarity; hence it attracts iron filings. It affords cast iron of but indifferent quality, but very excellent bar iron.

Process I.—Take one part of the ore, levigated as fine as possible, add to it three or four parts of solution of potash or soda; boil the mixture in a silver basin or crucible, for at least two hours, taking care to supply the water as it evaporates: lastly, evaporate the mixture to dryness; and raise the heat so as just to fuse the whole, and suffer it to remain fused, at a dull red heat, for about half an hour.

II.—Soften the fused alkaline mass with water, transfer it into a flask, pour over it muriatic acid, previously diluted with two parts of water, digest it for a few minutes, and then evaporate it to dryness.

III.—Upon the dry mass obtained, pour about 10 parts of boiling water, and separate the insoluble part, which is silica, by the filter.

IV.—To the fluid from which the silica has been separated, after having been previously concentrated, add potash or soda, in excess; boil the whole for a few minutes, dilute it with water, suffer the precipitate to subside, or separate it by the filter; dry and wash it. The precipitate thus obtained may be mixed with a little nitric acid, and kept for a few minutes in an open crucible, at a dull red heat; it will become perfectly changed into the red oxide of iron; 100 parts of it indicate 70 of iron.

V.—If to the alkaline fluid, from which this oxide has been separated, muriate of ammonia be added, the alumina, if any be present, may be thrown down. The precipitate, after having been washed and dried, gives the quantity of alumina that was present in the ore.

Magnetic iron-sand, specular iron ore, micaceous iron ore, red iron-stone, and all its sub-species, may be analyzed in a like manner.

Analysis of Black Iron Ore.

This ore differs from the latter, in containing a small portion of manganese.

Process I.—Treat the ore with potash or soda, as directed in page 355, process I.; separate the silica according to process II. and III.; decompose the muriatic solution, as stated process IV.; and collect the precipitate. It consists of oxide of iron and oxide of manganese, which may be separated in the following manner.

II.—Transfer the precipitate into a Florence flask, and effect a solution of it, by means of muriatic acid, assisted by a gentle heat.

III.—To the obtained solution add succinate of soda, whilst boiling hot, till no farther cloudiness ensues. The precipitate thus obtained is succinate of iron : 100 parts of it, after having been heated with a little wax, in a low red heat, are equal to 70 of metallic iron.

IV.—Or the two metals may be separated by dissolving the compound precipitate of oxide of iron, and oxide of manganese, in muriatic acid, by a gentle heat, and then adding, when boiling hot, a solution of soda, in small quantities at a time, till the fluid becomes colourless, or till the precipitate that is thrown down by each addition of soda begins to assume a white colour. Collect this precipitate, and heat it with nitric acid : it gives the quantity of iron as stated page 355, process IV.

V.—To the remaining fluid now add soda till no further precipitate ensues : the precipitate obtained is oxide of manganese.

For a better method of separating the oxides of iron and manganese, see Note K.

Analysis of Sparry or Spathose Iron Ore.

The composition of this ore is far more complicated than any of the former. It usually contains, besides oxide of iron, silica, and alumina, a considerable portion of oxide of manganese, and carbonate of lime, and sometimes, also, a small portion of the carbonates of magnesia and barytes.

The iron obtained from this ore is particularly valuable, as it may be converted into fine steel immediately from the state of cast iron. The bar iron which it yields possesses both hardness and tenacity in a high degree. The ore may be analyzed in the following manner:

Process I.—Take one part of the ore, finely levigated, put it into a bottle furnished with a spiral glass tube, and pour over it twice its weight of nitro-muriatic acid, and ascertain the quantity of carbonic acid by the loss of weight it sustains.

II.—Upon the ore thus freed from carbonic acid pour four times its weight of muriatic acid, and digest it in a flask with like portions of muriatic acid, till no further action ensues, or till tincture of galls does not change the solution, when rendered neutral by an alkali, blue or black.

III.—Mingle the obtained solutions, and having concentrated the whole by evaporation, decompose it whilst boiling hot, by soda, adding this alkali rather in excess, and boil the whole for about a quarter of an hour. The alumina will, by this means, become dissolved in the excess of the alkali. Separate the insoluble residue by the filter.

IV.—To separate from the insoluble residue of the last obtained process the lime, barytes, and magnesia it may contain, let it be digested in dilute nitric acid. These earths will become dissolved, and the oxides of iron and manganese will be left untouched, and may be separated by filtration.

V.—Into the solution of process IV. previously diluted with 20 parts of water, let fall sulphuric acid, till no further cloudiness ensues; the barytes which was present will be separated in the form of an insoluble white powder, being sulphate of barytes; and the other earths which were present in the solution will remain undisturbed.

VI.—To separate these earths, again concentrate the fluid from which the barytes has been removed, and decompose it by the addition of carbonate of potash. The obtained precipitate consists of carbonate of lime and carbonate of magnesia.

VII.—To separate these earths, cover them with sulphuric acid, and evaporate the mixture to dryness, till no more fumes are visible; and lastly pour thereon a small portion of water, which will dissolve the sulphate of magnesia, and leave the sulphate of lime.

VIII.—To the obtained solution of sulphate of magnesia add carbonate of potash. The precipitate obtained is carbonate of magnesia, which after having been freed from its carbonic acid, by exposure to a red heat, gives the quantity of magnesia that was present in the ore.

IX.—To ascertain the quantity of lime, take the sulphate of lime obtained in process VII., boil it with three times its weight of carbonate of potash, and ten of water, repeatedly, until it is found to be completely soluble in nitric acid ; evaporate the nitric solution to dryness, and decompose it at a red heat. The lime that was present will thus become evident.

X.—To separate the oxides of iron and manganese obtained in process IV., let the mass be digested at a gentle heat with dilute nitric acid, and a small piece of sugar; the manganese will be dissolved, and the oxide of iron will be left behind, from which the quantity of iron may be inferred.

XI.—To ascertain the quantity of manganese, add to the nitric solution from which the iron has been separated, carbonate of soda, till no farther cloudiness ensues: this precipitate is carbonate of manganese, containing the metal in the state of protoxide.

Analysis of Common Argillaceous Iron Ore.

This ore is chiefly composed of oxide of iron, alumina, and a small portion of silica, and hence its analysis may be effected according to the rules already pointed out for separating these bodies: it usually yields from 30 to 40 per cent. of iron.

The other sub-species of argillaceous iron ores sometimes contain, besides the ingredients already stated, variable proportions of oxide of manganese, phosphate of iron, and silica; they may, therefore, be analyzed thus:

Process I.—Digest a portion of the ore repeatedly in nitric acid, until all the iron is extracted by the acid.

II.—Evaporate the nitric solution almost to dryness, and suffer the residue to digest in a closed phial, with cold water. The phosphate of iron, if any were present, will become precipitated.

III.—Fuse the insoluble residue left in process I. with four times its weight of soda, for one hour; dissolve the mass in water; filter, and separate the silica from the alkaline solution, by the admixture of muriatic acid; collect and dry it.

IV.—To the fluid from which the silica has been obtained, add the solution from which the phosphate of iron has been separated (process II.); supersaturate the whole with soda, and boil the mixture for about half an hour. The alumina, if any, will be dissolved in the excess of soda added, and the metallic oxides, together with the lime, will remain unacted on: separate the insoluble part by the filter.

V.—Digest the mass obtained in process IV. in concentrated nitric acid; evaporate the solution to dryness. Repeat this operation for several times successively; and lastly, again digest it in dilute nitric acid, and separate the fluid by the filter.

VI.—Decompose the obtained nitric solution by carbonate of potash, and expose the precipitate to a red heat for half an hour: the lime which was present in the ore will thus be obtained.

VII.—To separate the metallic oxides, namely, the oxide of iron and oxide of manganese, left undissolved in process V., proceed as before directed.

ORES OF ANTIMONY.

Analysis of Sulphuret of Antimony.

The sulphurets of antimony usually contain, besides antimony, a portion of lead, copper, iron, and silver; to which must be added the earths composing the stony matrix, from which they cannot be perfectly separated previously to analysis. With these compound ores the best method of proceeding is as follows:—

Process I.—Take 500 grains of ore, finely pulverized, digest it with 1500 grains of pure nitric acid, specific gravity 1.25, and 1000 grains of water, for about half an hour, at the temperature of 150° Fahr. and repeat this process several times.

II.—Mingle the solution with a quantity of water equal to the rest of the fluid, and pour off the liquor as soon as it becomes clear; it may consist of the nitrates of silver, lead, and copper, with probably a little iron, dissolved in an excess of acid.

III.—To separate the iron, boil the fluid, and the iron will be separated in the state of red oxide, by subsequent filtration.

IV.—Drop muriate of soda into the solution, as long as a precipitate takes place, and allow the whole to stand till the supernatant fluid becomes perfectly clear; the precipitate is chloride of silver, which, being separated and washed, may be mixed with two or three times its weight of dry carbonate of soda, and reduced by fusion to the metallic state;

or the quantity of metallic silver may be estimated theoretically.

V.—The solution obtained in process IV. must now be saturated by potash or soda, and concentrated by evaporation to about one-third of its bulk, and then mingle with it ammonia in excess: the lead will be precipitated as white oxide, and the copper remains in solution. The former, by fusion with black flux, may be reduced to the metallic state.

VI.—The solution, freed from lead, may then be slightly acidulated with nitric acid, and carbonate of potash added to it, which will throw down carbonate of copper; and this, after being exposed to a low red heat, becomes converted to the state of peroxide, 100 parts of which denote 80 of metal.

VII.—The insoluble portion of the ore left in process I. is to be digested at a temperature somewhat inferior to boiling, with successive portions of nitro-muriatic acid (consisting of nitric acid one part, strong muriatic acid four parts), as long as any action takes place; the solutions being then mixed and concentrated by evaporation, are to be poured into a considerable quantity of pure water; an immediate precipitate of protoxide of antimony takes place, which, being separated, washed, and mixed with twice its weight of black flux, and a little nitre, is easily reduced to the metallic button by a full red heat continued for a few minutes.

VIII.—The solution obtained in process VI. now contains only a little sulphuric acid, and perhaps iron, with some earthy matter. The addition of nitrate of barytes throws down a precipitate of sulphate of barytes, from which the quantity of sulphur may be inferred: excess of caustic potash being next added to the solution, and assisted by a boiling heat, will throw down the iron in the state of peroxide, but will retain the alumina and silica, which may be separated according to rules given repeatedly already.

IX.—The insoluble residue of process VII. containing only sulphur and earth, is decomposed by ignition, the sulphur flying off, and the earths remaining.

Thus the quantity of antimony is obtained by process VII.

Of sulphur and earth by VIII. IX.

Of iron by II., III., and VII.

Of silver by IV.

Of lead by V.

Of copper by VI.

DISTINGUISHING CHARACTERS OF METALLIC SUBSTANCES*.

