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A

PRACTICAL TREATISE

THE USE AND APPLICATION

OF

CHEMICAL TESTS,

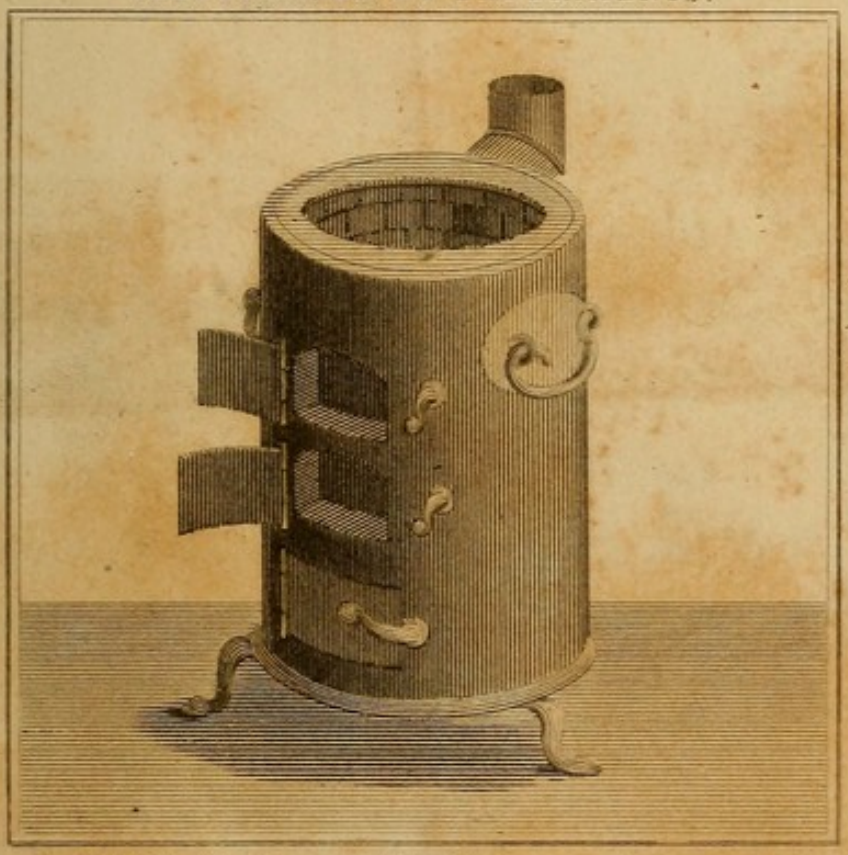
WITH

Concise Directions for Analyzing

METALLIC ORES, EARTHS, METALS, SOILS, MANURES,

And Mineral Waters.

ILLUSTRATED BY EXPERIMENTS.



Third Edition, with Plates, Enlarged,

BY FREDRICK ACCUM,

OPERATIVE CHEMIST,

Lecturer on Practical Chemistry, on Mineralogy, and on Chemistry applied to the Arts and Manufactures; Member of the Royal Irish Academy; Fellow of the Linnæan Society; Member of the Royal Academy of Sciences, and of the Royal Society of Arts of Berlin, &c. &c.

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1820.

PREFACE

TO

THE SECOND EDITION.

11, *Compton Street, Soho.*

THE favourable reception which the first Edition of this Treatise has met with amongst the Votaries of Chemical Philosophy, and the flattering character it has received in the most esteemed Journals of Science, have induced me to re-print the Work.

The treatise, as now presented to the Public, comprehends a summary view of the general nature of chemical re-agents or tests, with the effects and phenomena which are produced by the action of these bodies—the particular uses

to which they may be applied in the various pursuits of chemical science—and the art of applying them successfully for detecting the chemical nature of bodies, or the proportion of their constituent parts.

To accomplish this object, I have, in the first place, stated the characteristic powers of each individual test, and have afterwards proceeded to illustrate its attributes, and peculiar mode of action, by a series of experiments sufficiently striking to interest the mind, and imprint its generalities on the memory.

In selecting the illustrative proofs, I have chosen such experiments only as are easy to be performed, and the exhibition of which requires no other agents, than a mere collection of the chemical tests enumerated in the treatise, in addition to a few articles of commerce which may readily be procured; and to render the

work still more useful, I have given numerous examples of analysis, taken from the memoirs of Davy, Klaproth, Thenard, Murray, and other celebrated Analysists.

I have, likewise, furnished a list of al hose substances for which there exists any appropriate tests, with direct references to the manner in which those substances may individually be detected; together with the necessary precautions to be observed, to guard against certain deceitful appearances that may occur under peculiar circumstances, and without which precautions, chemical tests are of little utility.

In fact, I have not only endeavoured to render this Treatise useful to the young chemist, but it has also been my aim to give it such a popular form, as to place the subject on which it treats within the reach

even of those who are unacquainted with the principles of chemical science.

The student, in particular, will, it is presumed, readily comprehend the signals by which the chemist steers; he will find no difficulty in applying chemical re-agents to original investigations, whilst, at the same time, he will become enabled to perform a series of instructive experiments, well calculated to illustrate the chemical affinities of different bodies, and the most important changes of which they are susceptible in their reciprocal action—he will thus become acquainted with the laws that govern the composition and decomposition of bodies, and with the practical processes by which the constituent parts of compound bodies are discovered.

FREDRICK ACCUM.

LONDON, JULY 1, 1818.

PREFACE

TO

THE THIRD EDITION.

Compton Street, Soho.

I HAVE carefully revised the Second Edition of this Work. The typographical errors of the former Edition, some of which materially affected the sense, have been corrected; and no labour has been spared to render the Third Edition, now presented to the public, worthy of the marked approbation which the Treatise has met with among the cultivators of chemical science.

FREDRICK ACCUM.

LONDON, NOV. 15, 1819.

ADVERTISEMENT.

The Public is respectfully informed, that portable Chests, containing a Select Collection of the Chemical Tests and Apparatus, necessary for performing the Experiments described in this Treatise, may be had as a Companion to this Work.

FREDRICK ACCUM.

No. 11, *Compton Street, Soho.*

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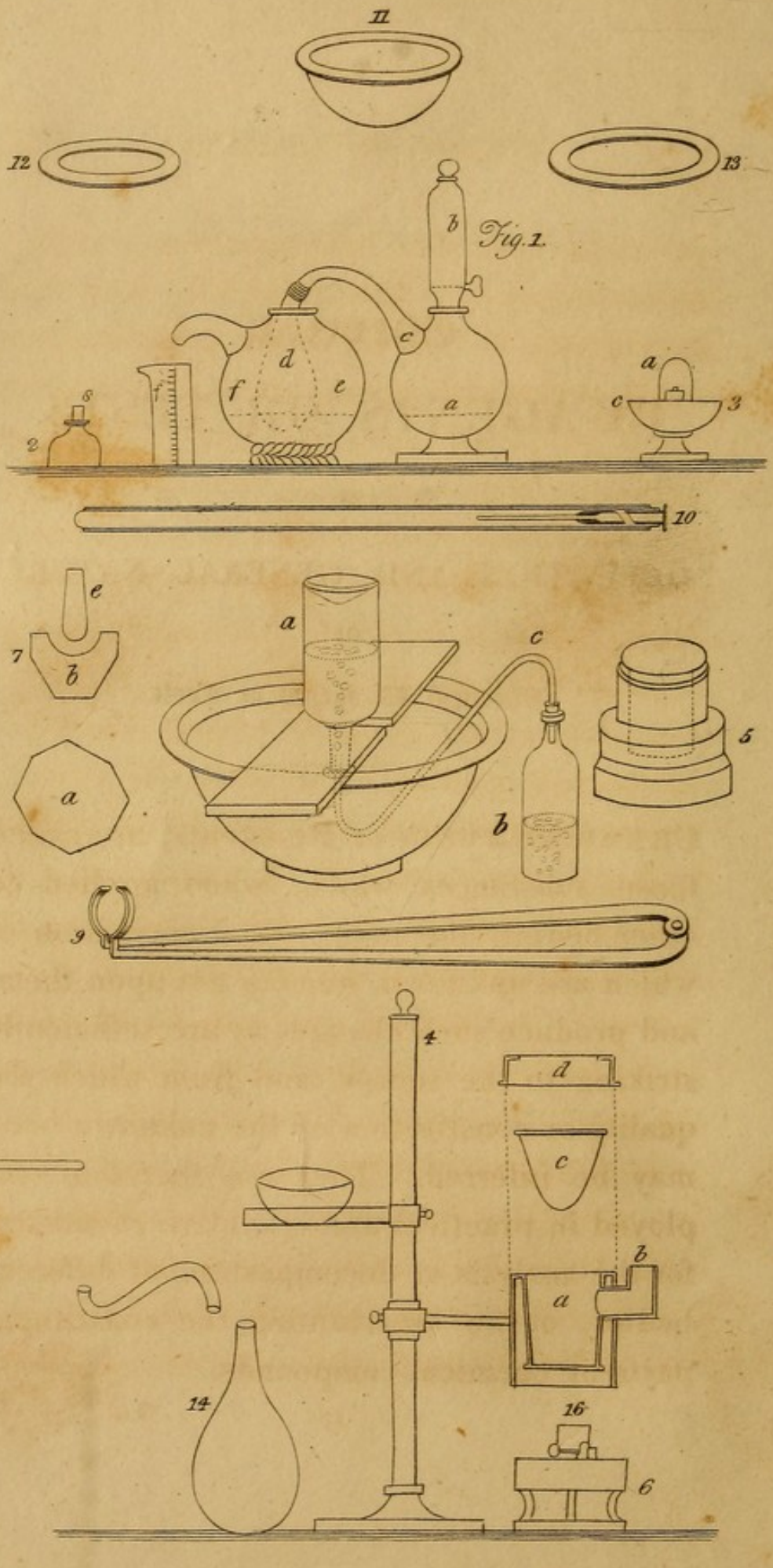
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Chemical
RE-AGENTS OR TESTS.

DEFINITION AND GENERAL NATURE
OF
Chemical Re-agents or Tests.

CHEMICAL TESTS or Re-agents, are called those substances which, when applied to other bodies, the nature or composition of which are unknown, *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. 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 chemistry in its 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 principal of the body with which it is brought into contact, and a compound arises, whose characters at once indicate the nature of the principal 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 process 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, 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 car-

bonate, 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 portion of liquid ammonia: by this means the silver becomes dissolved, and the lead is left behind.

To pursue our inquiry further by means of tests, let us suppose that sulphate of iron produced 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 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 other 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 the silver and the copper (European silver coins are all alloys of silver and copper). The copper gives the solution a green colour.

To separate the silver, add to the solution common salt previously dissolved in water; a white curdly precipitate will ensue; decant the supernatant fluid, and put it aside. Collect the white precipitate, wash it by pouring water over it repeatedly, dry it, and lastly expose it to a heat sufficient to fuse it. 100 parts by weight of it, contain in round numbers 75 of silver.

2. Into the liquid thus deprived of its silver pour 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 into 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 together with the copper. When this has been done, wash the metallic copper again, dry it, and weigh it.

If this analysis be rightly conducted, the weights of the silver and copper 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, learnt to make a 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 similar 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, and 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 enquiries 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 reddening 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 alcalies 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 alcali 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 alcalies restore the original colour of the tincture. That silver is precipitated from its solutions by common salt and sulphuric 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 effusion of boiling water. That quicksilver dissolved in nitric acid occasions an orange-coloured precipitate with fixed alca-

lies; and that metals and metallic solutions become blackened by sulphates of all kinds. 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. Bouldoc pointed out the application of alcohol as an 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 enquiries; and his works are to this day pronounced to be the best guide to those who wish to become proficient in this department of operative chemistry.

Vanquelin 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 following are the most essential tests now made use of in chemistry.

LIST

OF

CHEMICAL TESTS.

1. Tincture of Litmus.
2. Litmus Paper.
3. Litmus Paper reddened by Vinegar.
4. Tincture of Red Cabbage.
5. Tincture of Brazil Wood, and Brazil Wood Paper.
6. Tincture of Turmeric, and Turmeric Paper.
7. Sulphuric Acid.
8. Nitric Acid.
9. Muriatic Acid.
10. Tartareous Acid.
11. Boracic Acid.
12. Acetic Acid.
13. Oxalic Acid.
14. Muriate of Ammonia.
15. Oxy-Muriate of Mercury, or Corrosive Sublimate.
16. Sub-Nitrate of Mercury.
17. Nitrate of Silver.

18. Acetate of Silver.
19. Sulphate of Silver.
20. Phosphate of Soda.
21. Lime Water.
22. Tan.
23. Nitrate of Cobalt.
24. Super Acetate of Lead.
25. Sub-Acetate of Lead.
26. Muriate of Platina.
27. Green Sulphate of Iron.
28. Arsenious Acid.
29. Muriate of Gold.
30. Sulphate of Copper.
31. Muriate of Lime.
32. Benzoate of Ammonia.
33. Water Impregnated with Sulphuretted Hydrogen Gas, or Liquid Sulphuretted Hydrogen.
34. Tincture of Galls.
35. Sulphate of Copper and Ammonia.
36. Sub-Borate of Soda.
37. Sub-Muriate of Tin.
38. Liquid Ammonia.
39. Oxalate of Ammonia.
40. Prussiate of Potash.
41. Prussiate of Ammonia.
42. Prussiate of Mercury.
43. Barytic Water.
44. Muriate of Barytes.

45. Acetate of Barytes.
46. Nitrate of Barytes.
47. Muriate of Alumine.
48. Succinate of Ammonia.
49. Solution of Starch.
50. Sulphate of Soda.
51. Carbonate of Ammonia.
52. Fluate of Ammonia.
53. Alcohol.
54. Solution of Soap.
55. Wine Test.
56. Zinc.
57. Iron.
58. Tin.
59. Copper.
60. Quicksilver, and Silver Leaf.
61. Fluxes for the Blowpipe.
62. Water impregnated with Carbonic Acid Gas, or Liquid Carbonic Acid.
63. Water impregnated with Sulphuretted Hydrogen Gas, or Liquid Sulphuretted Hydrogen.

PHENOMENA PRODUCED

BY

CHEMICAL TESTS,

AND

ART OF APPLYING THEM.

I. Tincture of Litmus.

THIS test is employed for detecting the presence of uncombined acids, by which it becomes changed to red: its natural colour is a dark blue, inclining to purple. If the redness vanishes by suffering the fluid 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; and a precipitate falls down, which is soluble with effervescence 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. A drop of nitrate of silver, superacetate of lead, or muriate of bismuth, renders it instantly *black*; but no such effect is produced with carbonic acid gas.

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 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.

EXPERIMENT I.

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.

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* *Test tubes* are called 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.

EXPERIMENT II.

Add to a wine-glass full 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.

EXPERIMENT III.

To shew the extreme sensibility of this test, with regard to carbonic acid, let a few ounces of distilled water be tinged slightly

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* See description of the plates.

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 $8\frac{1}{2}$ per cent. If the water thus reddened be boiled, its original blue colour will re-appear, as in the before-mentioned experiment.

EXPERIMENT IV.

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.

EXPERIMENT V.

Add to the same quantity of distilled water, a grain of alum, salt of sorrel, or acidulous tartrate of potash: no change will take place; but if a few drops of tincture of litmus be added, the fluid instantly becomes red; because these salts contain a portion of a free or uncombined acid.

EXPERIMENT VI.

Take water impregnated with sulphuretted hydrogen gas, and add to half a wine-glass full, a little tincture of litmus: the fluid will exhibit a red colour; boil the reddened tincture, 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.

EXPERIMENT VII.

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 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; and if nitrate of silver be dropt into the other tube, a black precipitate will instantly be produced.

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.

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.

EXPERIMENT VIII.

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.

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.

EXPERIMENT IX.

To two ounces of water, sulphuric acid was added in the proportion of 1 to 307 200. 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 paper, 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.

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 liquid 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.

II. Litmus Paper.

Paper stained with tincture of litmus, is also used as a test for detecting acids, in an uncombined state, by all of which it is reddened. 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; whereas all other acids redden it permanently.

Water impregnated with sulphuretted hydrogen gas, likewise produces an evanescent feeble redness with this test.

EXPERIMENT X.

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 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.

EXPERIMENT XI.

Add a few drops of sulphuric, nitric, or muriatic acid, to half a wine-glass full 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.

EXPERIMENT XII.

Immerse a slip of litmus paper into any sort of wine, cyder, 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 in tincture of litmus, is owing to the presence of citric, tartaric, malic, or acetic acid.

EXPERIMENT XIII.

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.

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

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

Litmus paper is readily prepared, by dipping fine writing paper into tincture of litmus, and suffering it to dry slowly. The paper employed should first be freed from the portion of glue, alum, and other foreign matters, which all writing paper contains,

which may be done by a repeated affusion of distilled water.

This test paper is reddened by water, containing $\frac{1}{4695}$ part of sulphuric acid.

III. Litmus Paper reddened by Vinegar.

Litmus paper, when slightly reddened by an acid, has its blue colour restored by alcalies, their carbonates, and alcaline 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 alcalies are in direct opposition to each other, the acid restoring the colour to its original state, after it has been changed by the alcali, and *vice versa*. A single coloured test paper of litmus becomes therefore a delicate test for both acids and alcalies.

To know whether the effect which this paper suffers be owing to an alcali, 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.

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 alcaline 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.

EXPERIMENT XIV.

To one quarter of a pint of distilled water, strongly impregnated with carbonic acid gas, (or common seltzer 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 calcareous earth of the marble or chalk will become dissolved in the water. When the fluid has become clear, decant part of it, or better filtre it, and immerse into 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.

EXPERIMENT XV.

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 turpid, 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 gas, 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 filtred, and immerse into it a piece of reddened litmus paper; the colour of which now will no longer be altered.

EXPERIMENT XVI.

To a test tube full of distilled water, add a few grains of sub-carbonate of potash, soda, or any other alcali, 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.

EXPERIMENT XVII.

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

EXPERIMENT XVIII.

Litmus paper reddened by an acid has also its colour restored by alcaline 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 alcalies, 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 carbonated alcalies, namely, potash, soda, and ammonia, as well as lime, are not effected by it.

IV. Tincture of Red Cabbage.

This tincture, which is of a bright blue colour, is an exceedingly delicate test both for acids and alcalies, when present in an uncombined or free state. A very minute portion of any alcali changes its vivid blue colour to green, whilst acids turn it red. The alcaline earths, barytes, strontia, and lime, here also act as alcalies.

EXPERIMENT XIX.

Add to half a wine-glass full 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 will lose its blue colour, and become changed to green, because the white of the egg contains soda.

EXPERIMENT XX.

Let distilled water be tinged blue, by adding to it tincture of 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 sub-carbonate of potash, or any other alcali to the other tube, the blue becomes changed to green.

The action of barytes, strontia, and lime, need not to be illustrated, because they act

precisely like alcalies upon this tincture, and we are in possession of excellent tests for discriminating these bodies, as will be seen hereafter.

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 (brassica rubra) into small pieces, and pouring over it boiling-hot distilled water, and suffering the whole to macerate for a few hours. The clear fluid being then decanted and mixt with one-eighth of its bulk of spirit of wine, is fit for use.

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, the red colour will vanish,

and the tincture become blue. This being done, suffer the mixture to become clear by subsidence, or filtre it; and lastly, mingle it with 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.

V. Tincture of Brazil Wood, and Brazil Wood Paper.

Tincture of Brazil wood, which is of a fine dark red colour, becomes changed to violet or purple by alcalies, either in a pure state, or when combined with carbonic acid; and also by alcaline earths. It is, however, liable to mislead, because a solution of magnesia, or calcareous earth, with excess of carbonic acid, produces a similar change. If, therefore, the test be employed in the analysis of a mineral water, containing super-carbonate of lime, or magnesia, these substances should first be got rid of by concentrating the water

by boiling, or the excess of the carbonic acid which held these earths in solution flies off, and the neutral carbonates fall down. If the test be then applied to the filtred water, we may know whether the change of colour is produced by a free or uncombined alcali, or by a carbonated earth. If by the former, the purple colour becomes more intense, because the evaporated water holds a greater quantity of alcali 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.

EXPERIMENT XXI.

Into distilled water dip a piece of Brazil wood paper: its red colour will not be altered.

EXPERIMENT XXII.

Add to half a test tube full of the same water, a grain of sub-carbonate of potash, or any other alcali, and into this solution immerse a slip of Brazil wood paper: its red colour will instantly be changed to violet.

EXPERIMENT XXIII.

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 of carbonate of lime in carbonic acid, 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, filtre it; and dip into the filtred fluid

Brazil wood paper, which now no longer will suffer a change of colour.

EXPERIMENT XXIV.

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 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 filtred, and dip into it a piece of Brazil wood paper, the colour of which will be changed to a faint violet.

EXPERIMENT XXV.

Add to half a test-tube full 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.

Brazil wood paper, when rendered violet by a dilute solution of an alcali, may be used as a test for acids, which cause the original red colour to re-appear.

VI. Tincture of Turmeric, and Turmeric Paper.

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

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 alcalies may be ascertained with great nicety, which is often of considerable consequence in chemical operations.

EXPERIMENT XXVI.

Dip a piece of turmeric paper into distilled water: its yellow colour will remain unaltered.

EXPERIMENT XXVII.

Add a grain of potash, or soda, either in a pure state, or in the state of a carbonate, to half a test tube full of distilled water, and immerse into the solution a piece of turmeric paper; it will instantly acquire a

brown colour; and if the paper be now dipped into a dilute acid, its original yellow colour will re-appear.

EXPERIMENT XXVIII.

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 become 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.

EXPERIMENT XXIX.

To seltzer 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, filtre it, or suffer the mixture to stand undisturbed till it is become transparent. Dip into this solution of super-carbonate 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 alcalies, and on this account is preferable to Brazil wood paper (page 93). Barytes, strontia, and lime, act, as stated already, in this case also like alcalies.

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, p. 32.

EXPERIMENT XXX.

" 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 re- " main in it for one minute at this tempera- " ture. 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 effect the colour of paper stained with " turmeric, when allowed to remain in it " one minute. The evaporation was con- " tinued in a temperature never exceeding " 140°, and gradually 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 removed 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 " dissolved in eleven ounces of distilled " water, and exposed to a temperature of " 115°; the paper stained with turmeric " immersed into it; but I now measured " the water as soon as the least discolour- " ation 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 " temperature, when one-eighth was evapo- " rated. 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 alcali was thus de- " tected by turmeric paper."

Turmeric paper rendered brown, or orange, by alcalies, is restored to its original yellow colour by acids.

EXPERIMENT XXXI.

Dip a piece of turmeric paper into 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, and its yellow colour will be restored.

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.

VII. Sulphuric Acid.

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, alcaline, 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 the nitric, muriatic, acetic, and fluoric acids (besides many others) from their combinations. 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 belonged to the class of nitrates, the vapours produced by the action of the sulphuric acid have a yellow or orange colour, and the salt then deflagerates 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. Sulphuric acid has also been re-

commended 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, being soluble in 500 parts of water, and much more so, 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 chrystals, 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 by its affording a precipitate with oxalic and barytic salts. When a liquor containing selenite is rapidly evaporated, this salt separates as a brittle shining laminæ.

EXPERIMENT XXXII.

To half a wine-glass full 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 become disengaged.

EXPERIMENT XXXIII.

Into the same quantity of water impregnated with carbonic acid gas, or to common seltzer water, add a like quantity of sulphuric acid. A multitude of very minute air bubbles will rapidly become disengaged, which indicate the presence of carbonic acid gas.

EXPERIMENT XXXIV.

Having dissolved ten or fifteen grains of muriate of soda (common salt) in about two tea-spoonsfull of water, add to it ten or fifteen drops of 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 liberated, assumes the gaseous form, and would be invisible if no humidity was present ; but being condensed by the moisture which it meets with in the atmosphere, it appears as a cloud. The liquid ammonia producing dense white clouds, is owing to the production of muriate of ammonia, a salt formed from the vaporous muriatic acid combined with the volatilized ammonia, and thus producing muriate of ammonia.

EXPERIMENT XXXV.

Put into a small evaporating basin, or watch glass, ten or twenty grains of pulverised nitrate of potash (salt-petre), and pour upon it twenty or twenty-five drops of sulphuric

acid; stir the mixture with a glass rod, and warm it gently over the spirit lamp: yellow fumes will be produced, which indicate the presence of nitric acid. If a little of the salt be thrown on ignited coals, it will deflagerate.

EXPERIMENT XXXVI.

Put ten or twenty grains of super-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 super-acetate of lead, and unites with its base to produce sulphate of lead.

EXPERIMENT XXXVII.

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 the 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 out upon the varnish or wax by means of a needle, or other sharp-pointed instrument, as is done in common copper-plate 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.

The 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.

VIII. Nitric Acid.

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 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 the solution mingled with alcohol; which throws down the starch from its solution in this acid.---*Ann. de Chim. l. v.* 28.

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. The substance requires simply to be heated in a retort, and the gaseous product to be collected in the usual manner. That the nitric acid did not furnish the azote, may be proved by saturating an aliquot portion of the acid employed in the experiment with an alcali; for it will be seen, that the portion of acid thus tried, saturates as much alcali as a like portion of the same acid which has not been made to act upon the substance; consequently the azote must have been produced from the

substance submitted to the action of the acid. 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.

EXPERIMENT XXXVIII.

Tin of commerce frequently contains either a minute portion of copper and lead, and sometimes both these metals are present. To ascertain the purity of tin by means of nitric acid, put one part of the filing 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.

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 filtre 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. 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 (sulphate of lead), which is highly insoluble in water, and therefore falls to the bottom.

EXPERIMENT XXXIX.