I. A METAL which does not act sensibly on water at common temperatures, but dissolves in dilute sulphuric acid with the extrication of hydrogen gas, will be either iron, zinc, or manganese.

Iron.—If the solution contain the metal in the state of protoxide, solution of potash, soda, or ammonia, will throw down a white or olive-green precipitate, which, on exposure to air, soon becomes deep-green, and then reddish-yellow. Ferrocyanate of potash gives a white precipitate, which changes to a deep blue by contact with air, or on the addition of a few drops of solution of chlorine. Infusion of galls gives a purple precipitate, which afterwards becomes black. If the metal be in the solution

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[*] From Thénard's Traité de Chimie, tome IV.

in the state of peroxide, the alkalies will immediately throw down a reddish, and ferrocyanate of potash a deep-blue precipitate.

Zinc.—Solution of potash, soda, or ammonia produces in solutions of zinc a white precipitate, which does not alter by contact with air, and which is soluble in an excess of alkali. Solution of ferrocyanate, or hydrosulphuret of potash, produces a grey or white precipitate.

Manganese.—The solutions of potash and soda, produce, in a solution containing manganese, a white precipitate, which is insoluble in an excess of alkali, and changes to a chesnut-brown colour, by contact with air. Ferrocyanate and hydrosulphuret of potash also produce a white or greyish precipitate; and lastly, the oxide separated by the alkaline solutions, on being dried, and mixed with five or six times its weight of carbonate of potash, and then exposed to the action of a red heat for 15 or 20 minutes, affords a green mass, possessing all the properties of mineral cameleon *.

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* By exposing equal parts of nitrate or carbonate of potash, and peroxide of manganese, to a red heat, a green compound is

II. Let us now suppose that the metal has no action on water, nor on sulphuric acid diluted with water, at the common temperature, but that it is susceptible of being dissolved by nitric acid, at least with the assistance of heat; it will be one of the following: tin, antimony, molybdenum, arsenic, cobalt, uranium, copper, nickel, palladium, mercury, bismuth, tellurium, lead, silver, or cadmium.

Cobalt, uranium, copper, nickel, and palladium, being the only metals of these fifteen which colour nitric acid, they can, therefore, but be confounded with one another: they are to be distinguished by the properties of the respective solutions.—The metal is

Cobalt, if the liquor be of a violet-red or rose-

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obtained, possessing remarkable properties. This compound being put in contact with cold or warm water, dissolves and colours it green: a little afterwards the solution, whether in contact with air or not, deposits reddish-yellow flakes, and it acquires at the same time a violet tint. It preserves this hue, and undergoes no alteration in close vessels; but in open vessels it becomes colourless: when it is green or violet, acids always render it of a rose colour. It was on account of these changes of colour that Scheele called this singular compound *mineral cameleon*. For the nature and composition of this substance see the opinion of Messrs. Chevillot and Edwards, by referring to any respectable chemical treatise.

colour; if it form a precipitate of a violet-blue with alkalies; green with alkaline ferrocyanates; black with alkaline hydrosulphurets; and particularly if the oxide which is separated by the alkalies be capable, at a red heat, of colouring a great quantity of borax, and producing with it a blue glass.

Palladium, if it be red; if the protosulphate of iron quickly reduce the metal; if protomuriate of tin throw down from it a black, and ferrocyanate of potash an olive precipitate; lastly, if by evaporating it to dryness, and exposing the residue to a red heat, not only the decomposition of the nitrate is effected, but also that of the oxide.

Copper, if the solution be blue, or of a greenish-blue colour; if it form with potash and soda a blue precipitate, insoluble in an excess of alkali; with ammonia, a bluish-white precipitate, which an excess of ammonia dissolves immediately, imparting an azure-blue colour to the solution; with ferrocyanate of potash, a brown precipitate; and lastly, if, by immersing polished iron in the solution, the iron become covered with a coat of copper.

Nickel, if it be of a grass-green colour; if potash and soda precipitate from it an oxide of a green colour; if ammonia change the colour of it to a violet-blue; if ferrocyanate of potash produce an apple-green precipitate, hydrosulphuret of potash a black precipitate, and if polished iron do not at all reduce the metal.

Uranium, if the solution be yellow, or inclining to yellow; if by proper evaporation and cooling, crystals of a citron-yellow colour be separated; if potash, soda, or ammonia produce a pale yellow precipitate, insoluble in an excess of alkali; if ferrocyanate of potash produce a blood-coloured precipitate; and lastly, if iron do not reduce the solution containing the oxide.

How to ascertain the Nature of a Metallic Compound[*].

I.—The first step to be taken is to put the mixture in contact with water, to determine whether it contain potassium, sodium, barium, strontium, calcium, or lithium: if it contain any of these substances, hydrogen gas will be disengaged, and the liquid will become alkaline; then an excess of carbonate of ammonia may be poured into it, in order to convert into carbonates the different oxides produced by the decomposition of the water; and as the carbonates of barytes, strontia, and lime, are insoluble, whilst those of potash, soda, and lithia, are on the contrary very soluble, the filtered liquid and the precipitate well washed, if any be produced, are to be treated in the following manner:

The liquid is to be evaporated to dryness. The residue thus obtained will consist of the carbonates of potash, soda, and lithia, which were held in solution. Let them be re-dissolved in water; then, after having decomposed them

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[*] In this example of analysis it is not only supposed that the metals are combined, but likewise that they act as though they existed in a separate state, which is not the case always.

by sulphuric acid, to convert them into sulphates, the latter are to be separated by crystallization: the sulphate of potash being least soluble, separates first in octohedrons. In the case where the concentrated liquid is incapable of rendering a concentrated solution of platinum at all turbid, it would be useless to crystallize, as the solution would consist of sulphate of soda, or sulphate of lithia. The sulphates of soda and lithia are too equally soluble to be separated by crystallization, therefore convert them both into muriates, by adding muriate of barytes till it occasion no further precipitate. Filter and evaporate the solution to dryness, and digest the residue in strong alcohol, muriate of lithia will be held in solution, but the common salt will remain unacted upon.

As regards the insoluble carbonates, collect them from the filter, dissolve them in muriatic acid, and evaporate the solution to dryness, and heat the residue in successive portions of boiling alcohol, which will not act on the muriate of barytes, but readily holds in solution the muriates of strontia and lime. Dilute this solution with water, and pour in carbonate of potash, which instantly precipitates the strontia and lime in the state of carbonates. These are to be separated by dissolving them in nitric acid, and evaporating to dryness. Boiling alcohol will now take up nitrate of lime; but the nitrate of strontia remains undissolved.

II.—When water has no action on the alloy, boil it with weak sulphuric acid. The manganese, iron, and zinc, which it may contain, and even nickel, according to M. Tupputi, will be dissolved, producing a disengagement of hydrogen gas, see page 367. The mixture contains

Iron, if the solution form, with ferrocyanate of potash, a precipitate which becomes blue with chlorine, or on exposure to the air.

Nickel, if ammonia give a clear violet-blue solution with it, when the oxides insoluble in that alkali are removed by the filter.

Zinc, if the iron of the solution being highly oxidized, the addition of carbonate of potash or soda form in it a precipitate partly soluble in caustic potash or soda; for then, by filtering the liquid, and mixing it with a small excess of nitric acid, white flakes will be deposited, which will disappear almost immediately, and nitrate of zinc will be produced, which will exhibit, with alkalies, hydrosulphurets, and the alkaline ferrocyanates, all the phenomena that we have pointed out in speaking of zinc. (See page 368.)

Manganese, if, by putting the preceding precipitate in contact with ammonia, washing it well, dissolving it in nitric acid, evaporating the liquid to dryness, exposing the residue to a red heat, and throwing water afterwards on the remaining mass, a solution be obtained, which furnishes, by evaporation, a residue, capable of forming mineral cameleon with potash. (See page 368.)

III.—To the action of water and of weak sulphuric acid should succeed that of boiling with concentrated muriatic acid. If a disengagement of hydrogen gas result; if the liquid precipitate a solution of gold, brown, or purple; if, by pouring into it carbonate of potash or soda, a white precipitate be obtained insoluble in nitric acid, the mixture contains tin.

IV.—The mixture, after having been digested successively in water, in weak sulphuric acid, and muriatic acid, must now be digested in boiling nitric acid. The latter will dissolve, or at least oxidize, the arsenic, molybdenum, antimony, cobalt, uranium, bismuth, tellurium, copper, nickel, lead, mercury, silver, palladium, and cadmium ; but will not sensibly attack chromium, tungsten, columbium, titanium, cerium, osmium, rhodium, platinum, gold, and iridium. If the solution be incapable of being made turbid by water, a certain quantity of this liquid is to be added, then it is to be filtered, and the residue washed ; but if it be rendered turbid by water, it must be diluted with weak nitric acid, which will produce no alteration in it, then filtered as usual, and the residue being washed with weak nitric acid, should next be put in contact with muriatic acid, and exposed to the action of heat, in order to dissolve the metals which the nitric acid may only have oxidized ; namely, the portion of antimony and tin, which may have escaped the first action of the muriatic acid, a certain quantity of arseniate of bismuth, which would be formed and precipitated in case bismuth and arsenic made part of the mixture, and perhaps, also, a certain quantity of molybdate ; after which, the two solutions must be examined.

Let us speak of the nitric solution in the first place :

The nitric solution should be evaporated by little and little, so as to drive off the greater part of the excess of acid. Possibly it may become turbid during the course of the evaporation: from that circumstance we may conclude, that it probably contains an arseniate or a molybdate, and perhaps both. Now, this point is to be ascertained by separating the deposit, washing it with water, or with weak nitric acid, treating it with hydrosulphuret of potash, which will produce a soluble arseniate or molybdate, and an insoluble sulphuret; afterward saturating the liquid with an acid, filtering it, and trying it with suitable tests, as well as the sulphuret which may be formed. If the liquid contain molybdic acid, it needs only to be strongly concentrated, and to have a little concentrated sulphuric acid poured into it: the molybdic acid will precipitate in the form of a white powder. If it contain arsenic acid, it will be ascertained by evaporating the liquid to dryness, and mixing the residue with dried soap, and heating the mixture in a small earthen retort: a crystallized sublimate of arsenic will be produced. As for the sulphuret, it must be put in contact with nitro-muriatic acid: the latter will dissolve the metal of the sulphuret; and as this metal can be but one of those just named, it will always be easily discovered by its test.

When the solution is concentrated, as we have just mentioned, it is to be examined successively to detect the presence of bismuth, palladium, silver, lead, copper, tellurium, mercury, cobalt, uranium, and cadmium. It contains

Bismuth, if, on dilution with water, it deposit a white precipitate, which, well washed, is capable of becoming black with sulphuretted hydrogen, of melting before the blowpipe into a yellowish mass ; and lastly, of being reduced by heating it with a blowpipe in a cavity of charcoal, and affording a brittle and very fusible metal.