To distinguish 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 conversion of the carbon of the steel into charcoal, which thus becomes predominant, and iron being nearly free from carbon, can produce only a grey stain.

IX. Muriatic Acid.

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 boiling water, and in dilute nitric acid.

It is also employed for discovering ammonia when in a disengaged state; a glass rod or other substance moistened with this acid, and held in the atmosphere of ammoniacal gas, becomes immediately surrounded by dense white clouds of muriate of ammonia. 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 platina 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.—See *Annals of Philosophy*, 1814, xxvi. p. 312.

EXPERIMENT XL.

Mix five or six drops of super-acetate of lead with half a wine-glass full of distilled water, and add to it a drop or two of muriatic acid: a dense white precipitate will fall down, which is muriate of lead. This salt being soluble in about twenty-two parts of water, in which latter respect, as well in not changing colour by a short exposure to light, it may be distinguished from muriate of silver (see nitrate of silver) which it resembles; and water may therefore be used to separate the muriate of lead from that of silver; but nitric acid is preferable. The

muriate of lead is likewise soluble in acetic acid, by which it may further be distinguished from muriate of silver, and from sulphate of lead. According to Klaproth, one hundred grains dried fully, but short of volatization, contains seventy-five of lead, and fourteen of muriatic acid.

EXPERIMENT XLI.

Mix a few grains of muriate of ammonia with double its weight of sub-carbonate of potash or quick lime, intimately together, and bring near it a feather, or glass rod, moistened with muriatic acid; dense white fumes will become visible, which indicate the presence of ammonia.

EXPERIMENT XLII.

Add a few drops of liquid ammonia to half a test tube full 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 muriatic acid, as a test for silver, see nitrate of silver.

X. *Tartareous Acid.*

The two alcalies, namely soda and potash, resemble each other so closely in their most obvious chemical characters, that they are not readily distinguishable than by studying the characters of their combinations, namely, 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 the acid and alcaline solutions are somewhat concentrated, when mixed;

whereas sulphate of soda is very soluble. Nitrate of potash crystallizes in long six-sided prisms, but nitrate of soda in cubes. However, by means of tartareous acid this trouble may be saved, for it produces with potash, when added in excess, a highly insoluble salt; but with soda, a salt which is easily soluble in water. The alcali to be examined is first dissolved in muriatic or any other acid, and a solution of tartareous acid added in excess: if the salt has potash for its basis, there will be a chrystalline 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 tartareous acid be always added in excess.

EXPERIMENT XLIII.

Make a concentrated solution of sulphate of soda in distilled water, and add to it a concentrated solution of tartareous acid: no change will take place, because the salts of soda are not altered by tartareous acid.

EXPERIMENT XLIV.

Make a concentrated solution of sulphate of potash in water, and add to it tartareous acid in excess: a chrystalline salt will gradually collect, and fall to the bottom of the tube. The salt is super-tartrite of potash.

EXPERIMENT XLV.

Drop tartareous acid into a solution of phosphate of soda: no change will take

place, for the same reason as stated in Experiment XLIII.

EXPERIMENT XLVI.

Add to a solution of prussiate of potash a little tartareous acid, and suffer the mixture to stand for a few minutes: minute chrystals of super-tartrite of potash will be deposited on the sides of the vessel.

EXPERIMENT XLVII.

Dissolve eight or ten grains of caustic soda in half a test tube full of water, and add to the solution tartareous acid in excess: no change will take place.

EXPERIMENT XLVIII.

Dissolve the same quantity of caustic potash in a like quantity of water, and add to the solution tartareous acid: in a few seconds the mixture will become turbid, and a quantity of white granular powder will fall to the bottom, which is super-tartrite 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.

XI. Boracic Acid.

The 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 is of use to the mineralogist, as a flux for the blow-pipe assay; it particularly facilitates the lution to separate the silex. The liquid is

fusion of earthy substances, and produces with them 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 substances, 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.

It is likewise a very useful agent for discovering the presence of alcalies 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 so-

lution then mixed with carbonate of ammonia in excess, boiled and filtred. By this means all the earthy and metallic ingredients are separated. The liquid is next mixed with a sufficient quantity of nitric acid, and evaporated till the whole of the boracic acid is separated. Nothing now remains but the nitric acid combined with the alcaline constituents of the mineral (and with ammonia), the nature of which may then be readily ascertained by tartareous acid, or muriate of platina, the nitrate of ammonia being first got rid of by an exposure to a dull red heat.

XII. Acetic Acid.

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.

XIII. Oxalic Acid.

The 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 calcareous salts. 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.*

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 titanium, and which may be decomposed by exposure to a heat, sufficient to destroy the oxalic acid. This 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.

XIV. Muriate of Ammonia.

This is one of the tests employed for detecting platina, with the solution of which it produces (if the platina be pure) a bright

yellow precipitate; but if it contains iridium, the precipitate slightly verges to the orange. The precipitate is a triple compound, consisting of oxide of platina, ammonia, and muriatic acid. And by this character platina is distinguished from all other metals, and may be separated when combined with them. The precipitate, or triple salt, obtained by muriate of ammonia, when exposed to a strong red heat, furnishes a grey spongy mass, which is metallic platina.

This test therefore furnishes a ready expedient for detecting the adulteration of gold with platina, 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 platina, by muriate of ammonia.

When this test is added to a solution of the *ore of platina*, 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 platina; a clear yellow colour of the precipitate is therefore a criterion of the purity of platina. The yellow precipitate forms an useful pigment for the painter, a very bright and permanent colour.

Muriate of ammonia is also used as a test to detect alcalies, and alcaline 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 alcali,

or alcaline earths, unequivocal; besides this, we have better tests for alcalies and alcaline earths.

Mr. Chevenix recommends this salt as an useful agent for separating alumine from its alcaline solutions; the alcali combines with the muriatic acid, and the liberated ammonia determines the precipitation of the alumine, which, after being washed and dried, is perfectly pure.

EXPERIMENT XLIX.

Mix a little muriate of platina with half a test tube full of distilled water, and add to the mixture a solution of muriate of ammonia: a yellow precipitate will fall down, consisting of oxide of platina, muriatic acid, and ammonia.

EXPERIMENT L.

Mingle a solution of muriate of platina 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 platina will be obtained in the form of a grey porous mass.

XV. Oxy-Muriate of Mercury, or Corrosive Sublimate.

This salt of mercury is employed as a test for indicating the presence of alcalies and

alcaline earths. The fixed alcalies, when caustic, produce with it a yellow; and carbonated alcalies, 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 alcalies. 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 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. And hence Dr. Bostock has proposed the following ingenious method of estimating the quantity of albumen contained in an animal fluid, viz:—Add to the fluid a quantity of oxy-muriate of mercury, more than sufficient to saturate the albumen, and then heat the mixture. By this double action a coagulum is formed, which may be separated

by the filtre. The precipitate is a compound of the metallic salt with albumen, in the proportion of about one of the former to three or four of the latter. From the quantity of corrosive sublimate, therefore, required to decompose entirely a solution of albumen, we may infer the quantity of the latter; for three grains of the metallic salt being entirely decomposed, indicate $10\frac{1}{2}$ grains of albumen.

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 muriate of mercury does not. 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.

EXPERIMENT LI.

Dissolve one or two grains of sub-carbonate of potash in half a test tube full of

distilled water, and add to it a few drops of the solution of oxy-muriate of mercury; an orange-coloured precipitate will immediately fall down to the bottom of the tube.

EXPERIMENT LII.

Add to half a test tube full of distilled water a grain or two of sub-carbonate of soda, and drop into the solution oxy-muriate of mercury: and the same effect will take place as in the preceding experiment.

EXPERIMENT LIII.

Dissolve a few grains of caustic potash or soda in half a test tube full of water, and drop into the fluid a solution of oxy-muriate of mercury: at first a sulphur-yellow precipitate will fall down, but, by increasing the admixture of oxy-muriate, the precipitate will assume a dull orange colour.

EXPERIMENT LIV.

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.

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 muriate of mercury: a milkiness will ensue; and after some time a white flocculent precipitate becomes deposited.

The same effect takes place if serum of blood be mixed with water, or any other albuminous matter. A drop of a saturated solution of oxy-muriate 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 should be kept in the dark, because light renders it turbid; a white precipitate (sub-muriate of mercury) separates, and its action is impaired.

EXPERIMENT LVI.

Dissolve one grain of muriate of ammonia in a wine-glass full 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 oxy-muriate of mercury be added, the mixture will become milky, and a white precipitate falls down, consisting of muriatic acid, mercury, and ammonia.

EXPERIMENT LVII.

Add one grain of nitrate of ammonia to a wine glass full of distilled water; and after having added to it also a drop of a solution of any alcali, let fall into the mixture a drop of the solution of corrosive sublimate, or oxy-muriate of mercury; a white precipitate (sub-oxy-muriate of mercury and ammonia) will instantly fall down.

It is essential that the solution be neutral. The delicacy of oxy-muriate 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.

XVI. Sub-Nitrate of Mercury

Is employed as one of the re-agents for detecting uncombined ammonia, with which

it produces an ash-grey or black precipitate. It may likewise be used for detecting muriatic acid, with which it occasions a white precipitate; one part of muriatic acid combined with 300,000 parts of water, may readily be discovered by this re-agent.

It is also an useful test 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, which the precipitate produced by muriatic acid is not. The precipitate obtained by phosphoric acid (phosphate of mercury) may be decomposed by mere exposure to heat, and thus the phosphoric acid is obtained in a pure state. Or if the precipitate is 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. With a solution of muriate of gold it produces a dense precipitate, of a bluish black colour; and with muriate of platina, an orange-coloured precipitate.

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 alcali, or alcaline earth. Sub-nitrate 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.

EXPERIMENT LVIII.

Add to half a test tube full of distilled water a drop of liquid ammonia: no change will take place; but if a few drops of a

solution of sub-nitrate of mercury are added, an ash-grey precipitate instantly falls down to the bottom of the tube.

EXPERIMENT LIX.

Add to half a wine glass full of distilled water a drop of muriatic acid, or a single grain of common salt, and pour into the solution a few drops of sub-nitrate 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.

EXPERIMENT LX.

Dissolve a few grains of phosphate of soda in half a test tube full of distilled water, and add to it a solution of sub-nitrate 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.

EXPERIMENT LXI.

Add to half a test tube full 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 sub-nitrate 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.

EXPERIMENT LXII.

Mix with half a test tube full of distilled water a few drops of muriate of gold, and

add to the mixture one or two drops of sub-nitrate of mercury: a bluish black precipitate will instantly be formed.

EXPERIMENT LXIII.

Let fall one drop of muriate of platina into half a wine glass full of distilled water, and add to this mixture a drop of sub-nitrate of mercury: a bright orange-coloured precipitate will fall down to the bottom of the tube.

XVII. Nitrate of Silver.

The solution of silver in nitric acid is an excellent test for discovering muriatic acid, either in a free state, or when combined with other bodies. It produces with it a curdy white precipitate, which is insoluble in water, but readily soluble in liquid ammonia, and which becomes speedily blackened on exposure to light.

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.

In applying this test, certain precautions are necessary, because it is also acted on by alcaline and earthy carbonates, and by sulphuric acid and its combinations. This may be guarded against by first removing the sulphuric acid by nitrate of barytes; and the action of the carbonates may be prevented, by supersaturating them previously with pure nitric acid. The precipitate produced by carbonated alcalies (carbonate of silver) is soluble in dilute nitric acid with effervescence; the precipitate produced by muriatic acid is not. With the assistance of an alcali, 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 sulphurets in general, for it produces with them a black precipitate. It affords with chromic acid a carmine red precipitate.

EXPERIMENT LXIV.

Mix a drop of muriatic acid with a wine glass full of distilled water, and add to the mixture a drop of the solution of nitrate of silver: a white curdy precipitate (muriate of silver) will immediately be produced, and fall rapidly to the bottom of the glass. 100 grains of this precipitate thoroughly dried, but not melted, contain 75,235 grains of silver; the remaining 24,765 grains consist of muriatic acid and oxigen. It may be reduced in the following manner to the metallic state, and affords the purest silver which can be obtained.

EXPERIMENT LXV.

Mix one part of dry muriate of silver with three of sub-carbonate of soda, or potash of commerce, freed from water by heat; put the mixture into the 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.

Nitrate of silver is used as a test by the refiners for examining and purifying their aqua-fortis, or nitrous 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 (muriate 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.

EXPERIMENT LXVI.

Add a grain or two of common salt to half a test tube full 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. Decant the supernatant fluid, and pour liquid ammonia upon the precipitate, which will immediately produce with it a transparent solution, namely, nitrate of silver and ammonia. This is one of the characters by which muriate of silver is discriminated from muriate of lead; for the latter is not soluble in liquid ammonia.

EXPERIMENT LXVII.

Prepare muriate of silver in the manner stated; namely, by decomposing a solution

of common salt in water, with nitrate of silver; wash the muriate, whilst 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 change of colour is supposed to be owing to the partial reduction of the oxide of silver, from the light expelling a portion of its oxigen. There is reason to believe that it originates solely from a partial disengagement of a portion of the acid, because it is produced likewise by heat; for muriate of silver becomes blackened before it enters into fusion, and a small quantity of muriatic acid, without any oxigen, becomes disengaged. It likewise takes place by the action of air, independent of light; for muriate of silver, exposed in an utter dark place to a brisk current of air, becomes blackened; but not so speedily as in the rays of the sun.

EXPERIMENT LXVIII.

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 muriate of potash and of soda, all other ingredients having been previously separated, we have only to decompose them by nitrate of silver, and to dry the precipitate; for 217.65 of muriate of silver indicate 100 of muriate of potash, and 235 of muriate of silver indicate 100 of common salt.

EXPERIMENT LXIX.

Let five or six grains of sulphate of soda (Glauber's salt), or Epsom salt, or alum, be dissolved in a test tube full 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 containing distilled water, which will speedily dissolve it when assisted by a gentle heat, but which is not the case with muriate of silver, which is perfectly insoluble in water.

EXPERIMENT LXX.

Add to the other half of the solution of sulphate of soda (Experiment LXIX.) nitrate of barytes, till no further cloudiness takes place; separate the precipitate, which is sulphate of barytes, by throwing the whole on a filtre, and assay or test the fluid which passes through the filtre, 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.

EXPERIMENT LXXI.

Dissolve a few grains of sub-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 muriate of silver.

EXPERIMENT LXXII.

Again: add a few grains of sub-carbonate of potash, or of soda, to half a wine glass full of distilled water, and drop into it so much nitric acid as is sufficient to neutralize the sub-carbonate of potash, which 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 alcali is thus counteracted by nitric acid. If a grain of common salt or any other combination of 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.

EXPERIMENT LXXIII.

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 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.

Sub-nitrate of silver, either in a pure state, or combined with 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. [*See Hume's Method of detecting Arsenic, Phil. Magazine, August*, 1812.] Mr. Hume advises to saturate first the arsenic with any alcali, and then to apply the sub-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.

EXPERIMENT LXXIV.

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 the lamp till the solution boils, and then add to it a grain or two of sub-carbonate of potash or of soda. Pour a few table spoonsfull of the solution into a wine glass, and present to the

mere surface of the liquid a stick of dry sub-nitrate of silver. A yellow precipitate will instantly appear, proceeding from the point of contact of the sub-nitrate of silver with the fluid, and settle towards the bottom of the glass as a flocculent and copious precipitate. Dr. Marcet has lately pointed out the following modification of this test.

EXPERIMENT LXXV.

Let the fluid suspected to contain arsenic be filtred, 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 alcali.

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 remain in solution, and the addition of liquid ammonia will produce the yellow precipitate in its characteristic form.

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 to re-
" main on the surface of the fluid to which
" this test liquor is to be applied.

" Here we have one neat and simple li-
" quid, 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 pro-
" cured 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 alcali, nor even of the test liquor
" itself, as to require very great caution."

Mr. Hume further observes, " that in pro-
" portion 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 pro-
" duced by arsenic; and that false con-
" clusions might be drawn, were similar
" steps pursued with two solutions of phos-
" phate of soda, and arsenite of potash. A
" piece of dry nitrate of silver being pre-
" sented for a moment to the surface of
" either of the liquids, would certainly give,
" in resemblance, the *yellow* and plentiful
" precipitate, and a by-stander would con-
" sequently 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 sim-
" ple 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. A separate
" piece of sub-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 sub-nitrate, is not
" to be regarded as arising from any union
" with arsenic. Being now convinced that
" there is no *yellow* precipitate yet gene-
" rated, 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 in-
" stantly form a copious yellow indication
" of the presence of arsenic.

" These experiments may be further illus-
" trated 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 expe-
" riments, just mentioned, be made upon
" two separate pieces of clean writing pa-
" per; 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 dis- " tinctive 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 for- " wards, 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, ac- " cumulating, and assembling together in " spots, as if it were a *yellow* muriate of " silver; while the phosphate offers to our " view a homogenous colour, totally differ- " ent 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."

EXPERIMENT LXXVI.

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, into distilled water mixt 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, illustrates this fact.

EXPERIMENT LXXVII.

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 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 colour.

EXPERIMENT LXXVIII.

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 into 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.

XVIII. Acetate of Silver.

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 or 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 alcali combined with the muriatic acid, more readily, by its appropriate tests, namely, muriate of platina, &c.; or even without the usual tests for alcalies; 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, affords a deliquescent salt, we have reason to believe that the base of the salt is pot-

ash; and if it effloresces and remains dry on exposure to the air, there is then reason to believe it to be 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 alcali be present, it ought, of course, to be previously saturated with an acid. 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 opake bottles, or in the dark.

XIX. *Sulphate of Silver.*

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, with a base of sulphuric acid; so that when sulphate of silver is employed, we are certain that the precipitate produced by this test, when no uncombined alcali or earth is in the solution, is produced by muriatic acid only.

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.

XX. *Phosphate of Soda.*

This salt, in combination with carbonate 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 neutral carbonate of ammonia into the fluid suspected to contain magnesia: no magnesia becomes precipitated if this earth be present, because the carbonic acid of the carbonate of ammonia is sufficient to keep it in solution. But on adding phosphate of soda, the magnesia is transferred to the phosphoric acid, and 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 carbonate of ammonia be neutral. Phosphate of soda, when deprived of its water of crystallization, is likewise employed as a flux for the 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.

EXPERIMENT LXXIX.

Add to a solution of sulphate of magnesia a solution of carbonate 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.

100 grains of this salt, dried at a temperature of 100°, contain 19 of magnesia, about 6 of muriate of magnesia, and 62 of desiccated, or double that quantity of crystallized sulphate of magnesia. If instead of drying the precipitate at a gentle heat, we calcine it, we may then reckon the calcined phosphate of magnesia to indicate, in every 100 grains, 38,5 of magnesia, or to be equivalent to 226 grains of the crystallized sulphate of that earth.

EXPERIMENT LXXX.

Dissolve common magnesia of commerce (sub-carbonate of magnesia) in muriatic acid, and add to the solution carbonate 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 carbonate of ammonia, the mixture becomes turbid, and phosphate of magnesia and ammonia is deposited.

XXI. Lime Water.

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 the 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 alumine, 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. Lime water is farther made use of as a test for oxy-muriate of mercury, or 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 arsenic, with the solutions of which it forms a white pre-

cipitate (arseniate of lime), which being scarcely more soluble than sulphate of lime, sinks to the bottom in the form of minute crystals, and when laid on an ignited piece of charcoal, diffuses the alliaceous odour peculiar to arsenic.

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.

EXPERIMENT LXXXI.

Half fill a wine 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.

EXPERIMENT LXXXII.

Half fill a test tube with water impregnated with carbonic acid gas, 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.

EXPERIMENT LXXXIII.

Fill a two-ounce phial with carbonic acid gas, and add to it about a table spoonfull 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. 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.

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.

EXPERIMENT LXXXIV.

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

EXPERIMENT LXXXV.

Dissolve five or six grains of sulphate of magnesia (Epsom salt) in half a wine glass full 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.

EXPERIMENT LXXXVI.

Mix five or six drops of a concentrated solution of corrosive sublimate, with half a test tube full 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.

EXPERIMENT LXXXVII.

Let fall eight or ten drops of a solution of arsenious acid, into a wine glass containing about one table spoonfull 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. If the precipitate (arsenite of lime) be dried, and placed on an ignited piece of charcoal, it yields an alliaceous odour, which is peculiar to arsenic.

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 a part of the lime left undissolved, in a well-corked bottle, and filtre or decant off the lime water when wanted for use.

The proportion of water above stated to be used, is scarcely sufficient to dissolve one-tenth part of the lime; but lime being of little value, and seldom thoroughly good, a little waste of this material is of no import-

ance, 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 quicklime as is just sufficient to cause the lime to fall into a perfectly dry powder. In this compound or *hydrate of lime*, the lime is to the water as 23 to 8. It may safely be preserved in this state, in glass bottles; which cannot be done with quicklime in its perfect 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.

XXII. Tan.

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.

Dr. Bostock has also pointed out a very ingenious method of detecting and ascertaining the quantity of gelatine contained in

an animal fluid. If oxy-muriate of mercury produces no precipitate (see oxy-muriate of mercury), 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 filtred 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.

EXPERIMENT LXXXVIII.

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.

EXPERIMENT LXXXIX.

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, like in the preceding experiment. The same will be the case if tan be dropped into broth.

XXIII. Nitrate of Cobalt.

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 alumine 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 alumine 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 alumine which it contains.

The test may be applied to the hardest gems, or softest clays. When the mineral is a hard stone, it is only necessary to pulverise 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 platina foil. The test, however, labours under one disadvantage, for the earth of 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 be owing.

EXPERIMENT XC.

Let fall a drop of a 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 platina foil, before the blowpipe flame: the clay will acquire a small blue colour.

EXPERIMENT XCI.

Moisten a piece of quicklime, chalk, magnesia, or a minute portion of pulverised 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.

EXPERIMENT XCII.

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 alumine. The oxide of iron which it contains acquires a red colour when heated, and this, with the blue effected by alumine, produces the purple or violet tinge.

XXIV. Super-Acetate of Lead.

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, muriate 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 alcalies and earthy carbonates; but this may be prevented by a pre-

vious admixture of nitric acid. Super-acetate of lead (or more properly acetate of lead) may also be employed as a test for phosphoric acid, with which it produces a white precipitate; even a solution 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 22.5 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 super-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. Super-acetate of lead is one of the most delicate tests for discovering minute portions of sulphuretted hydrogen gas, or sulphurets 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 acids. It has also been used as a test for uncombined boracic acid, particularly in the analysis of mineral waters. In that case the uncombined alcalies and earths (if any be present) must be saturated with acetic acid. The sulphates, if any are present, must be decomposed by acetate or nitrate of barytes, and the muriates by acetate or nitrate of silver. The filtred 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 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 digested in alcohol, which then takes up the boracic acid.

EXPERIMENT XCIII.

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 super-acetate of lead: a white precipitate will immediately fall down, which is muriate 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 75 of metallic lead.

EXPERIMENT XCIV.

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

EXPERIMENT XCV.

Repeat the same experiment with a single drop of sulphuric acid, added to a wine-glass full of water; and the same appearance as in Experiment XCIV. will take place; 100 parts of the precipitate (sulphate of lead), after having been heated moderately to redness, indicate 71 of lead.

EXPERIMENT XCVI.

Super-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 super-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 re-dissolved, 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 Experiment XCV.

EXPERIMENT XCVII.

Dissolve a few grains of sub-carbonate of soda, or potash, in a wine glass full of distilled water, and pour half the solution into another glass. Drop into one of the glasses a little super-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 super-acetate of lead: no precipitate will now appear, because the action of the sub-carbonated alcali is thus counteracted, and the test will now indicate muriatic and sulphuric acid.

EXPERIMENT XCVIII.

Add to any quantity of water impregnated with sulphuretted hydrogen gas, a drop of super-acetate of lead: clouds of a dark brown colour will immediately appear, and

a precipitate of the same colour will be deposited, which is hydro-sulphuret of lead.

EXPERIMENT XCIX.

The effect of a sympathetic ink with super-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 super-acetate of lead: no characters will be visible if the writing has been made with a dilute solution of the re-agent; and 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 colour.

EXPERIMENT C.

Dissolve two grains of phosphate of soda in half a test tube full of distilled water,

and drop into the solution a little super-acetate of lead: a white precipitate will take place, which is phosphate of lead.—This precipitate disappears again by the admixture of nitric acid.

EXPERIMENT CI.

Affuse upon pulverised 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 super-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.

EXPERIMENT CII.

Let fall into water impregnated with carbonic acid gas, two or three drops of super-acetate of lead : a white powder will fall down, which is carbonate of lead (white lead of commerce). 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 super-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.

Super-acetate of lead strongly attracts carbonic acid from the air ; it ought therefore be kept in a well stopped bottle.

XXV. Sub-Acetate of Lead.

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 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 sub-carbonated alcali, 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 al-

cohol or brandy from wine, at once destroys the commonly received opinion, first entertained by Fabrony, namely, that the spirit obtained from wine be 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.

EXPERIMENT CIII.

Add to eight parts, by measure, of the 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 filtre, and collect the filtred fluid. It contains the brandy or spirit, and water of the wine, together with a portion of the sub-acetate of lead, provided the latter has not been added in excess; in which case a part (of course) remains undecomposed. Add, in small quantities at a time, to this fluid, warm, dry and *pure* sub-carbonate of potash *(not salt of tartar, or sub-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 sub-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 alcaline 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 sub-carbonate of potash, after the colouring and acid matter has been separated by sub-acetate 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.

[Journal of Science and Arts, No. viii. p. 290.]