Lead, if, after having diluted it with water, it form, with sulphuric acid or sulphates, a white precipitate, which is immediately blackened by sulphuretted hydrogen, like the preceding, and which, when boiled with water and nitrate of barytes, produces by evaporation white crystals, of a sweet taste, and such as would be obtained by digesting litharge with nitric acid.

Silver, if, after having diluted it with water, and added sulphuric acid, it suddenly become turbid by adding muriatic acid, the precipitate being white, flaky, and insoluble in an excess of acid, but soluble in ammonia, and becoming black on exposure to light.

Palladium, if the protosulphate of iron speedily separate from it a brilliant white metal, forming with nitric acid a red solution, capable of being precipitated in a brown powder by protomuriate of tin.

Copper, if a polished iron plate, immersed in it, become covered with a metallic coating of a red or copper colour.

Tellurium, if, after having extracted the bismuth, lead, silver, and palladium, carbonate of potash produce with it a precipitate partly soluble in caustic potash ; if, saturating afterwards the alkaline solution with an acid, a white oxide subside ; lastly, if that oxide, mixed with oil, and heated to redness in a retort, sublime in bluish-white metallic globules.

Mercury, if, on heating to redness in a retort, or glass tube, that part of the precipitate of the preceding experiment which resisted the action of the alkali, globules of mercury be afforded ; or, still better, if similar globules be obtained by heating the alloy before treating it with nitric acid.

Cadmium, if, after the separation of the above metals, the remainder of the precipitate obtained by carbonate of potash, and from which the mercury has been distilled, be dissolved in muriatic acid, and a considerable excess of ammonia added, and the solution filtered and diluted, pure potash throw down a white hydrated oxide of cadmium.

Cobalt, if the alkaline fluid from which the potash has separated the cadmium, be boiled till no further precipitate be thrown down, and if the precipitate, melted with 20 or 25 times its weight of borax, will form an intensely blue glass.

Uranium, if, by digesting in nitric acid the precipitate formed with ammonia in the experiment on cadmium, evaporating the nitric solution to dryness, pouring water on the residue, and repeating these two operations for several times successively, a yellow liquid be obtained, possessing the same properties as that which is produced by the action of nitric acid on uranium, as explained page 371.

Let us now examine the second solution (IV. pages 375 and 376).

The muriatic solution should be concentrated like the nitric; and when it is so far concentrated as to have lost the greater part of its excess of acid, a small excess of hydrosulphuret of potash may be added by degrees; the arsenic and molybdic acids which it may contain, will unite with the potash, and remain in solution, while the metals, whatever they are, become precipitated in combination with the sulphur, forming sulphurets; then, after having filtered the liquid, it is to be treated as has been stated at page 377, in order to discover in it those two kinds of metallic acids. As for the *precipitate,* which is composed of sulphuret of antimony, sulphuret of tin, or sulphuret of bismuth, it is to be boiled with concentrated muriatic acid, which readily decomposes and dissolves the sulphurets of antimony and tin, but has no action on the sulphuret of bismuth. If the new solution afford a precipitate with water, it is a proof that it contains antimony, and by its action on a solution of gold, it will be known whether it contain tin, by producing a brown or purple precipitate.

Moreover, the sulphuret of bismuth is acted on by nitric acid, and by digesting it in that acid with the assistance of heat, a nitrate of bismuth is formed, which is crystallizable, and is decomposable by water; a deposit of sulphur and sulphate of bismuth is also produced by the action of nitric acid.

V.—After having examined the mixture of the different metals, the nature of which we are desirous of ascertaining, by the action of weak sulphuric acid, muriatic acid, and nitric acid, the residue must be heated to redness with once, or once-and-a-half its weight of nitrate of potash, in a platinum basin; if the residue be composed, as it possibly may be, of chromium, tungsten, columbium, titanium, cerium, osmium, rhodium, platinum, gold, and iridium, the following effects will take place: the chromium, tungsten, and columbium will be acidified, and will unite with the potash; the titanium, cerium, iridium, and osmium, will be oxidized; and perhaps a very little platinum will be also oxidized.

In every case, the remaining mass is to be boiled at first in water, and afterwards with muriatic acid, and lastly with nitro-muriatic acid: three solutions will be thus obtained, one alkaline, and the two others acid. In the alkaline solution will be found the chromium, tungsten, columbium, and a portion of the osmium.

It contains

Osmium, if, by pouring nitric acid into it, filtering it in case it become turbid, and submitting it to ebullition in a retort, a colourless liquid pass over into the receiver, possessing an odour similar to that of chlorine, and becoming blue with infusion of galls, and depositing black flakes by the contact of zinc.

Chromium, if, after the examination for osmium, the excess of acid being saturated with potash, soda, or ammonia, the acid nitrate of mercury produce a red precipitate, which becomes green when strongly heated.

Tungsten, if sulphuric, nitric, and muriatic acids form with it a white precipitate, which becomes yellow when boiled in aqua regia.

Columbium (or *Tantalum*), if the sulphuric, nitric, and muriatic acids, form a white precipitate, as above mentioned; and if, by digesting this precipitate with boiling muriatic acid, evaporating the liquid to dryness, heating to redness the residue, and digesting it with water, a white powder remain, possessing the same properties as that which is produced by digesting columbic acid in the same manner.

The titanium, cerium, iridium, and rhodium, are to be found in the muriatic solution (see V. page 382). To determine whether it contain these metals, it must be concentrated, diluted with water, and filtered. A plate of iron must be immersed in it; and lastly, when the iron has ceased to precipitate, the liquid must be decanted, and tartrate of potash added to it. The water will precipitate the greater part of the titanium in the state of oxide; the iron will precipitate the iridium in a black powder in the metallic state; and the tartrate of potash will precipitate the cerium in the state of tartrate of cerium. By decomposing this salt at a red heat, an oxide of cerium will be obtained of the colour of ochre, which, heated with muriatic acid, disengages chlorine, and affords a solution which is sweet and colourless.

The iridium and rhodium may be discovered, by calcining them again in a platinum crucible, with an equal quantity of nitre, lixiviating the mass, and boiling the residue, which will be found to consist principally of the oxides of these metals, in muriatic acid; concentrate the solution and add ammonia, but not in such quantity as to saturate the excess of acid; this will occasion a precipitate of ammoniaco-muriate of iridium, which will consist of small shining black particles. Next evaporate the remaining solution to dryness, and wash the residue with water a little acidulated with muriatic acid. The two salts thus obtained, being separately calcined, will afford the metals nearly pure.

The nitro-muriatic solution must be examined for platinum and gold. If it contain ever so little platinum, that metal will be successively detected by concentrating the solution, and pouring into it a solution of muriate of ammonia; a yellow precipitate will result, from which the platinum is to be extracted by heat.

After having tried the solution with muriate of ammonia, it must be tested with protosulphate of iron and protomuriate of tin. If it contain gold, the latter will produce a precipitate of purple of Cassius, and the former will precipitate the gold immediately in the metallic state.

In case the solution should contain a little iridium, which is possible, the precipitate formed by the muriate of ammonia will be of an orange-yellow colour.

Analysis of a Metallic Compound, consisting of Tin, Bismuth, Lead, Copper, and Silver.*

Digest the alloy with an excess of nitric acid with heat; evaporate the liquid nearly to dryness, and pour water upon the residue: a solution will be produced of the nitrates of silver, lead, and copper, and a deposit of peroxide of tin and oxide of bismuth: these last, separated by putting them again in contact with nitric acid, as mentioned at page 399, will give, by their weight, the quantities of tin and bismuth of the alloy. The quantities of silver, lead, and copper, are to be determined by pouring into the solution, first, muriatic acid; afterwards, a solution of sulphate of potash or soda; and lastly, potash: the muriatic acid will precipitate chloride of silver, the sulphuric acid of the alkaline sulphate will precipitate sulphate of

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* We shall content ourselves merely by indicating the general way of proceeding that should be adopted in this analysis, as well as in those following; therefore, the washings, filtrations, desiccations, and all other operations practised in analyzing the different compounds, will not again be considered, the reader being now, it is supposed, familiar with all these analytical details, more especially as they have been repeatedly described.

lead, and the potash peroxide of copper. As some chloride of lead will be thrown down with the chloride of silver, in precipitating the latter by means of the muriatic acid, the solution must be boiled, and the chloride of lead will be dissolved, and may be separated by filtering while hot, previously to adding the sulphate of soda. The quantities of lead, silver, and copper, are very readily deduced theoretically from the respective precipitates containing these metals.

Analysis of a Metallic Compound consisting of Tin, Bismuth, Lead, Silver, Copper, and Zinc.

The quantities of the first four metals are to be determined as in the preceding analysis, and the two others which remain in solution in the nitric acid are to be separated by potash, as in the analysis of zinc and copper, or brass (see page 395) : the alkali will precipitate both in the state of an oxide; it will re-dissolve the former, and leave the peroxide of copper pure.

Analysis of a Metallic Compound consisting of Tin, Bismuth, Lead, Silver, Copper, Zinc, and Manganese.

By always pursuing the same mode of analysis, the tin, bismuth, lead, silver, and zinc, will become isolated; but the copper and manganese remain combined. Now, since they are oxidized, and as ammonia readily dissolves peroxide of copper, and has no action on oxide of manganese, it will be easy to separate them; moreover, by expelling the ammonia by heat, the peroxide of copper is obtained pure. The quantity of the copper is to be deduced from the weight of this oxide, and the quantity of the manganese from that of its oxide, which is also at the *maximum* of oxidizement.

Analysis of a Metallic Compound consisting of Tin, Bismuth, Lead, Silver, Copper, Zinc, Manganese, Gold, and Platinum.

By treating this alloy like the preceding, we shall separate the bismuth, lead, silver, copper, zinc, and manganese, and obtain a residue composed of peroxide of tin, gold, and platinum: digesting afterwards this residue with muriatic acid, the peroxide of tin becomes dissolved, and may be precipitated by adding ammonia: we shall then have remaining only gold and platinum, which may be converted into muriates with nitro-muriatic acid: then pouring protosulphate of iron into the solution of these two metals, the gold will be reduced and will gradually subside: now, passing a current of sulphuretted hydrogen through this solution, thus freed from gold, we shall combine the platinum with sulphur; and lastly, heating in contact with air this sulphuret of platinum, which will appear in the form of black flakes, we shall extract the platinum pure.

Analysis of a Metallic Compound consisting of Tin, Bismuth, Lead, Silver, Copper, Zinc, Manganese, Gold, Platinum, and Iron.