	Proportion of Spirit per cent. by measure.		Proportion of Spirit per cent. by measure.
Lissa	26,47	Raisin Wine. .	25,77
Ditto	24,35	Ditto	23,30
Average. .	25,41	Average. .	25,12
Raisin Wine. .	26,40	Marcella . . .	26,03

	Proportion of Spirit per cent. by measure.
Marcella . . .	25,05
Average. .	25,09
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

	Proportion of Spirit per cent. by measure.
Cape Madeira .	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
Roussillon . .	19,00
Ditto	17,20
Average .	18,13
Claret	17,11
Ditto	16,32
Ditto	14,08
Ditto	12,91
Average. .	15,10
Malmsey Madeira	16,40
Lunel	15,52
Sheraaz . . .	15,52
Syracuse . . .	15,28
Sauterne . . .	14,22
Burgundy . .	16,60
Ditto	15,22

	Proportion of Spirit per cent. by measure.
Burgundy. . .	14,53
Ditto	11,95
Average .	14,57
Hock	14,37
Ditto	13,00
Ditto (old in cask)	8,68
Average. .	12,08
Nice	14,62
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
Ditto	12,80
Average. .	13,37
Frontignac . .	12,79
Cote Rotie . .	12,32

	Proportion of Spirit per cent. by measure.
Gooseberry Wine	11,84
Orange Wine, aver.	11,26
Tokay	9,88
Elder Wine . .	9,87
Cyder, highest aver.	9,87
Do. lowest ditto	5,21
Perry, average :	7,26
Mead	7,32
Ale (Burton). .	8,88
Do. (Edinburgh)	6,20
Do. (Dorchester)	5,50
Average. .	6,87
Brown Stout. .	6,80
London Porter, aver.	4,20
Do. Small Beer, do.	1,28
Brandy . . .	58,39
Rum	53,68
Gin	51,60
Scotch Whiskey	54,30
Irish ditto. . .	53,90

EXPERIMENT CIV.

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 filtre 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 is produced if the solid matter obtained by evaporating saliva to dryness be re-dissolved in water, filtred, and submitted to the action of this test.

XXVI. Muriate of Platina.

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 platina, but a triple salt (muriate of platina and potash), and 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 tartareous acid. Is also a test for tin.

EXPERIMENT CV.

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

EXPERIMENT CVI.

Add to a like quantity of distilled water a few grains of soda, or of sub-carbonate of

soda, and add to it also muriate of platina: no change will take place, because soda is not precipitable by this test.

EXPERIMENT CVII.

Drop into a concentrated solution of sulphate of potash a little muriate of platina: the same phenomena will take place as in experiment CV.

EXPERIMENT CVIII.

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

In this manner the two alcalies, viz. potash and soda, and their combinations, are easily discriminated. *See also Tartareous acid.*

XXVII. Green Sulphate of Iron.

This salt has been recommended for ascertaining the presence of oxigen 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 oxigen, 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 oxigen of the water; and a small portion of it, in this more highly oxidated state, leaving the acid, becomes precipitated.

Green 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.

EXPERIMENT CIX.

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 oxigen gas was present in the water.

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 boil-

ing; 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 atmospherical 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 gasses are expelled.

EXPERIMENT CX.

Add to half a test tube full of distilled water a few drops of muriate of gold: no change will take place; but if sulphate of iron, dissolved in water, be added, a brown precipitate will fall down, which is gold in a metallic state. This process has been recommended for obtaining pure gold.

From the purplish colour which the precipitate possesses, there is however reason to believe that it contains a portion of oxide;

and, according to Proust, both muriatic and nitric acid dissolve a little of it, which must be regarded as a proof of this oxidized state.

XXVIII. Arsenious Acid.

A solution of arsenious acid in water, is of use for discovering the presence of sulphuretted hydrogen gas, and sulphurets in general, with which it produces a yellow precipitate; 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.

EXPERIMENT CXI.

Add a little of the solution of arsenious acid to half a test tube full 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 hydro-sulphuret of arsenic.

XXIX. Muriate of Gold.

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 sub-muriate of tin, are reciprocally tests for each other. *See sub-muriate of tin.* Muriate of 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 oxy-muriate of mercury 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.

XXX. *Sulphate of Copper.*

This salt may be employed for discovering arsenic, with which it produces a bright yellowish green precipitate, provided a very small quantity of a sub-carbonated alcali 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 hydro-sulphuret of copper.

EXPERIMENT CXII.

Add a small quantity of solution of arsenious acid, to half a wine glass full of distilled water, in which previously a grain

of sub-carbonate of potash has been dissolved: a green flocculent precipitate will instantly fall down. This substance, after being dried and mixed with a little powdered charcoal, and put into a glass tube, closed at the bottom, and lightly stopped at the top, and then heat it slowly to redness, will yield a metallic sublimate, which will give the strong smell peculiar to arsenic, and which condenses on the sides of the tube, and lines it with a brilliant metallic coating. The same strong smell, and dense white fumes, will be given merely by putting the dried precipitate on an ignited piece of charcoal.

To indentify arsenic, when this is one of the tests employed for detecting it, Dr. Henry advises (very properly) 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 alcali employed, have considerable influence on the distinct exhibition

of the effect. Those which answer best are, one of arsenic, three of sub-carbonate of potash (or 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 a 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 one fortieth of a grain of arsenic diffused through 60 grains of water, afforded to Dr. Bostock, by the addition of sulphate of copper and potash, in proper proportions, a distinct yellowish green precipitate. *See Edinburgh Medical*

and Surgical Journal, 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.

XXXI. Muriate of Lime

Is of some use, as an auxiliary test, for discovering the presence of alcaline 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 tartareous acid, with which it produces a white crystalline precipitate, which is highly insoluble in water, but readily soluble in dilute nitric acid, and the precise nature of which may then be farther examined with less difficulty, so as

to discriminate which particular vegetable acid entered into its composition.

Dry muriate of lime is employed also to strengthen spirit of wine, because the affinity of alcohol for water is so strong, that it cannot be entirely freed from it by simple distillation. And by muriate of lime this may readily be effected. For this purpose one part of muriate of lime, 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.

XXXII. Benzoate of Ammonia.

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 alcali; 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.

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 the 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 filtre, wash the insoluble residue with cold water, and dry the precipitate at a temperature of 212°. The benzoate of iron thus obtained, contained 25 per cent. of red oxide of iron, and 75 of benzoic acid and water.

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.

XXXIII. Water Impregnated with Sulphuretted Hydrogen Gas, or Liquid Sulphuretted Hydrogen.

This fluid precipitates many of the genera of 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 zircon and alumine, it gives 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; platina, 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 combination. And particularly the degree of oxidizement of the metal in the solution has a material influence on the colour of the precipitates. Most of the precipitates are compounds of sulphuretted hydrogen with the metallic oxide; or, in some cases, a decomposition, more or less complete, takes place; part of the hydrogen first unites with part, if not all, of the oxigen of the metallic oxide, and reduces it nearly to the metallic state, or to a state of *minimum* of oxidizement, and the remainder of the sulphur and hydrogen unite with the metal; and the whole is separated from the acid of the solution in the form of a coloured precipitate, which therefore is either a sulphuret, or a hydro-sulphuret, of the metal, according to circumstances. Some-

times 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 oxigen, 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 oxigenized 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.*

* A Treatise on the Adulterations of Food and Culinary Poisons, and the methods of detecting them.

EXPERIMENT CXIII.

Dissolve one or two grains of sulphate of zinc (white vitriol) in half a test tube full 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 hydro-sulphuret of zinc.

EXPERIMENT CXIV.

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

EXPERIMENT CXV.

Mingle a small quantity of the solution of arsenious acid with half a test tube full of

distilled water, and add to the mixture liquid sulphuretted hydrogen: *a yellow* precipitate will immediately be produced.

EXPERIMENT CXVI.

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

EXPERIMENT CXVII.

Mix a few drops of muriate of gold with half a test tube full of distilled water; and add to the mixture liquid sulphuretted hydrogen: a dark *orange brown* precipitate will fall down, which is sulphuret of gold, and which is composed of 80.39 gold, and 19.61 sulphur. (*Thomson's Annals, No.* 2, 1813, *p.* 141.) When exposed to heat it give up its sulphur, and the residue is metallic gold.

EXPERIMENT CXVIII.

Add to half a test tube full of distilled water ten or twenty drops of muriate of platina; 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 platina.

XXXIV. Tincture of Galls.

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 a red oxide, and if oxidized in a less degree, the effect will not be instantaneous, but will only take place after leaving the mixture to stand some time in contact with the air. The black colour can however be also rendered apparent, even in solutions of iron, containing the metal in a lower state of oxidation, by causes which cannot change the state of oxidation, as by dilution with water, or by the addition of a little alcali; and the reason

therefore of its not appearing when the solution contains the iron at a *minimum* of oxidation, is, that the oxide in that state is retained by a stronger attraction in combination with the acid, than when the oxidation is more perfect.

The action of this test is influenced by the presence of other bodies. For example: if alcalies and earthy carbonates are present, it then produces with iron a violet colour. If neutral alcaline 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 alcaline 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 maxi-

mum 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, by the test of effusion of galls; 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.

Tincture of galls produces with the solutions of osmium a vivid blue colour. With the solution of tellurium it affords a yellow precipitate—with solutions of mercury an orange coloured precipitate. Silver is precipitated of a white colour—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 metal, and its degree of oxidizement.

EXPERIMENT CXIX.

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 filtre it. Take half a wine glass full 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, tan, and oxide of iron.

EXPERIMENT CXX.

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, filtre it; a brown precipitate (carbonate of iron) will fall down. The remaining clear fluid will no longer be altered by tincture of gall, which shews that the iron was combined with an excess of carbonic acid, which held it dissolved in the water.

EXPERIMENT CXXI.

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 filtred, 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, filtre 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 tan contained in the tincture of galls. In order that the iron may produce immediately a black precipitate, it must be in the state of red oxide; 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 oxigen into the combination, is, however, such, that it is difficult to prevent

a black precipitate from being obtained. A few moments exposure to the atmosphere, or the action of the oxigen, 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 per-oxide, and, combining with a portion of acid, falls down in the form of a brown powder, which is a sulphate of the per-oxide with *excess of base*, or a sub-sulphate of iron.

EXPERIMENT CXXII.

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; and 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.

XXXV. Sulphate of Copper and Ammonia.

This test, which is of a very fine azure blue colour, may be 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 put upon ignited coals, produces a peculiar garlic-like odour, which is characteristic to arsenic when in contact with red hot coals. 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.

EXPERIMENT CXXIII.

Into half a wine glass full 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, dried, and laid on an ignited piece of charcoal, will diffuse the peculiar garlic-like odour, which characterises arsenic when heated with combustible bodies.

EXPERIMENT CXXIV.

Divide the whole of the fluid, together with the precipitate of Exper. **CXXIII.** 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, dissolve the precipitate, and form with it a colourless solution.

XXXVI. Sub-Borate of Soda,

Or common borax, when deprived by fusion, of its water of crystallization, becomes (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 analysing argillaceous minerals; these substances, which are but feebly acted on when fused with alcalies, yield readily to glass of borax. Corundum, and the hardest gems, may be subdued by fusion, by means of this salt.

XXXVII. Sub-Muriate of Tin.

This is a delicate test for platina, 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. Submuriate 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 of mercury. 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.

EXPERIMENT CXXV.

Mix a drop of muriate of platina with a wine glass full of distilled water, and add to the mixture a drop or two of sub-muriate of tin: a dense orange coloured precipitate will fall down.

EXPERIMENT CXXVI.

Add to a wine glass full of distilled water one drop of muriate of gold, and let fall into this fluid a few drops of sub-muriate of tin: a purple coloured precipitate will be obtained, consisting of oxide of tin and 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 to oxigen, and the large quantity of that principle, with which it is disposed to

combine. When the two solutions are mixed, the oxide of tin, being at the minimum of oxidizement, attracts part, or the whole of the oxigen 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, or as nearly so as possible; and hence, it must be used newly prepared, as otherwise the tin passes to too highly an oxidated state, and the effect of the test is lost.

The colour of the precipitate approaches more to a violet, as the muriate 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 sub-muriate of tin 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 $20\frac{1}{2}$ per cent. of tin, and $79\frac{1}{2}$ 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 be employed, one part of gold will produce as much as $5\frac{1}{2}$ parts of purple precipitate.

EXPERIMENT CXXVII.

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

Sub-muriate of tin has a strong tendency

to acquire a further proportion of oxigen; it should therefore be preserved in a well stopped bottle.

XXXVIII. Liquid Ammonia.

Caustic, or liquid 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 ammonial solution be saturated in excess with sulphuric or nitric acid, and then immersing into it a slip or bar of zinc; this metal will precipitate copper, if the colour be owing to that metal; but with nickel it produces 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, nickel free from cobalt; the oxide of the latter, when dissolved in ammonia, being very slowly and sparingly precipitated by potash, while that of the former is precipitated immediately and largely. He ascribes these decompositions to the two alcalies combining, and thus weakening the affinity of either to the metallic oxide.