If the bismuth, lead, silver, copper, and zinc, are separated, as before mentioned, the iron, in the state of peroxide, will be found mixed, partly with the oxide of manganese, and partly with the oxide of tin, gold, and platinum. All that is then required to complete the operation, is to analyze the two residues that will then result. By digesting the latter repeatedly, first with potash, and then with muriatic acid, the oxide of tin and the oxide of iron will be dissolved: from the alkaline solution the oxide of tin may be precipitated by nitric acid, and from the muriatic solution the oxide of iron by ammonia. The gold and platinum remaining are to be treated as in the preceding analysis. The oxide of iron and the oxide of manganese are to be separated by one of the two following methods:—

The first consists in dissolving them in sulphuric acid, diluting the solution with water, and adding to it gradually a dilute solution of potash. A reddish precipitate of subsulphate of iron, and a yellowish-white precipitate of oxide of manganese, will be obtained: but the oxide of manganese will subside the last, and a considerable time after the other. It will, therefore, be easy to seize the proper time for filtering the liquid to collect the subsulphate; this will be when the solution, after having been made turbid by the addition of potash, ceases to become so by small additions of that alkali, and when, on the contrary, it is made turbid by greater quantities of potash. The subsulphate should be exposed to a red heat to expel the sulphuric acid, and the oxide of iron be added to that which was mixed with the oxide of tin; by this means all the oxide of iron will be obtained, from which the quantity of metal may be known: the weight of the oxide of manganese will also give that of the manganese. Possibly a little oxide of iron might yet be found in the washings of the oxide of bismuth. In case there should be any, it may be precipitated by potash, and added to that which is already obtained.

The second method of separating the two oxides is founded on the property possessed by nitrate of iron of being readily decomposed by heat, and on the property of nitrate of manganese of suffering by this means no alteration. Indeed, if we dissolve oxide of manganese and oxide of iron in nitric acid, evaporate the solution to perfect dryness, particularly if we heat to redness the residue, digest it afterwards with water, and throw the whole upon a filter, the oxide of iron remains upon the filter, while the oxide of manganese, combined with nitric acid, will pass through it, and may then be separated by the addition of potash. (See also Note K.)

Analysis of more complicated Metallic Alloys; namely, Mercury and Tin, Mercury and Bismuth, Mercury and Silver, Mercury and Gold.*

The proportion of their component parts is determined by gradually heating these different alloys in a very small retort, or bent glass tube, the neck of which is furnished with a linen rag dipping in water. The mercury is volatilized and condenses in the receiver, while the other metal remains in the retort or tube. Every other compound of mercury and a fixed metal, or one which is not volatilized below a red heat, may be analyzed in the same manner to detect the presence of mercury.

Analysis of an Alloy of Tin and Lead.

Let a certain quantity of the alloy be exposed to a gradual heat, in a flask containing pure nitric acid. The nitric acid is soon de-

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* Compounds of the other metals with mercury are more properly called *amalgams*.

composed, and from that decomposition results a white insoluble peroxide of tin, and soluble nitrate of lead. When no metallic particle is any longer to be perceived, and when, the liquid being very acid and boiling, gas is no longer disengaged, it must be evaporated to dryness, diluted with water, thrown upon a filter, and the residue washed till the water no longer reddens litmus, nor blackens sulphuretted hydrogen; then drying the residue, which is composed of peroxide of tin only, heating it to redness, weighing it, and calculating the quantity of tin contained in it theoretically, we shall know the quantity of tin of the alloy. Unite afterwards all the washings with the filtered liquid, and add an excess of sulphate of potash or soda; all the oxide of lead will precipitate, combined with the sulphuric acid, so that in order to ascertain the quantity of lead, we have only to collect the precipitate, and to wash, dry, and weigh it, and then calculating by the table of equivalents the quantity of lead, it will be found that 100 parts of sulphate of lead contain 68.42 of lead.

Analysis of an Alloy of Tin and Copper.

The analysis of this alloy is to be performed partly as the preceding: only, instead of sulphate of potash or of soda, an excess of a solution of potash or soda must be added to the filtered liquid. The precipitated peroxide of copper which will be obtained, must be washed by decantation till the washings cease to become turbid with nitrate of barytes. Dry this precipitate, and heat it to redness, to convert it into perfect peroxide of copper; weigh it, and deduct 20 per cent. of oxygen from its weight, and the remainder gives the quantity of copper of the alloy.

Analysis of an Alloy of Lead and Antimony.

This analysis is performed exactly the same as that of tin and lead (see page 392). The only difference is in calculating for the quantity of antimony from the residue, instead of calculating for tin, as in the analysis referred to.

Analysis of an Alloy of Zinc and Copper, Brass, Semilor, and all gold-coloured Alloys.

Dissolve the alloy, with the assistance of a gentle heat, in weak nitric acid. Dilute the solution with a little water; pour into it a considerable excess of a solution of potash or soda; boil the liquid for a quarter of an hour, and wash the residue, by filtration, till the washings no longer turn turmeric paper brown. Thus we shall obtain the oxide of zinc in solution in the liquid; and the copper, in the state of peroxide, will remain on the filter. It will be sufficient to dry, to heat to redness, and to weigh this residue, and to subtract 20 per cent. from its weight, to obtain the quantity of copper in the alloy; but it will be necessary to perform a greater number of operations to arrive at the quantity of zinc. For this purpose, after having united the washings with the liquid, add an excess of muriatic or sulphuric acid, which will convert the potash and oxide of zinc into sulphates or muriates of potash and zinc; then add carbonate of potash or soda, which will precipitate all the oxide of zinc in combination with carbonic acid; wash this carbonate, dry it, and heat it to redness; it will thus become decomposed, and we shall have the oxide of zinc alone, from which the quantity of zinc in the alloy is easily deduced theoretically.

Analysis of an Alloy of Silver and Gold.

Silver being soluble in nitric acid, and gold insoluble, the alloy must be laminated, and digested with nitric acid like the preceding, but repeatedly, or rather till red vapours cease to be disengaged. The residue, well washed, and heated to redness, will give the quantity of gold; and that of the silver is to be deduced from the quantity of chloride obtained by pouring muriatic acid into the liquid, then washing, drying, and weighing the precipitate.

If the quantity of silver is very small the nitric acid will not act on the alloy, or only in part. It will then be necessary to combine the alloy with a weighed quantity of silver by fusion—the latter may amount to at least three-fourths of the mass: this addition is to be allowed for at the end of the analysis.

Analysis of an Alloy of Silver and Copper.

Digest the alloy in nitric acid. The solution of the alloy in that acid being made and diluted with water, pour into it muriatic acid gradually, which will precipitate all the silver in the state of chloride : after which the liquid is to be filtered, and the precipitate washed, till long after the washings cease to become blue with ammonia; then the washings must be united with the filtered liquid, and an excess of a solution of potash or of soda added, which will separate all the copper in the state of peroxide. This oxide, well washed, dried, and heated to redness, gives the quantity of copper; and so likewise the chloride of silver will give the quantity of silver.

Analysis of an Alloy of Silver, Copper, and Gold.

This alloy also is to be treated with nitric acid. The silver and copper will dissolve, and the gold will remain behind. The weight of the gold is to be appreciated as in the article at page 396; and the quantity of silver and of copper, contained in the solution, determined as aforementioned. (See the preceding analysis.)

It is obvious that this analysis participates of the two preceding analyses; and consequently, if the alloy should contain too little silver or copper, it would be necessary to alloy it with a certain quantity of one of these metals, that it might be more readily attacked by the acid, and with silver in preference, because, this metal not being readily oxidizable, it will be easier to make allowance for the addition.

Analysis of an Alloy of Bismuth, Tin, and Lead.

It has been stated already that nitric acid only oxidizes tin, but that it both oxidizes and dissolves bismuth and lead; that water precipitates the oxide from nitrate of bismuth, without affecting the nitrate of lead; lastly, that sulphate of potash decomposes nitrate of lead, and the results of that decomposition are soluble nitrate of potash, and an insoluble sulphate, containing 68.42 per cent. of lead; and it will be seen, that the analysis of the alloy of tin, bismuth, and lead, may be easily effected in the following manner.

First, the alloy is to be digested with an excess of nitric acid with the assistance of heat, till there is no longer any metallic particle perceptible, or rather till no more gas or red vapours are disengaged; then the liquid is to be evaporated to dryness, and water poured repeatedly on the remaining mass to wash it. By these means all the lead will be dissolved in the state of nitrate, and a white residue will be obtained, containing the tin and bismuth oxidized; then heating this residue with a fresh quantity of nitric acid, all the oxide of bismuth will be re-dissolved; but in order to separate (without decomposing it) the portion of nitrate of bismuth which may adhere to the oxide of tin, the latter must be carefully washed with weak nitric acid.

These operations being ended, the analysis will be nearly completed. It will be sufficient to dry, to heat to redness, and to weigh the oxide of tin, to ascertain the quantity of tin; and to evaporate the solution of nitrate of bismuth to dryness, to decompose this nitrate, by heat, in a platinum crucible, and to weigh the oxide obtained, in order to determine the quantity of bismuth; and lastly, to pour sulphate of potash into the solution of nitrate of lead, and to collect, wash, dry, and weigh the sulphate of lead which will become precipitated: 100 of oxide of tin contain 78.38 of tin; 100 of oxide of bismuth contain 90 of bismuth; and 100 of sulphate of lead, 68.42 of lead.

ALKALIMETRY AND ACIDIMETRY.

Carbonate *of potash,* commonly known by the name of *subcarbonate of potash,* and in commerce called *woodash, potash,* and *pearl-ash,* according to its several degrees of purity; and *carbonate of soda,* more commonly called *subcarbonate of soda,* and known in commerce by the names of *barilla* and *kelp,* are met with in a state far from approaching to purity; and it is a problem of some practical importance to be able to decide how much *per cent.* of real alkali is contained in a rough sample from the markets. The editor takes the liberty of inserting the following directions of Dr. Henry as regards the manner of determining this point. The process depends upon the saturating power of the rough alkalies with an acid of known density.

"Provide a tube, nine inches and a half

long, and three-fourths of an inch internal diameter, provided with a lip for the convenience of pouring, and a glass foot to support it.

" A tube of this kind holds 1000 grains of water, and (which is desirable) a little more. To graduate it, weigh into it 100 successive portions of distilled water, at 60° Fahrenheit, of 10 grains each; or, if the tube be of equal bore throughout, it may be sufficient to weigh into it 10 successive portions of water of 100 grains each, dividing each of the intermediate spaces into 10 parts by a pair of compasses. When 1000 grains of water have been weighed into the tube, a line may be drawn with a file, which may be marked 0, the tenth below this 10, and so on.

" The test acid, which I prefer, is made by diluting one part of oil of vitriol of commerce of sp. gr. 1.849, with four parts of water; consequently, one-fifth part of its weight is concentrated oil of vitriol, and its specific gravity is, as nearly as possible, 1.141. Acid of this strength does not, on farther dilution, give out any heat that can be a source of inaccuracy.

" When an alkali is to be examined, find, by Dr. Wollaston's Scale of Equivalents, how many grains of oil of vitriol are required to neutralize 100 grains of what may be considered the proper alkaline ingredient of the substance in question. This, in *pearlash*, is subcarbonate of potash *; in *potash*, pure potash; in *barilla*, or *kelp*, dry subcarbonate of soda. Let us take pearlash as an example. On referring to the scale, we find that 100 grains of subcarbonate of potash are equivalent to 71 grains of concentrated oil of vitriol †. Put, therefore, into the test-tube a quantity of the dilute acid, containing 71 grains of concentrated acid, viz. 355 grains; and, to spare the trouble, on any future occasion, of weighing the acid, let a line be drawn with a file on the blank side of the tube, at the level of the acid liquor, which may be marked *Equiv. of Subc. Pot.*

" Fill up the tube with water to the line marked 0, and mix the acid and water completely by pouring them into a lipped glass vessel, stirring with a glass rod, and then returning them into the tube. Now, as the whole 100 measures contain a quantity of oil of vi-

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* The term *subcarbonate* is retained for the sake of custom.

† Dr. Ure makes it 70.4.

triol equivalent to 100 grains of subcarbonate of potash, it is obvious that each measure of the liquor in the tube is adequate to the neutralization of one grain of the subcarbonate.

" Let 200 grains, taken out of a fair average specimen of the pearlash to be examined, be dissolved in two ounce measures of warm distilled water; filter the solution, and wash the filter with two ounces more of water; which is best applied to the margin of the paper by means of a dropping bottle, or dropping tube (see plate 1, fig. 11, plate 2, fig. 8, and plate 3, fig. 3 *b*). Add the washings to the solution; and, having mixed the whole together, pour one half into a tumbler or goblet, reserving the other half for a repetition of the experiment, if necessary.

" To the liquor in the glass goblet add the diluted acid very gradually, making the additions more and more slowly towards the last. As soon as the point of neutralization is attained, which will be shewn by the cessation of a change of colour in slips of litmus and of turmeric paper, dipped from time to time into the liquor, no more acid must be added. It is proper, however, the operator should be aware, that there will often be an apparent excess of test acid, in consequence of the carbonic acid which is disengaged acting on the litmus paper. To avoid this source of error, it is advisable, towards the last, to warm the liquor, by setting the glass containing it for half an hour near the fire; and while thus warmed, to add, very cautiously, the rest of the acid required for saturation. This point being attained, the number on the test-tube, at the level of the acid remaining in it, shews at once, without any calculation, how much *per cent.* of subcarbonate of potash is contained in the pearlash under examination. In the samples I have tried, it has generally been about 80 *per cent.*

" In operating on barilla, kelp, or any variety of the mineral alkali*, the process is exactly the same; except that, as 93 † of oil of vitriol are equivalent to 100 of subcarbonate of soda, we must take 93 × 5 = 465 grains of sulphuric acid, of density 1.141. This may be marked on the tube *Equiv. of Subc. of Soda.* In a similar manner we may mark on the tube the equivalent of *pure potash*, viz. 520

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* Soda is called the mineral, and potash the vegetable alkali.

† According to Dr. Ure, 91.4 is the true equivalent.

grains of the above diluted acid; and that of *pure soda,* 783 grains; with any other equivalents that may be likely to be of use.

"Having ascertained the proportion of subcarbonate of potash in any sample of pearlash, it is easy to find, by the sliding scale, its equivalent quantity of pure or caustic potash. Thus, supposing the pearlash to contain 80 *per cent.* of subcarbonate, that number being set to subcarbonate of potash on the scale, the equivalent in pure potash is at once seen to be 55.

"To determine, by the same graduated tube, the strength of *any acid* whose equivalent is known (which is the reverse of the foregoing process), we must put 100 grains of the acid, with a sufficient quantity of water, into a goblet; and use for saturating it its equivalent of any alkali. For example, 100 grains of concentrated oil of vitriol, requiring for saturation 108 grains of dry subcarbonate of soda, dissolve the latter quantity of alkali in water sufficient to make up 100 measures of solution in the tube; then pour the alkaline solution to the acid liquor, till the latter is neutralized; and the number of measures which have been expended, exactly denote the strength of the acid.

"It may sometimes be desirable to know the proportion, not of concentrated or of real acid, but of acid of some inferior degree of density, in a specimen of acid. The method of doing this will be best explained by an example. Suppose that we wish to know the equivalent, in muriatic acid, of sp. gr. 1.160 to 100 grains of the same acid of sp. gr. 1.074; find, by the alkaline test, or by referring to Dr. Ure's Table of the quantity of real or dry muriatic acid in 100 parts of the liquid acid, at successive specific gravities*, how much real acid 100 grains of both those acids contain. In acid of sp. gr. 1.160, it will be 23.4 *per cent.*; in acid of sp. gr. 1.074, it will be 11. Then 23.4 : 100 :: 11 : 47. Therefore, 47 grains of muriatic acid of sp. gr. 1.160 are equivalent in acidity to 100 of sp. gr. 1.074.

"No chemical operation can be more simple, or more easily managed, than the measurement of the strength of alkalies by acid liquors, and of acids by alkaline ones, in the

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* This table may be met with in several elementary chemical works. It will be found in the Appendix of the 2d vol. of Dr. Henry's Chemistry.

way which has been described. The test-tube, which is the only instrument required for that purpose, may be had at any glass-house, and may easily be graduated by any person who will take the necessary pains. When once accurately prepared, it will be found, also, useful for a variety of other purposes, which will readily present themselves to the practical chemist."

If the acid form a soluble salt with lime, marble may be used for saturating it, instead of employing an alkali, as in the manner shewn above. Thus, muriatic acid forms a soluble salt with lime; and the number of grains of a given quantity of carbonate of lime, dissolved in a given quantity of muriatic acid multiplied by .74, gives the number of grains of dry acid, in the quantity employed; for, as the equivalent number of carbonate of lime is 50, and that of muriatic acid only 37, it is evident that muriatic acid decomposes .74 times its weight of carbonate of lime, for $\frac{37}{50} = .74$.

When we wish to ascertain the strength of nitric acid in a similar way, we then multiply the number of grains of marble dissolved, by 1.08, and that gives the quantity of dry nitric acid in the quantity of nitric acid employed in the experiment. Here, 54 being the equivalent of nitric acid, and 50 that of carbonate of lime, the nitric acid dissolves its own weight, and .08 more for $\frac{54}{50} = 1.08$, and hence the necessity of multiplying by that quotient: and so of any other acid whose equivalent number is ascertained. This method of determining the strength of acids is particularly applicable to acetic acid, because the specific gravity of that acid forms no criterion of its strength; and it is well established that it dissolves, or rather decomposes, its own weight of carbonate of lime. Therefore, if we put a given quantity of small pieces of marble (not in fine powder), say 300 grains, into a flask, and add to it a given quantity of a sample of any kind of vinegar, for instance, 1000 grains; after the solution is become neutral, care being taken to drive away the carbonic acid by warming it, if we pour it off, and wash the marble remaining, this, when dried and weighed, will enable us to ascertain the quantity of dry acid present from the quantity it has lost: thus, if 110 grains of marble have disappeared, the 1000 grains of vinegar added to the marble contained 110 grains of dry or real acetic acid.

NOTES.

Note A.—(*Page* 98, *No.* 115.)

As water, impregnated with carbonic acid gas, is one of the articles requisite for the performance of several of the experiments exhibited in this Treatise, and as this article cannot be readily procured on all occasions, we shall give a description of an *extemporaneous* apparatus, by which means this fluid may easily be prepared.

It consists of a common earthenware basin (plate 2, the central figure), across the rim of which is placed a wooden board, four or five inches wide, and about three quarters of an inch thick, having a slit terminating in a hole cut in the centre of the board, which hole serves to receive the inverted common quart bottle *a*, as shewn in the drawing. *b* is a similar bottle, furnished with a bent glass tube *c*, which connects the two bottles, and serves to convey the gas from the bottle *b* to *a* ; for one extremity of the tube *c* passes air-tight through the cork in the neck of the bottle *b*, whilst the other end is inserted into the neck of the inverted bottle *a*. To impregnate water with carbonic acid gas (or with any other gas which is not immediately absorbable by water) by means of this apparatus, let the bottle *a* be filled with water, quite full ; stop it with a cork, and invert it, with its neck downwards, in the earthenware basin, also previously filled with water, and let it rest in the centre hole of the board, as represented in the design, and then withdraw the cork. This being done, put some white marble, limestone, or common chalk (which are all carbonates of lime), broken into pieces of the size of a pea, into the bottle *b*, and pour upon it common muriatic acid, diluted with two or three times its bulk of water: the muriatic acid having a greater affinity for the lime contained in the marble or chalk, unites with it, and the carbonic acid gas consequently becoming extricated, will pass through the bent glass tube *c*, and enter the bottle *a*, from which it expels the water, and the bottle thus becomes filled with carbonic acid gas. When this has been effected, cork the bottle, in its inverted position, with its neck under the surface of the water; and having next removed it out of the basin, pour into it about half a pint of distilled water, cork it again perfectly air-tight, shake it for about three or four minutes, and then suffer it to stand for two or three hours, taking care to agitate it during that time frequently. The water will thus become strongly impregnated with carbonic acid gas (or become converted into an artificial Seltzer water); it will send forth a multitude of air-bubbles when exposed to the air, and particularly when poured from one vessel into another, or when gently warmed. The colder the water is, the more carbonic acid gas will be absorbed.

It is obvious that a quantity of carbonic acid gas, equal to the portion of water poured into the bottle, is wasted, but this is not an object; and this loss may even be avoided by inverting the bottle filled with carbonic acid gas, in a small cup containing distilled water, and suffering it to stand for a few hours, or till a sufficient quantity of the water has ascended into the bottle, and has become impregnated with the gas.

Instead of the glass tube and bottle *c*, *b*, a common *gas* or *proof bottle* may be used.

From marble may be obtained in this way from 40 to 44 per cent. of its weight of carbonic acid gas, so that 100 grains will produce between 90 and 100 cubic inches.

NOTE B.—(*Page* 102.)

Tan, or *tannin*, is the principal cause of the astringency of certain vegetables. It exists in oak-bark, as well as in the barks of a great variety of trees. It is also contained plentifully in the gall-nut, and in other varieties of vegetable productions, such as kino, catechu, &c. Tannin is insoluble in pure alcohol; but it is soluble in alcohol diluted with water, and in water itself, which affords a deep brown-coloured solution. This solution may be made by pouring water on bruised gall-nuts, or on oak-bark, catechu, &c., and allowing the infusion to stand some time. Dr. Bostock recommends extract of Rhatany to be digested in hot water, and filtered after it becomes cold: this form of the *tan-test* is not so liable to decomposition by being kept.