Liquid 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 abase 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; because, although magnesia cannot be precipitated entirely from many of its solutions by ammonia, yet, if alumine 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 alumine, nothing remained in the solution but muriate of ammonia: the two earths were precipitated in combination, and the affinity of the alumine 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 alumine. 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 alumine be present, they will likewise be affected.

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 it from absorbing carbonic acid of 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 pulverised 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 subcarbonate of potash, to decompose the carbonate of magnesia, and the latter, when washed, dried, and ignited in a strong red heat, will be magnesia.

Liquid 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 reddened litmus paper: the oxide of iron will thus be separated, and remain on the filtre 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 that the fluid be evaporated to dryness, and exposed to a red heat, to expel the muriate of ammonia.

EXPERIMENT CXXVIII.

Add three or four drops of the solution of sulphate of copper to half a test tube full of distilled water: no change will take place: but if a few drops of liquid 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.

EXPERIMENT CXXIX.

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); and if the paper be held over the surface of liquid 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.

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

* A Treatise on the Adulterations of Food and Culinary Poisons, and the methods of detecting them.

to mince the suspected pickles, and to pour liquid 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.

EXPERIMENT CXXX.

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

EXPERIMENT CXXXI.

Dissolve five or six grains of sulphate of magnesia in half a test tube full of distilled water, and add to the solution liquid 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 formed, consisting of sulphuric acid, magnesia, and ammonia.

Liquid 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 nitrous, muriatic, or acetic acid. This last, which is a most delicate test, should be made in a well corked bottle; for though liquid ammonia will not precipitate lime, carbonated ammonia will do it very readily, and the alcali, 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 liquid 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.

XXXIX. *Oxalate of Ammonia.*

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 a small quantity of 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 continues 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 alcali. 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. Accord-

ing to Dr. Marcet, 117 grains of sulphate of lime give 100 of oxalate of lime, dried at 160 degrees Fahrenheit.

EXPERIMENT CXXXII.

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 filtre it.

To one half of this solution add a few grains 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 filtred when cold, will now no longer

be rendered turbid by the test; because the carbonic acid which held the lime in solution by virtue of an excess of carbonic acid being volatilized, the lime becomes precipitated in the form of carbonate of lime.

EXPERIMENT CXXXIII.

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 glass full of the fluid, and add to it a few grains of oxalate of ammonia: the solution 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; be-

cause the acid which holds the lime dissolved cannot be volatilized by heat.

EXPERIMENT CXXXIV.

Pour a few drops of a solution of oxalate of ammonia into a test tube full of lime water, and the same phenomena will take place as in the preceding Experiment.

EXPERIMENT CXXXV.

Pour a little oxalate of ammonia into a tumbler full 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.

EXPERIMENT CXXXVI.

Dissolve one or two grains of sulphate of magnesia in a test tube full of distilled water, and add to it a few grains of oxalate of ammonia: the solution will not become turbid. This experiment shews that magnesia does not form a salt of so difficult a 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 grains or more 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.

XL. Prussiate of Potash.

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

metallic solutions, except those of platina, gold, antimony, tellurium, iridium, rhodium, and osmium; and from the colour of the precipitate, the particular metal may, in many cases, be inferred, and its quantity ascertained by easy means. It is chiefly used for detecting iron. If this metal exists in a state of high oxidizement in any fluid, it produces with this test a Prussian blue precipitate; and when in a low state of oxigenation, the precipitate is white, but even then it very rapidly assumes a blue colour on mere exposure to the air. Copper is precipitated brown: zinc and tin afford a white gelatinous precipitate, and cobalt a distinct olive-green one. Bismuth gives with it a yellow precipitate. 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, affords 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 continues 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.

It is stated by some authors, that alumine is also precipitated by prussiate 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 analysis 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 prussiate of potash to a barytic salt when the prussiate is pure, yet, in a few hours, small crystals are deposited from the liquor, but these crystals consist of prussiate of barytes; which proves, that the salts have, in part at least, exchanged their principles: and this, as Guyton has remarked, is not peculiar to this earth; a similar exchange happens with the salts of other earths and alcalies. Dr. Henry observes, likewise, that the same crystals are formed from barytic water added to the prussiate.

EXPERIMENT CXXXVII.

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 filtre the solution, which will be an artificial chalybeate aërated water. To one half of it add a grain or two of prussiate of potash: the liquid will become blue, and some time after a blue precipitate will be deposed.

EXPERIMENT CXXXVIII.

Evaporate the other half of the chalybeate aërated water, obtained in Experiment CXXXVII. to one half of its bulk: a brown powder, or sub-carbonate of iron, will fall down. When the water has become cold, filtre it, and assay it again with prussiate 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 of iron, is no longer soluble in the water.

EXPERIMENT CXXXIX.

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 filtre it (or dissolve a few grains of sulphate of iron in half a wine glass full of distilled water): to one half of this clear solution, add a few drops of a solution of prussiate 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.

EXPERIMENT CXL.

Put into one wine glass, half filled with distilled water, a few grains of prussiate of

potash, and into 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 an olive green precipitate will be produced, which will speedily acquire a blue colour.

The effect of a sympathetic ink may be obtained by means of this re-agent, namely, writings made on paper with a dilute solution of sulphate of iron, when dry, are invisible; but by passing a feather or sponge, wetted with a solution of prussiate 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 sulphate of iron.

EXPERIMENT CXLI.

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 filtre the fluid. Add a drop of this solution to a test tube full of water, and let fall into the liquor also a few drops of a solution of prussiate of potash, and then cork the tube immediately: a copious *white* precipitate will fall down, which is white prussiate of iron, and which soon becomes green; but, if the tube remains corked, the white colour does not deepen, nor alter by exposure to light.

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

EXPERIMENT CXLII.

Add a few drops of nitric acid to the solution of sulphate of iron, prepared in Experiment CXLI., and again test it with

prussiate of potash: it will now produce Prussian blue, because the iron, having received oxigen from the nitric acid, and being higher oxidated, yields a blue precipitate with this test.

EXPERIMENT CXLIII.

Dissolve a grain of prussiate of potash in half a test tube full of distilled water, and add to the solution a drop or two of a solution of sulphate of copper: a *brown* precipitate (prussiate of copper) will immediately be produced.

EXPERIMENT CXLIV.

Put a grain of sulphate of zinc (white vitriol) into a test tube full of distilled water, and add to the solution a few drops of prussiate of potash: a gelatinous *white* precipitate (prussiate of zinc) will fall to the

bottom, which *again becomes dissolved* by the addition of liquid ammonia.

EXPERIMENT CXLV.

Add a few drops of the solution of submuriate of tin to a test tube full of distilled water, and let fall into the mixture a few drops of prussiate of potash: a very dense *white* gelatinous precipitate (like in Experiment CXLIV.) will be produced; which does *not* become re-dissolved by the addition of liquid ammonia: it is prussiate of tin.

EXPERIMENT CXLVI.

Let fall a few drops of the solution of nitrate of cobalt into half a wine glass full of distilled water, and add prussiate of potash to the mixture: a pale *olive green* precipitate (prussiate of cobalt) will be produced.

EXPERIMENT CXLVII.

Add to half a test tube full 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 prussiate of potash; a sulphur *yellow* precipitate, or prussiate of bismuth, will be produced.

EXPERIMENT CXLVIII.

Let three test tubes be half filled with distilled water; put into the first a drop or two of muriate of platina; into the second, put a like quantity of muriate of gold; and into the third, a solution of super-tartrite of potash and antimony. If to either of these solutions prussiate of potash be added, no change will take place, because the

metals which form the bases of those salts, are some of those which are not precipitable by this re-agent.

EXPERIMENT CXLIX.

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 prussiate of potash be added to these solutions, no change will take place, because none of the earth contained in these salts is precipitable by prussiate of potash.

In using prussiate of potash for detecting the quantity of iron in a fluid, when no other metal is present, considerable caution is required to attain accurate results. The prussiate should, on all occasions, be previously crystallized, and the quantity of oxide of iron, essential to its constitution, or at least an invariable accompaniment,

should be previously ascertained, which may be done in the following manner: Expose a known weight of the crystallized salt to a low red heat, in a silver crucible, by which means the prussic acid becomes destroyed, and the potash and oxide of iron is left behind; wash off the soluble part with distilled water; collect the rest on a filtre; dry it, and again calcine it with a little wax, and let it be again weighed: the result shews the proportion of oxide of iron contained in the salt. This varies from 22 to 30 *per cent.*; when the quantity of iron is greater, the test is unfit for use, because it deposits Prussian blue by the contact of acids. When the test is, therefore, employed for discovering the quantity of iron contained in any liquid, let a known weight of the salt be dissolved in a given quantity of water; add the solution gradually, and observe how much is expended in effecting a precipitation; and before collecting the precipitate, warm the liquid, which generally throws down a further

portion of Prussian blue. Let the whole be washed and dried, and then ignite the residue with wax. From the weight of the oxide, thus obtained, deduct the quantity of iron, which, by the former experiment, is known to belong to the prussiate which has been added; and the remainder denotes the quantity of oxide of iron present in the liquor under examination.

On account, however, of the great difficulty of preparing this test with a constant or uniform portion of iron, it is seldom employed (but it certainly may) for ascertaining the *quantity* of iron in solutions, but only its presence.

Prussiate of potash, when in solution, and kept exposed to the light for some time, becomes partly decomposed; and hence it should be preserved in any opake bottle. It is difficult to explain this change.

XLI. Prussiate of Ammonia.

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 alcaline bases, together with metallic salts. In this case, prussiate of potash cannot be well applied to separate the metallic salts, because it then would be difficult to ascertain whether the alcaline salts were originally present in the solution, or not. But if prussiate of ammonia be employed, no ambiguity can result; for the metallic salts need only be precipitated by this test, and the earths, by carbonate 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, glucine, or zircon. The alcaline salts may be separated from these earths, by boiling the mixture in water, and filtering and evaporating it. The salts, with bases of fixed alcalies, 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 alcali.

XLII. Prussiate of Mercury.

This combination of prussic acid with mercury is a delicate test for palladium, which it separates in the form of a yellowish white precipitate (prussiate of palla-

dium) 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 barley 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 pointed out a method of obtaining palladium with facility, from the ore of platina. The process is as follows: let any quantity of platina of commerce be dissolved in a sufficient quantity of nitro-muriatic acid, and free the solution as much as possible of its excess of acid (if it contains any) by evaporation, or by the addition of an alcali. This being done, mingle the solution with prussiate 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 prussiate 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 platina employed. It is no matter whether the solution of the ore of platina has been rendered neutral by evaporation of the redundant acid, or saturated by the admixture of potash, of soda, or ammonia, by lime or magnesia, by mercury, by copper, or by iron; or whether the platina has, or has not, been precipitated from the solution by muriate of ammonia. The prussiate of mercury acts equally well in either case: for prussiate of mercury Dr. Wollaston found peculiarly adapted to precipitate palladium, exclusively of all other metals, on account of the great affinity of mercury for the prussic acid, which in this case prevents the precipitation of iron or copper. The

decomposition of muriate of palladium 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 affinity 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.

XLIII. Barytic Water

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

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.

EXPERIMENT CL.

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

EXPERIMENT CLI.

Blow the air, respired from the lungs, through barytic water, by means of a quill

or glass tube: a white precipitate (carbonate of barytes) will fall down, originating from the carbonic acid gas contained in the air respired from the lungs.

EXPERIMENT CLII.

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 common air, 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.

EXPERIMENT CLIII.

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

EXPERIMENT CLIV.

Drop barytic water into a decanter full 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 waters always contain 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.

EXPERIMENT CLV.

To a solution of a few grains of sub-carbonate of potash, or of soda, in half a wine glass full of distilled water, add barytic water, which will immediately produce a turbidness; because the barytes separates the carbonic acid from the sub-carbonated alcali, and falls down with it in the state of a 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 alcali, and the alcali remains perfectly pure, or, at least, free from carbonic and sulphuric acid.

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 moved 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, and 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.

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.

XLIV. Muriate of Barytes.

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. 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, without addition, except the loss of water which it may contain. In a very

strong fire, or before the blow-pipe flame, it melts into an opake 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 very nearly two-thirds of barytes, and one-third of acid, or 66.6 per cent. of the former, and 33.3 of the latter. Dr. Wollaston assumes 66 parts of barytes, and 34 of sulphuric acid; Berzelius, 65,69 of barytes, and 34.31 of acid. This test, which forms one of the most important instruments in analysis, is also decomposed (like barytic water) by carbonated alcalies; 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 alcali 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, and does not touch the sulphate.

Concentrated nitric acid also decomposes a concentrated solution of muriate of barytes; the precipitate is crystallized nitrate of barytes. This is owing to the more sparing solubility of the nitrate, than of the muriate of barytes in water. Hence, in this case, the precipitate is soluble in water, by which it may be easily distinguished from sulphate and carbonate of barytes. This 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.