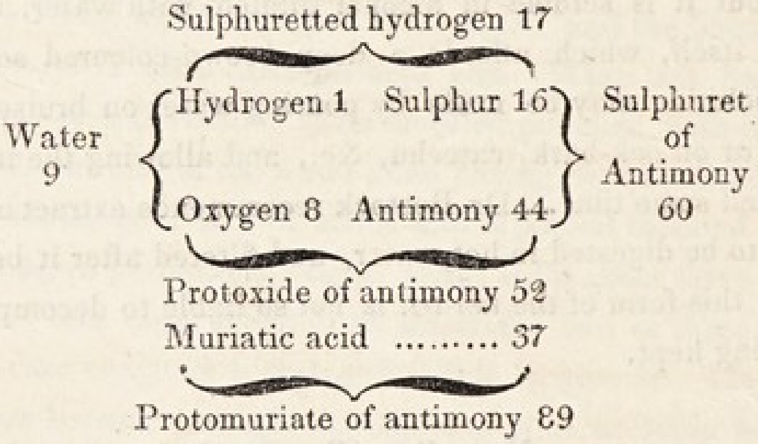
NOTE C.—(*Page* 123.)

Muriate of gold has been recommended as a most delicate test of protoxide of iron; but in its application it is requisite that a little carbonate of soda should be present: this, in some cases, may militate against its use. The precipitate which is formed gradually assumes a purple colour.—*Quart. Journ.* xv. 382.

NOTE D.—(*Page* 130.)

Sulphuretted hydrogen is not met with as an article of commerce, but as it is necessary for the performance of several experiments exhibited in this Treatise, it may easily be prepared for immediate use in the following manner:

Put into the *bottle b*, plate 2, central figure, or into the gas bottle, plate 2, fig. 14, one part of sulphuret of antimony of commerce, broken into a coarse powder, and pour upon it three or four parts of concentrated muriatic acid, and assist the following action by a gentle heat of the spirit lamp:—the sulphur of the sulphuret unites with the hydrogen of part of the water, and sulphuretted hydrogen is formed, and given off in a gaseous state; and the oxygen of the water, with the antimony, forms protoxide of antimony, which, uniting with the muriatic acid, forms protomuriate of antimony, as may be better elucidated by the following diagram:



It is stated by some chemists, that the sulphur acquires the necessary charge of hydrogen from the muriatic acid, and not from the water as above.

The sulphuretted hydrogen gas thus disengaged may be made to combine with distilled water, as in combining water with carbonic acid gas, Note A. It is advisable to let the first portion of the gas which becomes liberated escape, because it is mingled with a portion of common air contained in the gas bottle; and the bottle containing the water to be impregnated should be made of green glass, as the white glass contains lead, on which the sulphuretted hydrogen acts. Care should be taken not to inhale any of this gas, as it is highly prejudicial, even when much diluted with atmospheric air.

Distilled water takes up about three-fourths of its bulk of sulphuretted hydrogen gas; and acquires from it a sweetish and very nauseous taste, and strong fœtid odour, resembling the smell of putrid eggs, or a foul gun-barrel when wetted. The Harrowgate, Moffat, and other similar waters, are natural solutions of sulphuretted hydrogen in water. The former contains no more than about one-twelfth of its bulk of this gas. Water impregnated with sulphuretted hydrogen gas does not keep for a long time, even when preserved in corked bottles; because the hydrogen quits the sulphur, which then becomes precipitated in the form of a white powder. But for the performance of the experiments exhibited in this Treatise, the water, when kept in a dark place, or in an opaque and well-corked bottle, retains a sufficient strength for two or three months. The gas is expelled from the water without change by boiling.

NOTE E.—(*Page* 142.)

Ammoniacal sulphate of copper may be made either by adding solution of bisulphate of copper (blue vitriol) to solution of ammonia, until it is no longer dissolved; or by triturating two parts of the bisulphate in crystals with three of carbonate of ammonia, until the whole assumes a deep blue colour. The compound thus formed is also called *ammoniuret of copper*.

NOTE F.—(*Page* 149.)

To separate nickel from cobalt, Mr. Phillips (*Phil. Magazine*, XVI. p. 313,) recommends the ammoniated solution of the two metals to be evaporated until the excess of ammonia is expelled, which is known by the vapour not acting upon moistened turmeric paper; then largely dilute it, and pour in solution of pure potash or soda, as long as any precipitation takes place: the oxide of nickel is thrown down immediately, while the oxide of cobalt remains some time in solution, and may be obtained by accurately neutralizing the alkaline solution with nitric acid, and then adding carbonate of soda.

Note G.—(*Page* 170.)

M. Plessin having occasion to ascertain whether the action of a salifiable base upon a body containing azote was simply that of evolving ammonia previously existing, or that of forming ammonia by combination, endeavoured to find a base which would effect the former object, but not the latter. Potash, lime, magnesia, and many other bodies, do both; but the hydrated oxide of lead answered the purpose very well. It gives no indication of ammonia when put into contact with azotated substances not containing that alkali; even urea is not affected by it; but being put in contact with an ammoniacal salt, ammonia was instantly evolved, and rendered evident by the visible fumes which arose upon the approximation of a little acetic acid.—*Annales de Chimie,* xxxvi. p. 377, *viâ Philosoph. Mag. & Annals of Philosophy, June* 1828.

Note H.—(*Page* 211 *et passim.*)

To detect the presence of arsenic by means of the *black flux;* put a little of any substance suspected to contain it into a test-tube with a little of the flux; stop the mouth of the tube with a bit of paper put in rather loosely; hold that part of the tube containing the materials in the flame of a spirit lamp, and the arsenic will sublime, and collect in the metallic state in the cool part of the tube, having a steel-coloured lustre. The precipitates thrown down by the different tests for arsenic in fluids, may be treated in the same way, after being properly dried. The manner of making the black-flux is shewn page 211; and the way it acts when thus applied is in consequence of the charcoal of the flux abstracting oxygen from the arsenious acid; and the potash of the carbonate of potash, contained in the flux, serves to retain the arsenious acid until the temperature is sufficient for this to take place. The steel-coloured coating placed on a hot iron will give the smell of garlic peculiar to arsenic. It is stated by some authors, that white arsenic will give the same smell when put upon hot iron; but if this should be the case, it must be in consequence of the reduction of the metal, because the garlic smell arises only from metallic arsenic.

NOTE I.—(*Page* 336.)

Should there be a considerable proportion of silver and copper along with the gold, the analysis may be rendered more easy by first employing nitric acid, which will dissolve the silver and copper, but will not act on the gold. Solution of common salt, or muriatic acid, will throw down the silver from the solution in the state of chloride, and the copper may be precipitated in the metallic state, as already directed, by iron, or in the state of peroxide, by adding solution of pure potash. When the latter precipitate is washed, dried, and ignited, the quantity of pure copper it contains is very easily estimated, as repeatedly shewn.

NOTE K.—(*Pages* 358 and 392.)

The following method of separating the oxides of iron and manganese has been proposed by Mr. Hatchett:

The muriatic solution being filtered, must be diluted with cold distilled water. To this diluted solution add gradually pure ammonia, occasionally stirring the liquor until the acid has become perfectly neutralized: a few drops of ammonia may then be added, so that the liquor shall very slightly restore the blue colour of reddened litmus paper. The ferruginous precipitate must then be separated by filtration, and the liquor which passes will be found devoid of colour, and contains the manganese in permanent solution. It affords a white precipitate, with prussiate *(ferrocyanate)* of potash; and the oxide of manganese may be obtained by evaporating the solution to dryness, and by expelling the muriate of ammonia by heat; after which, if any of the muriate should be suspected to remain, it may be separated by washing the oxide upon a filter.

Other methods have also been devised by Mr. Faraday.

APPENDIX.

APPENDIX.

COLOUR OF PRECIPITATES THROWN DOWN FROM METALLIC SOLUTIONS, BY VARIOUS RE-AGENTS.

Metals.	Prussiates, or Ferro-cyanates.	Tincture of Galls.	Water impregnated with Sulphuretted Hydrogen.	Hydro-sulphurets.
Antimony	White	A white oxide merely from dilution	Orange	Orange
Arsenic	White	Little Change	Yellow	Yellow
Bismuth	White	Orange	Black	Black
Cadmium	White	No change	Orange	Orange

Cerium	White	Yellowish		Brown, becoming deep green
Chromium	Green	Brown		Green
Cobalt	Grass-green	Yellowish-white	Not precipitated	Black
Columbium	Olive	Orange		Chocolate
Copper (per-salts)	Bright reddish-brown	Brownish	Black	Black
Gold	White	Solution turned greeen. Precipitate brown of reduced gold	Yellow	Yellow
Iridium	No precipitate. Colour discharged	No precipitate. Colour of solutions discharged		

Metals.	Prussiates, or Ferro-cyanates.	Tincture of Galls.	Water impregnated with Sulphuretted Hydrogen.	Hydro-sulphurets.
Iron {1. Proto-salts 2. Per-salts	White, changing to blue. Deep blue	No precipitate. Black	Not precipitated	Black
Lead	White	White	Black	Black
Manganese	White	No precipitate	Not precipitated	White
Mercury	White, changing to yellow	Orange-yellow	Black	Brownish-black
Molybdenum	Brown	Deep brown	Brown	
Nickel	Apple-Green	Greyish-white	Not precipitated	Black
Osmium		Purple, changing to deep vivid blue		
Palladium	Olive (*Chenevix*) Deep-Orange (*Wollaston*)		Dark-brown	Dark-brown

Platinum	No precipit. ; but an orange - coloured one by cyanuret of mercury	Dark-green becoming paler	Precipitated in a metallic state	
Rhodium	No precipitate			No precipitate
Silver	White	Yellowish-brown	Black	Black
Tellurium	No precipitate	Yellow		Blackish
Tin	White	No precipitate	Brown	Black
Titanium	Reddish-brown	Reddish-brown	Not precipitated	Grass-green
Tungsten				
Uranium	Blood-red	Chocolate		Brownish-yellow
Zinc	White	No precipitate	Yellow	White

TABLE

OF

CHEMICAL EQUIVALENTS, DEFINITE PROPORTIONS, OR ATOMIC WEIGHTS*.