EXPERIMENT CLVI.

Fill two test tubes with distilled water, and let fall into one of them, a drop of

sulphuric acid, and in the other a few drops 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 (sulphate of barytes) will take place, which will not become re-dissolved by the admixture of dilute muriatic or nitric acid.

EXPERIMENT CLVII.

Put a grain of sulphate of soda (Glauber's salt) into half a wine glass full of distilled water, and when dissolved, add to the solution a few drops of muriate of barytes. The same appearance will be perceived as in Experiment CLVI.

A like effect will take place if the liquid holds alum, Epsom salt, white vitriol, or any other sulphate in solution.

EXPERIMENT CLVIII.

Dissolve a few grains of sub-carbonate of potash in a wine glass full 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 (carbonate of barytes), which 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 sub-carbonate of potash 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 alcali being neutralized by the nitric acid, the precipitate produced by the test can only be occasioned by the presence of sulphuric acid.

XLV. Acetate of Barytes.

This salt of barytes, the action of which, as a test, is similar to the preceding reagent, is particularly well adapted for ascertaining the presence of sulphuric acid, when contained in vinegar,* and in sulphureous acid. And although it may produce a white precipitate with genuine vinegar, on account of the malic, citric, or tartaric acid which this fluid may contain, either in a free state or combined with an alcaline base, but the precipitate then produced may be discriminated 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 sub-carbonated alcali. This being done, the residue will dissolve and effervesce with dilute acids. Whereas the precipitate pro-

* A Treatise on the Adulterations of Food and Culinary Poisons, and the methods of detecting them.

duced 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 alcalies and alcaline sulphates in fluids, when no other sulphates are present, in the manner to be stated presently.

EXPERIMENT CLIX.

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 platina 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 sub-carbonate of potash, into a test tube, and pour upon it dilute muriatic or nitric acid, which will instantly dissolve it, with an effervescence, which therefore shews, that the vinegar was free from sulphuric acid.

EXPERIMENT CLX.

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.

EXPERIMENT CLXI.

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. 176 grains of ignited sulphate of barytes indicate 100 grains of dried sulphate of soda; while 136.36 grains of sulphate of barytes indicate 100 of dry sulphate of potash. The two alcalies, viz. potash and soda, may thus be discriminated.

XLVI. Nitrate of Barytes.

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 embarrassing, and in such cases, nitrate of barytes is employed more successfully. It is of particular use, also, to discover the alcalies, namely, potash or soda, when in fossils, and to ascertain their quantities. See *Manual of Analytical Mineralogy, intended to facilitate the Analysis of Minerals, by F. Accum, Vol.* II. *p.* 365.

XLVII. Muriate of Alumine.

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 alumine to the boiled water, a precipitate of carbonate of alumine is thrown down, if carbonate of magnesia be present; but not otherwise, unless there be an excess of alcali, which may easily be neutralized by an acid.

XLVIII. Succinate of Ammonia.

This test is recommended by Klaproth as an useful re-agent for detecting iron, and for readily ascertaining its quantity, when in a solution; the iron, however, must be in the highest state of oxidation, and, in

applying this test, 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. It produces, with iron, a brown precipitate. It is very useful to separate oxide of iron from oxide of manganese.

EXPERIMENT CLXII.

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. Re-dissolve this mass in distilled water, and having filtred it, drop into it succinate of ammonia: 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 an oxide of iron containing 70.5 per cent. of metal. The first heating decomposes the succinic acid, and the second reduces the metal to the state of a black oxide.

This succinate, however, precipitates also alumine, provided there be no considerable excess of acid in the aluminous solution.

XLIX. Solution of Starch.

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 Strohmeyer, 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 precipitated. The delicacy of this test is astonishingly great. It will indicate

(according to Strohmeyer) $\frac{1}{450000}$ 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. 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 engage 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.

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.

L. Sulphate of Soda.

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 this salt, 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.*

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* A Treatise on the Adulterations of Food and Culinary Poisons, and the methods of detecting them.

EXPERIMENT CLXIII.

Let fall into a test tube full of distilled water a drop of super-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, be added to it, it will become instantly blackened.

LI. Carbonate of Ammonia

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 and glucine from other

earths, for both are soluble in a solution of this salt. Copper is detected by this re-agent, by imparting to the fluid containing this metal a sapphire blue colour, and, like the rest of the carbonated alcalies, it precipitates the solutions of earthy and 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.

LII. Fluate of Ammonia.

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 effects also the salts with a base of magnesia, yttria, glucine, and perhaps alumine; its action upon the whole is much inferior to oxalate of ammonia.

LIII. Alcohol.

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 quantity 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, or selinite, 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 alcaline 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.

EXPERIMENT CLXIV.

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, super-sulphate of alumine, or nitrate of potash, be employed, the same effect will take place.

EXPERIMENT CLXV.

Mix about five grains of acetate of potash with any quantity of sulphate of potash; 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.

Thus the greatest 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 and 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 at once, 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 the latter salt is easily soluble in water, but the former with great difficulty, unless assisted by an acid.

EXPERIMENT CLXVI.

As many of the volatile or essential oils are produced but in a small quantity, 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 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 remain 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. 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 become evaporated, and no trace or spot remain on the paper; but if it has been mixed with a fixed oil, a greasy spot will remain behind. When essential, or volatile oils, are adulterated with alcohol, it 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.

LIV. Solution of Soap.

A solution of soap in alcohol is of some use, as a test, for ascertaining what is vulgarly called the *hardness* of waters; 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 purpose of washing, dying, bleaching, boiling ileguminous and cereal seeds, and other purposes of the culinary art and domestic œconomy, for which water as pure as possible ought to be employed.

EXPERIMENT CLXVII.

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.

EXPERIMENT CXLVIII.

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 alcali of the soap leaves the oil, with which it was chemically combined, and unites with the acid of the earthy bases of the 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 kind 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.

EXPERIMENT CLXIX.

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.

EXPERIMENT CLXX.

Dissolve a few grains of sulphate of magnesia, or muriate of lime, or of alum, in half a wine glass full of distilled water, and add to the mixture a few drops of the solution of soap: the fluid will become milky, and deposit a white flocculent precipitate.

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

EXPERIMENT CLXXI.

Mix a drop of a solution of sulphate of iron, or any other metallic salt, with half a wine glass full 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.

LV. Wine Test.

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 contains the minutest portion of lead, the test will occasion a black muddy precipitate (which is sulphate 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.

LVI. Zinc.

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 alcaline solutions; but it is seldom employed for that purpose, because we have better means (acids) of effecting the decomposition of these solutions.

When zinc (and 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.

EXPERIMENT CLXXII.

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

EXPERIMENT CLXXIII.

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 de-

canter, nearly filled with soft or rain water, put ¾ oz. of super-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 oxigen; 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 into 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 oxidable metal coming into 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 oxigen, becomes attracted by the metal positively electrified (the zinc), whilst its other constituent part, the hydrogen, is attracted by the metal, negatively electrified, namely, the lead; it there acts in producing the further reduction, by abstracting oxigen 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.

EXPERIMENT CLXXIV.

Immerse a bar, or a slip, of laminated zinc, into 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.

EXPERIMENT CLXXV.

Add to half a wine glass full of distilled water eight or ten grains of sub-muriate of tin, and immerse into 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.

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

EXPERIMENT CLXXVI.

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 half-penny. 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

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

LVII. Iron.

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.

EXPERIMENT CLVII.

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

LVIII. Tin.

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 a bar, of tin, be immersed into 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 sub-muriate of tin, and muriate of gold.

EXPERIMENT CLXXVIII.

Add to half a test tube full of distilled water, a few drops of muriate of gold, and immerse into it a piece of tin, or a tin wire.

In a short time a violet or purple coloured precipitate will fall down, which is a compound of gold and oxide of tin.

LIX. Copper

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 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 into 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.

EXPERIMENT CLXXIX.

Add to half a wine glass full of distilled water five or ten drops of the solution of nitrate of silver, and immerse into it a bar or slip of copper. 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.

EXPERIMENT CLXXX.

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 an 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.

LX. Quicksilver, and Silver Leaf.

Both these metals are useful for discovering minute portions of sulphuretted hydrogen gas, or 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 a loose combination.

EXPERIMENT CLXXXI.

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.

LXI. Fluxes for the Blowpipe.

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 sub-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 alcalies 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, opake, transparent, vitreous or enamelled, scorified, or dense and compact; the colour which it principally effects, 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.

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 the blowpipe experiments, and in all the 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 alcaline and 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 oxigen 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 oxigen 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.

The fluxes, which have obtained the general sanction of chemists, on account of their extensive use, are, phosphate of soda, sub-borate of soda, and boracic acid; besides these, fluor spar, gypsum, sub-carbonate of soda, nitrate of potash, and glass, are occasionally employed in the blow-pipe assay. These bodies are reduced to powder, and mixed up with the substances upon which they are to act. What is called *white flux*, is a mixture of a little potash with carbonate of potash, and is prepared by deflagrating together equal parts of nitrate of potash and supertartrate of potash. 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 supertartrite of potash, and one of nitrate of potash. It differs from the former only in containing a little charcoal. Soap, likewise, promotes

fusion by 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.

LXII. Blowpipe, and its Application.

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 opake 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 contents 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 *lime stone* 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 fall on it a drop of water, 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 opake 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 opake 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.

EXPERIMENT CLXXXII.

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 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.

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 intumescense, 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 vitrious globule, transparent, or opake, 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 afford it.

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 blowpipe, 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 mouth-piece 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.

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 does lie horizontal. 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.

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 it is 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.

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.

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 round the hole, and the hole is thus gradually enlarged; and the heat, too, is kept up round 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.

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 contrivance 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.

Those bodies upon which charcoal acts chemically (but when intended to be exposed to the blowpipe flame, without suf-

fering 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 platina. The spoon must, of course, be properly fixed into a wooden handle. Silver or gold spoons are best adapted for fusions with alcaline fluxes, for which those made of platina 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 platina are perfectly infusible by the blowpipe flame.

A small forceps, entirely made of platina, is 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 oxidated, nor does it become too hot to be held by the fingers during trial, on account of the bad conducting power of the metal of which it is fabricated. They are, also, convenient for handling or

taking out from the melted fluxes the small bead of the product.

Flattened platina wire is another very useful article for exposing fragments of infusable 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.

Platina 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 platina 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 asbestus may also be employed occasionally.

The best blowpipe for chemical and mineralogical purposes, is the *Pocket Blow-*

pipe,* invented by Mr. Pepys, which is sufficiently known, and does not require to be described.

LXIII. Water impregnated with Carbonic Acid Gas, or Liquid Carbonic Acid.

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,

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* Complete sets of *Pocket Mineralogical Blowpipe Apparatus*, of different kinds, and *Mineralogical Travelling Chests*, may be had with this Treatise.

four or five inches wide, and about ¾ 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 inerted bottle *a*. To impregnate water with carbonic acid gas (or with any other gas which is not 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 downward, into 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, lime-stone, or common chalk, 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 carbonic acid gas, which becomes extricated by the action of the acid upon the marble, 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 absorded.

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, into 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 *c*, a common *gas* or *proof bottle* may be used.

From marble may be obtained in this way, from 40 to 45 per cent. of its weight of carbonic acid gas, so that 100 grains will produce between 90 and 100 cubic inches.

LXIV. Water impregnated with Sulphuretted Hydrogen Gas, or Liquid Sulphuretted Hydrogen.

This fluid, which is not met with as an article of commerce, and which is likewise necessary for the performance of several experiments exhibited in this treatise, may easily be prepared for immediate use in the following manner.

Put into the *bottle b*, pl. 2 (central figure), one part of sulphuret of antimony of commerce, broken to a coarse powder, and pour upon it three or four parts of common concentrated muriatic acid, and assist the action of the acid by a gentle heat of the spirit lamp: sulphuretted hydrogen gas will become disengaged from the materials, and which may be made to combine with distilled water, as directed above, for combining water with carbonic acid gas. 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.

Instead of sulphuret of antimony, sub-sulphuret of iron may be used (but the former substance yields the purest gas). Sulphuretted hydrogen gas will be liberated in abundance, and may be made to combine with distilled water in the manner stated. Distilled water takes up about $\frac{3}{4}$ 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 and Moffat 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 opake and well corked bottle, retains a sufficient strength for two or three months.

The sub-sulphuret of iron may be obtained by melting together, in a covered crucible for a few minutes, three parts of iron filings, and one of flowers of sulphur; or a crucible may be half filled with common iron pyrites, covered with half its weight of iron filings, and putting over this a layer of charcoal powder, and then exposing the whole to a dull red heat for half an hour.

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

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

waters. Dr. Murray has suggested a process which appears to admit of very general 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, therefore, it was 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 em-

ploying 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, not original ingredients. Whether they are so or not, and what the real composition is, are to 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 sepa-

ration is easily effected. Nothing is easier, for example, than to estimate the total quantity of sulphuric acid by precipitation by barytes (see page 271), or of lime by precipitation by oxalate of ammonia (see page 241). 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 of 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 analytic 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 216, 279), 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 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 49, 76, 271); of muriatic acid by nitrate of silver (see pages 138, 159, 161); of lime by oxalic acid (see page 112); of magnesia by ammonia (see page 233); and of any alcaline 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.