Acid, acetic real	50
crystallized (1 water)	59
arsenic 1 ar. + 3 ox.	62
arsenious 1 ar. + 2 ox.	54
benzoic	120
boracic 1 bor. + 2 x.	24
crystallized (2 wat.)	42
carbonic, 1 c. + 2 ox.	22
chloric, 1 chl. + 5 ox.	76
chromic, 1 chr. + 3 ox.	52
citric (dry)	58
crystallized (2 wat.)	76
ferro-cyanic ?	108
fluoric	10
gallic	62
hydriodic, 1 iod. + hyd. 1	125
hydrochloric (muriatic)	37
hydrocyanic, 1 cy. + 1 hyd.	27
hyponitrous, 1 nit. + 3 ox.	38
iodic, 1 iod. + 5 ox.	164
malic	70
Acid, muriatic, 1 chl. + 1 hyd.	37
nitric (real) 1 nit. + 5 ox.	54
(liquid sp. gr. 1.5) 2 water	72
nitrous, 1 nit. + 4 ox.	46
oxalic (dry)	36
crystallized (4 water, T.)	72
(3 do. Berz.)	63
phosphoric, 1 p. + 2 ox.	28
succinic	50
sulphuric (dry) 1 s. + 3 ox.	40
liquid sp. gr. 1.4838 (1 water)	49
sulphurous, 1 s. + 2 ox.	32
tartaric, dry	66
crystallized (1 water	75
Alcohol, 1 ol. gas + 1 aq. vapour	23
Alum, dry,	262

---

* The use of this table, which is compiled from the best authorities, is explained in the Introduction, to which the reader is referred.

Alum, crystallized, 25 water*	487
Alumina (27 Phillips) Thomson	18
sulphate	58
Aluminum (19 Phillips) Thomson	10
Ammonia, nit. 1 + 3 hyd.	17
bicarbonate, 1 am. + 2 c. a.	61
cryst. 2 w.	79
carbonate, 1 am. + 1 c. a.	39
citrate, do.	75
muriate, 1 am + 1 m. a.	54
nitrate (dry) 1 nit. ac. + 1 am.	71
crystallized, 1 water	80
oxalate, dry	53
crystallized, 2 water	71
phosphate, dry	45
crystallized, 2 water	63
succinate, dry	67
tartrate, dry	83
Antimony	44
chloride	80
deutoxide, 1 ant. + 1½ ox.	56
hydrosulphuret	69
iodide	168
peroxide, 1 ant. + 2 ox.	60
protoxide, 1 ant. + 1 ox.	52
sulphuret, 1 ant. + 1 s.	60
tartarized (T. 2 w.)	354
(P. 3 w.)	363
Arsenic	38
sulphuret (realgar)	54
sesquisulph. (orpiment)	62
Azote, or Nitrogen	14
Barium	70
chloride of, 1 b. + 1 chl.	106
peroxide, 1 b. + 2 ox.	86
protoxide, 1 b. + 1 ox. (barytes)	78
sulphuret	86
Barytes, dry, 1 barium + 1 ox.	78
hydrate, 1 b. + 1 w.	87
crystallized (20 wat.)	258
acetate, dry	128
cryst. (3 w.)	155
carbonate, dry	100
chlorate, do.	154
chromate do.	130
nitrate cryst. (no water)	132
oxalate, dry	114
muriate, cryst. (1 water)	124
sulphate, dry	118
Bismuth	72
chloride, 1 b. + 1 chl.	108
nitrate, dry	134
cryst. (3 w.)	161
oxide	80
sulphuret	88
Borax	88
cryst. (8 w.)	152
Boron?	8
Cadmium	56
oxide	64
Calcium	20
chloride	56

---

* According to Dr. Thomson, who considers it a sulphate of alumina and potash; but according to Mr. Phillips, 2 atoms of sulphate of alumina, 1 at. of *bisulphate* of potash, and 22 atoms of water.

Calcium, fluoride (fluor spar)	38
oxide (lime)	28
phosphuret	32
sulphuret	36
Calomel, see Mercury, protochloride.	
Carbon	6
Carbonic oxide (gas) 1 c. + 1 ox.	14
Cerium (Thomson)	50
Chlorine	36
protoxide, 1 c. + 1 ox.	44
peroxide, 1 c. + 4 ox.	68
Chromium	28
protoxide	36
deutoxide (T.)	44
Cobalt (Thomson)	26
chloride	62
nitrate, dry	88
peroxide, 1 c. + 1½ ox.	38
protoxide, 1 c. + 1 ox.	34
sulphate, dry	74
cryst. (7 wat.)	137
Columbium?	144
Copper	64
acetate, 1 ac. + 1 perox.	130
cryst. (6 wat.)	184
binacetate, 2 ac. + 1 perox.	180
cryst. (3 wat.)	207
bisulphate	160
cryst. (10 water) bl. vitriol	250
bisulphuret, 1 c. + 2 s.	96
binitrate, 1 perox. + 2 ac.	188
perchloride, 1 c. + 2 chl.	136
protochloride, 1 c. + 1 chl.	100
protoxide, 1 c. + 1 ox.	72
Copper, peroxide, 1 c. + 2 ox.	80
subnitrate, dry, 4 perox. + 1 ac.	374
subacetate, 2 perox. + 1 ac.	210
subsulphate, 2 perox. + 1 ac.	200
sulphuret	80
Corrosive sublimate, see Mercury, bichloride.	
Cyanogen, 1 nitr. + 2 carb.	26
Ether, sulphuric, 4 ol. gas + 1 aq. vap.	37
Fluorine?	2
Glucina	26
Glucinum	18
Gold?	200
chloride	236
protoxide, 1 gold + ox.	208
peroxide, 1 gold + 3 ox.	224
perchloride	272
sulphuret, 1 gold + 3 sul.	248
Hydrogen	1
Bicarburetted hydrogen, (olefiant gas) 2 car. + 2 hydr.	14
Carburetted hydrogen, light, 1 car. + 2 hyd.	8
bisulphuretted	33
sulphuretted	17
Iodine	124
Iridium	30
Iron	28
protoxide, 1 ir. + 1 ox.	36
peroxide, 1 ir. + 1½ ox.	40
persulphate, 1 perox. + 1½ ac.	100
protosulphuret, 1 ir. + 1 s.	44
persulphuret, 1 ir. + 2 s.	60
subsulphate, 4 perox. + 1 ac.	204
sulphate, dry, 1 prot. + 1 ac.	76

Iron, sulphate, cryst.(7 wat.)	139
Lead	104
acetate (dry)	162
cryst. (3 water)	189
arseniate, dry	174
carbonate, do.	134
chloride	140
deutoxide, 1 lead + 1½ ox.	116
nitrate, cryst. (no wat.)	166
oxalate, dry	148
peroxide, 1 lead + 2 ox.	120
protoxide, 1 lead + 1 ox.	112
subnitrate	278
sub-trit-acetate, 3 prot-ox. + 1 ac.	386
sulphate, dry	152
sulphuret	120
Lime. 1 calcium + 1 ox.	28
acetate, dry	78
arseniate	90
biphosphate, dry	84
carbonate, dry	50
chlorate, dry	104
chloride 1 l. + 1 chl.	64
citrate, dry	86
hydrate, 1 l.+ 1 water	37
hydrogd. sulphuret	89
muriate	65
cryst. 5 w.	110
oxalate, dry	64
phosphate, do.	56
subchloride, 2 l.+1 chl.	92
(6 water)	146
sulphate, dry	68
cryst. (2 water)	86
tartrate	94
(4 water)	130
Lithia	18
Lithium	10
Magnesia, 1 magnesium + 1 ox.	20
ammonia-phosph.	93
cryst. (5 water)	138
carbonate, dry, 1 m. + 1 ac.	42
Magnesia, carbonate, cryst. (3 water)	69
chloride, dry	56
hydrate 1m.+1 wat.	29
muriate	57
nitrate, dry	74
phosphate, do.	48
sulphate, do.	60
cryst. (7 water)	123
Magnesium	12
chloride	48
Manganese	28
deutoxide (brown) 1 m. + 1½ ox.	40
protoxide (green) 1 m. + 1 ox.	36
tritoxide, 1 m. + 2 ox.	44
sulphate, 1 prot-ox. + 1 ac.	76
crsyt. 5 water	121
Mercury	200
bichloride (corros. subl.)	272
bicyanide	252
binitrate, 1 perox. + 2 ac.	324
bi-persulphate, dry	296
bisulphuret (cinnabar)	232
perchloride (corros. subl.)	272
peroxide, 1m.+2 ox.	216
protochloride (calomel	236
protonitrate, 1 prot. + 1 ac.	262
protosulphate, 1 prot. + 1 ac.	248
protoxide, 1 m. + 1 ox.	208
sulphate	256
sulphuret	216
Molybdenum	48
Nickel (26 T. 30 B.) Lassaigne	40
oxalate, dry	76

Nickel, peroxide (38 T.)	56
protoxide (34 T.)	48
sulphate, dry	88
cryst. (7 wat.)	151
Nitric oxide, 1 nitrogen + 2 ox.	30
Nitrogen or azote	14
Nitrous gas, see Nitric oxide.	
Nitrous oxide, 1 n. + 1 ox.	22
Olefiant gas	14
Oxygen	8
Palladium ?	56
oxide ?	64
Phosphorus	12
Platinum	96
ammonia-muriate	222
perchloride	168
peroxide	112
protochloride	132
protoxide	104
Potash, dry, 1 potas. + 1 ox.	48
arseniate, dry	110
arsenite, do.	102
bicarbonate, do. 1 p. + 2 ac.	92
cryst. (1 water)	101
binarseniate, dry	172
bichromate, do.	152
binoxalate, do. 1 p. + 2 ac.	120
biphosphate, do.	104
bisulphate, do.	128
cryst. (2 water)	146
bitartrate	180
cryst. (1 water)	189
carbonate, 1 p. + 1 ac.	70
chlorate, dry	124
chromate, do.	100
citrate, do.	106
hydrate, solid (1 water)	57
hydriodate, dry	174
muriate	85
nitrate, no water	102
Potash, oxalate, do. 1 p. + 1 ac.	84
perchlorate, do.	131
quadroxalate, do. 1 p. + 4 ac.	192
subcarbonate, see Carbonate.	
succinate, do.	98
sulphate, do.	88
tartrate, do.	114
Potassium	40
chloride	76
peroxide, 1 p. + 3 ox.	64
protoxide, (potash) dry, 1 p. + 1 ox.	48
Rhodium ?	44
protoxide ?	52
peroxide ?	60
Selenium	40
Seleniureted hydrogen	41
Silica	16
Silicium	8
Silver	110
chloride, dry	146
nitrate, do.	172
oxalate, do.	154
oxide, 1 s. + 1 ox.	118
sulphate, dry	158
sulphuret	126
Soda, 1 sodium + 1 ox.	32
acetate, dry	82
cryst. (6 water)	136
bicarbonate, do.	76
cryst. (2 wat.)	94
carbonate (subcarb.) dry	54
cryst. (10 wat.)	144
sesquicarbonate, 2 water	84
hydrate	41
nitrate, dry	86
oxalate, do.	68
sulphate, do.	72
cryst. (10 water)	162
tartrate, do.	98
tartarized, 114 + 98	212
Sodium	24
chloride (common salt)	60
peroxide, 1 s. + 1½ ox.	36

132
96
36

Sodium, protoxide, 1 s. + 1 ox. (soda)	32
Strontia	52
carbonate, dry	74
hydrate, 1 water	61
muriate	89
cryst. 8 water	161
nitrate, dry	106
oxalate, do.	88
sulphate, do.	92
Strontium	44
oxide	52
Sulphur	16
Tellurium	32
oxide	40
Tin	58
bisulphuret	90
peroxide, 1 tin + 2 ox.	74
protoxide, 1 tin + 1 ox.	66
perchloride, 1 tin + 2 chl.	130
protochloride, 1 tin+1 chl.	94
Tin, sulphuret	74
Titanium	32
oxide	40
Tungsten	126
oxide, 1 t. + 2 ox.	142
Uranium	208
oxide ?	216
Water (1 hydrogen + 1 ox.,	9
Yttria	42
Yttrium	34
Zinc	34
carbonate	64
chloride	70
nitrate, dry	96
oxalate, do.	78
oxide	42
sulphate, dry	82
cryst. (7 water)	145
sulphuret	50
Zirconia	48
Zirconium	40

DESCRIPTION OF THE PLATES.

PLATE I.

FIG. 1. *A Pair of Scales.*—The pillar from which the beam is suspended unscrews on the lid of the box, on which it is represented in the design, so that the whole may be packed up in the box.

FIG. 2. *A Filtering Stand,* for conveniently supporting funnels *a, a, a* ; and glass jars *b, b*.

FIG. 3. *A Test Rack,* or wooden stand, containing glass tubes for examining small portions of fluids by the action of tests, or for dissolving small quantities of earths, metals, and ores, in acids or other fluids, by means of heat, over a candle or lamp.

FIG. 4. *A Table Lamp Furnace.*—It consists of a brass rod, fixed into a solid brass foot, loaded with lead ; on this rod slide four metallic sockets, with straight arms, to which are screwed brass rings of different diameters, for supporting glass basins, *c c*, or a funnel *b* ; each of these rings may, by means of a milled head and screw, *a, a, a, a,* be set at different heights. Below these rings is placed a spirit-lamp, *d,* supported on one of the sliding rings, which may be elevated or depressed, in order to cause the lamp to communicate more or less heat to the vessel suspended over it. This lamp-furnace is one of the most convenient means of applying a moderate heat to the purposes of chemistry. A vast number of operations

may be performed by means of it, in the closet, and at a trifling expense.

Fig. 5. *A Digesting Flask*, for making solutions.

Fig. 6. *A Blowpipe.*—See description of blowpipe, page 225.

Fig. 7. *A Blowpipe Spoon.*

Fig. 8 *A Blowpipe Forceps.*

Fig. 9. *A Crucible Stand.*—By raising the crucible a few inches above the bars of the fire-grate in the furnace, the bottom part is effectually exposed to the action of the heat, which is not the case if this precaution be neglected; and as the strongest heat of furnaces is always within two or three inches of the grate, the crucible stand offers the most advantageous situation for exposing the crucible and its contents to the action of the fire.

Fig. 10. *A Glass Capsule, or Evaporating Basin.*—These basins being made of very hard glass, in the composition of which no oxide of lead enters, do not easily crack, and stand a low red heat in the sand-bath very well, without bending or losing their shape.

Fig. 11. *A Tube for dropping Fluids and for collecting Precipitates.*—It consists of a tube, blown in the middle into a ball. The ball is filled by the action of the mouth, applied to the upper orifice, while the lower one is immersed in the liquid. To the former the finger is then applied; and on cautiously removing it, the liquid is expelled in drops; or, when the ball is filled, the water may be again forcibly driven out by the breath; and if directed against the inner sides of the filter, will wash down to the bottom every minute particle of the precipitate adhering to it, and thus collect it together.

Fig. 12 and 13.—*A Mortar and Pestle of Porcelain Biscuit.*—These mortars are exceedingly hard, and not acted on by any of the chemical agents in common use. They will bear a smart blow, and are perfectly smooth within, so that the pulverized substance does not stick to the sides.

Fig. 14. *A precipitating or decanting Jar.*

Fig. 15. *A Crucible and its Cover.*

PLATE II.

The centre figure, which is not numbered, has been described page 411.

Fig 1. *Apparatus for the Analysis of Soils,* as described page 329.

Fig. 2. *A specific gravity Bottle.*—It consists of a small short phial, with a perforated ground stopper. When this bottle is filled with distilled water of a given temperature, it should hold exactly 1000, 2000, or any even number of grains. The quantity which it is found to contain of any other fluid at the same temperature denotes the specific gravity of the latter fluid: for example, if it holds 1000 grains of water, and 1850 of sulphuric acid, the specific gravity of the sulphuric acid is to that of water as 1850 to 1000.

Fig. 3. *A Spirit Lamp.*—For experiments in the small way, which demand a moderate degree of heat, and much neatness in execution, this lamp is an excellent contrivance. The flame of burning spirit of wine being always perfectly clear, and free from smoke, produces no soot on the vessel on which it acts. It may easily be made to burn slower or faster, and consequently occasion more or less heat, by merely enlarging or diminishing the surface of the cotton wick upon which the spirit burns; for as long as the wick is freely supplied with spirit, the flame is precisely of the same strength. The burning of spirit is, besides, more clear and elegant than oil; it gives no unpleasant smell, and does not produce any disagreeable consequence if spilt; the wick of the lamp is not rendered foul, nor is it scorched or consumed, and the vessel to

which the flame is applied does not become obscured by smoke. The expense of the spirit to supply the lamp for experimental purposes is quite inconsiderable. *c*, the lamp; *a*, a glass cap, fitted to the lamp by grinding, to prevent the evaporation of the spirit from the surface of the cotton when the lamp is not in use.

FIG. 4. *A Stand with sliding rings, for supporting basins, &c.: a, b, represents a Section of a Steam Bath for drying the products of analysis.*—The substance to be dried is placed in the conical glass, *c*, and when the vessel is filled with water up to the side tube, *b*, the desiccation may be performed by putting the apparatus over a lamp, and keeping the water in a state of ebullition. *d* is a rim, to secure the glass *c* in its place.

FIG. 5. *A Perspective View of the Diamond Mortar*, as described page 278.

FIG. 6. *A Chemical Lamp on Argand's Plan.*—The chimney of the lamp is marked 16. This lamp being flat and low, is very convenient for use. It produces a steady, permanent, and easily-manageable heat, which may be kept up for many hours.

FIG. 7. *An Agate Mortar*, as described page 279.

FIG. 8. *Another Modification of the Tube described Fig.* 11, *Pl.* 1.

FIG. 9. *A Pair of Crucible Tongs.*

FIG. 10. *Dr. Wollaston's Pocket Blowpipe.*

FIG. 11. *A Sand Bath, to fit the Portable Furnace, represented Fig.* 8, *Pl.* 3.

FIG. 12, 13. *Rings to fit the same Furnace, for contracting the opening of it.*

FIG. 14. *A Flask and Bent Tube.*

PLATE III.

FIG. 1. *Two Bottles, connected by a bent glass tube, elucidating*

the experiment, page 98, *No.* 152.—They may be used for a variety of purposes.

Fig. 2. *Another Form of the Pneumatic Trough or Water Bath, for collecting gases.*—The vessel, standing on the shelf, is filled with water, which is displaced by the gas issuing from the bent tube connected with the bottle standing outside the bath, and which contains the materials for generating the gas. The centre figure of Plate 2 is a similar apparatus, and has already been described, page 411.

Fig. 3. *a*, a bottle with an elongated stopper, with which a drop of any fluid may be directed to a solid or liquid under examination. *b*, a bottle for directing a few drops or a small stream of water upon a substance. It is useful for washing precipitates on filters. The manner of using it is to invert the bottle, and hold it in the hand, the warmth of which expands the air within the bottle, which expels the fluid, either in drops or in a stream. When it ceases to act, set it with the mouth upwards, cold air will rush in, and then it may be used as before.

Fig. 4. *a*, a precipitating glass, extremely useful in testing mineral waters and other fluids. *b* is another form, and is called Phillips's precipitating glass: in consequence of its shape, it allows the precipitate to fall readily to the bottom of the liquid. They should be kept of different sizes, to contain two, four, six, or more ounces.

Fig. 5. *Knight's Portable Furnace*, which is useful for a variety of chemical purposes.

Fig. 6. *A Glass for making Solutions, about the size of an Ale-Glass.*—It has a lip for decanting the supernatant fluid, &c.

Fig. 7. *Represents the manner of using the Blowpipe.*

Fig. 8. *Another Form of a Portable Furnace.*—Rings for contracting the opening at the top, and the sand bath to fit in the same, may be seen Plate 2, Figs. 11, 12, 13.

the experiment, page 56, No. 163.—They may be used for a variety of purposes.

FIG. 2. *Another Form of the Pneumatic Trough, or Water Bath, for collecting gases.*—The vessel, standing on the shelf, is filled with water, which is displaced by the gas issuing from the bent tube connected with the bottle standing out of the bath, and which contains the materials for generating the gas. The centre figure of Plate III. is a similar apparatus, and has already been described, page 436.

FIG. 3. *a*, a bottle with an elongated spout, with which a drop of any fluid may be dropped into a fluid or liquid under examination. *b*, a bottle for directing a few drops or a small stream of water upon a substance. It is useful for washing precipitates on filters. The manner of using it is to invert the bottle, and hold it in the hand, the warmth of which expands the air contained in the bottle, which expels the fluid, either in drops or in a stream. When it ceases to act, set it with the mouth upwards, cold air will rush in, and then it may be used as before.

FIG. 4. *a*, a precipitating glass, extremely useful in testing mineral waters and other fluids. *b* is another form, and is called Phillips's precipitating glass: in consequence of its shape, it allows the precipitate to fall readily to the bottom of the liquid. They should be kept of different sizes, to contain two, four, six, or more ounces.

FIG. 5. *Black's Portable Furnace*, which is useful for a variety of chemical purposes.

FIG. 6. *A Glass for making Solutions*, about the size of an Ale-Glass.—It has a lip for decanting the supernatant fluid, &c.

FIG. 7. *Represents the manner of using the Blowpipe.*

FIG. 8. *Another Form of a Portable Furnace.*—Rings for contracting the opening of the top, and the sand bath to fit in the same, may be seen Plate I, Figs. 11, 12, 13.

INDEX.

THE END.

W. WILSON, PRINTER, 57, SKINNER-STREET, LONDON.

ERRATA AND ADDENDA.

Page 96, line 10 from bottom, for *Mr. R. Dalton* read *Mr. John Dalton.*

Page 77, line 2 from bottom, dele *salt.*

Page 279, line 7 from top, for *lay* read *lays.*

The word "Example," page 51, should precede paragraph 63, page 49, instead of being placed where it now stands.

Page 59, under "Acetic Acid," it may be observed that it is an auxiliary test of the presence of ammonia, applied similarly to muriatic acid, which see.

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