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.

Add to the water thus concentrated a saturated solution of muriate of barytes (see page 271), 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 34 of acid. 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.

Add to the clear liquor a saturated solution of oxalate of ammonia (see page 241), 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.

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 prin-

ciple 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 241), 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 expelled at the end of the process by heat; but this decomposition, it is well known, is only partial. Sub-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 sub-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 sub-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 at 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.

Sub-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 easily to guard.

The method proposed by Dr. Wollaston, of precipitating magnesia from its solution, by first adding carbonate of ammonia, and then phosphate of soda (see page 161), 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 carbonate 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 effected by the addition either of phosphate of soda with ammonia, or of sub-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 muriate of soda (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 carbonate of ammonia were then employed to precipitate the magnesia in the mode proposed by Dr. Wollaston (see page 161); 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 10 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 become 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 sub-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 va-

pours exhaled. Being re-dissolved, a small portion remained undissolved; and on again adding sub-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 sub-carbonate of ammonia, as has been already stated; while, on the other hand, in its analysis by phosphate of soda and carbonate 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 .019 of this earth; but it is better, for the sake of accuracy, to convert in into phosphate of magnesia by calcination for an hour at a red heat: 100 grains, then, contain 40 of magnesia.

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, to be considered necessarily 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.

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 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 obtained.

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 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 it 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 analytic 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. Silex will be discovered by the gelatinous consistence it gives on evaporation, and forming a residue insoluble in acids, but dissolved by a solution of potash. Alumine 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. Silex will also be precipitated in the same stage of the process; its separation from the alumine 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 platina (see page 196) 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 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 at least of 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 suffi-

cient 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 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 the 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 dis-

cover other ingredients which are more rarely present in mineral waters. Thus alumine will remain in the state of sulphate of alumine, along with the sulphate of magnesia, and may be detected, by precipitation by bicarbonate of ammonia. Silex 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 where they consist chiefly of lime, magnesia, and alumine, its direct application is sufficiently obvious; where they require the previous action of an alcali from the predominance

of siliceous earth, on this being separated, the excess of alcali 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 quantities 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.

ANALYSIS

OF

EARTHS AND STONES.

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

The acids found in stones are chiefly sulphuric acid, carbonic acid, phosphoric acid, fluoric acid, boracic acid, arsenic acid, and tungstic acid. The bases are silex, alumine, 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 the stones.

Apparatus for Analysing Stones.

To analyse 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 fig. 8), 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 lies 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. Fig. 7 exhibits an outline of this mortar. *a* is a section of it, *b* a profile of it, and *c* 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 analysed. As agate mortars are composed almost entirely of silex, we have only to subtract from the weight of silex which we obtain from the mineral, the quantity which has been rubbed from the mortar. The remainder will be the silex really contained in the mineral. Suppose that, while pounding a mineral in our mortar, the mortar undergoes a loss of twenty grains, and that we obtain forty grains of silex by the subsequent analysis. It is obvious that our mineral will really

contain only twenty grains of silex, 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 both together.

When the mineral is reduced to an impalpable powder, the next step of the process is usually to mix it with 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 commom 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 alcalies 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 our mineral. If the

mixture has melted completely, we may be sure that the mineral either consists entirely of silex, or at least contains a considerable proportion of that earth. If it has not melted, the probability is, that a great deal of alumine 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 (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 pre-

sented for analysis. The first step of the process is to drop a fragment of it into muriatic acid. If it effervesces in the acid and dissolves, we may infer that it is an earthy carbonate; if it is not sensibly acted on by the acid, the process of analysis will be more complicated. We shall first give the mode of analysing the more complicated stones.

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 enables us to determine the weight of each constituent with sufficient exactness, while it 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 silex, 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 Wedgewood evaporating dish, fill the crucible with distilled water. After standing some hours covered with the 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 Wedgewood dish; fill up the crucible with distilled water again, and let it stand some hours as before. In this way you 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 Wedgewood dish. An effervescence takes place, because the alcali has absorbed carbonic acid during the preceding process, which is driven off as it dissolves in the muriatic acid. You 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 silex and a great deal of alumine, will not be rendered quite soluble by heating them with an alcali. 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 alcali, 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 will then obtain a complete solution by one process, which will greatly diminish the risk of error. If we employ too little alcali, it may happen that we do not obtain a complete solution in muriatic acid, even when our mineral contains a sufficient quantity of silex. The insoluble matter in such a case will be pure silex, and will readily enter into fusion when heated with a new portion of alcali.

Let us suppose the muriatic acid solution accomplished, the next step in the process is to evaporate this solution upon a lamp furnace (fig. 4). Place the Wedgewood 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 liquid is considerably concentrated by evaporation, it loses its liquid form, and assumes that of a jelly, at least if it contains any considerable proportion of silex. 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 need

not be carried farther than the gelatinizing of the silex if our sole object be merely to obtain the whole of that substance. For when silex 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 Wedgewood 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 filtre. The silex having been rendered insoluble by the evaporation of the muriatic acid liquid to dryness, will remain upon the filtre; 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 filtre. Distilled water must now be poured upon the filtre to wash the silex clean, and we must continue to do so till it passes through quite tasteless, and incapable of rendering a solution of common salt milky. The filtre is now to be dried,

and then accurately weighed. We then pour the silex into a platinum crucible, the weight of which has been previously noted. Wipe the filtre quite clean with a cloth, and weigh it again. The difference of weight gives the quantity of silex collected on the filtre. Let this weight be a. By weighing the platinum crucible containing the silex, 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 silex will be diminished; because it will, by the heat, be deprived of the whole water with which it was impregnated when weighed upon the filtre. Let its new weight be c. Let the weight of the whole silex, supposing it had been exposed to a red heat, be x. We have $b : c :: a : x$ and $x = \frac{ac}{b}$.

Having thus obtained the silex in a separate state, the next step of the process is to separate and weigh the alumine. For

this purpose we must pour carbonate of soda into the aqueous solution which has passed through the filtre, 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 alumine, 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 sal ammoniac into the potash till the liquid acquires a pretty strong smell of ammonia. The alumine will precipitate in white flocks. Continue to add sal ammoniac as long as any precipitate appears. The alumine thus separated must be washed, dried, and exposed to a red heat, and weighed.

Potash ley is capable of dissolving not

merely alumine, but glucine also. The white powder thus precipitated by sal ammoniac, may therefore be glucine as well as alumine. 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 silex, 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 alumine we shall find a number of crystals of alum deposited at the bottom of the vessel. If it was glucine, no such deposite 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 alumine 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 alumine. But if there be a deficiency, the probability is that some glucine was also present. This will be found in the sulphuric acid solution, from which it may be precipitated by an alcaline carbonate. We may be certain that this precipitate is glucine if we find it soluble in liquid carbonate of ammonia; if it forms sweet-tasted salts with acids; and if it be precipitated white from acids by prussiate 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 carbonate of ammonia, which will dissolve that earth, but leave all the other ingredients untouched. And the yttria may be obtained pure, and weighed, by evaporating the carbonate of ammonia to dryness, and exposing the residue to a red heat.

The residue of the mineral thus deprived of the silex, alumine, glucine, 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 ingredient. 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 sulphate 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 hydro-sulphuret 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 silex 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 silex, and thus has an apple-green colour. In this mineral it is associated with iron and lime. After the separation of the silex and alumine, the iron may be precipitated by ammonia, and when it is separated, we may throw down the nickel by hydro-sulphuret of potash. Nothing will remain but the lime, which may be thrown down by an alcaline 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 analysed, 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 alcali. For three different alcalies have been found in stones, namely, potash, soda, and lithina. To detect this alcaline 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 in-

tensity 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 filtre. 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 alcali 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 alcaline 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 lithina. 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 lithina, our mineral contained.

If no alcali 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 acquires a smell similar to that of muriatic acid, we may conclude that fluoric acid is present. To determinate its quantity we

must make a new analysis of the mineral. Fifty grains of it are to be fused with an alcali softened with water, dissolved in muriatic acid, and the silex separated from the method described at the beginning of this section. The remaining liquid is precipitated by carbonate of potash, and being filtred, and exactly neutralized, is precipitated by means of lime water. The precipitate is *fluor spar*. It must be exposed to a red heat. 26.5 *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 Ampere and Davy, in that case the fluorine will amount to 46.69 *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 the carbonates. Provide a phial with two mouths. To one of those 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 gas which the smoking acids of the shops always contains. Put into the mouth of the phial a plug of cotton wool. Balance this phial accurately upon the scales of a good beam. Suppose the carbonate to be subjected to analysis to 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, so 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 effects 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 had 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 analysed 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 analysed 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, 43.14
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 analysing 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 fur-

nished by Mr. Young; it has been examined by Lord Dundonald, in his treatise on the Connection of Chemistry with Agriculture, and by Mr. Kirwan, in his excellent Essay on Manures: but the enquiry 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 honor of laying before the board an account of those modes of analysing 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 analagous 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 bason 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

* 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.

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 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 four hundred 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 a large proportion of alumine. 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 acid; 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 greatest number of soils, besides gravel and stones, con-

tain 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. This may be effected in a way sufficiently accurate, by agitating the soil in water. 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 filtre; 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 as 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 analysis, is the exposure of the fine matter of the soil to the action of the muriatic acid. This substance should be poured upon the earthy matter in an evaporating bason, 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 seldom any alumine.

The fluid should be passed through a filtre; 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 common prussiate of potash 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.

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 alcaline salt.

The precipitate that falls down is carbonate of lime; it must be collected on the filtre, 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 alumine 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 alumine, 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 45 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 unknown, 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 half 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 destructable by air and fire.

It is not possible 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 portion of vegetable matter. In cases when the experiment is needed to be very quickly performed, the destruction of the decomposible 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 affords the principle necessary to the combustion of the animal and vegetable matter, which it causes to be converted into elastic fluids; and 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 alumine and silex with combined oxide of iron.

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 alumine and the oxide of iron, if any exist, are both dissolved by the sulphuric acid; they may be separated by carbonate of ammonia, added to excess: it

throws down the alumine and leaves the oxide of iron in solution, and this substance may be separated from the liquid by boiling.

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 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 earths, except silex, will be dissolved in combination as muriates. The silex, 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 strong and fetid, it contains animal mucilaginous or gelatinous substance; if it be white and transparent, it may be considered as prin-

cipally 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 precipitate 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 filtre, and exposed for some days to the atmosphere in an open vessel. If any soluble quantity of sulphate of lime (gypsum) existed in the soil, a white preci-

pitate 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 of 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 classed, 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 is discovered by the independent process **11**, a correction must be made for the independent process, by subtracting a sum equal to its 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 are obtained.

Thus 400 grains of a good siliceous sandy soil may be supposed to contain

	Grains.
Of water of absorption	18
Of loose stone and gravel, principally siliceous	42
Of undecomposed vegetable fibres	10
Of fine siliceous sand	203
Of minutely divided matter separated by filtration, and consisting of	
Carbonate of lime	25
Carbonate of magnesia	4
Matter destructable by heat, principally vegetable	10
Silex	40
Alumine	33
Oxide of iron	4
Soluble matter, principally sulphate of potash and vegetable extract	5
Gypsum	3
Phosphate of lime	2
	126
Amount of the products	325
Loss	4

In this instance the loss is supposed small; but, in general, in actual experiments, it will be found much greater, in consequence of the difficulty of collecting the whole quantities of the different precipitates; and when it is within thirty for four hundred grains, there is no reason to suspect any want of due precision in the 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 operation, 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 analysed 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 pulverisation and exposure to air, by paring and burning, or the agency of lately made quick-lime. 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,

* Philosoph. Trans. for 1799, p. 305. This limestone is found abundantly in Yorkshire, Derbyshire, and Somersetshire.

and under different circumstances. The power of soils to absorb moisture, a principle essential to 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.

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* Kirwan Trans. Irish Academy, vol. v. p. 175.

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, however, very various, and, in some cases, exceedingly small. A very fertile corn soil from Ormiston, in East Lothian, afforded me, in an hundred parts, only eleven parts of mild calcareous earth; it contained twenty-five parts of siliceous sand; the finely divided clay amounted to forty-five parts. It lost nine in decomposed animal and vegetable matter, and four in water, and afforded indications of a small quantity of phosphate of lime.

This soil was of a very fine texture, and contained very few stones or vegetable fibres. It is not unlikely that its fertility was in some measure connected with the phosphate; for this substance is found in

wheat, oats, and barley, and may be a part of their food.

A soil from the low lands of Somersetshire, celebrated for producing excellent crops of wheat and beans, without manure, I found to consist of one-ninth of sand, chiefly siliceous, and eight-ninths of calcareous marl, tinged with iron, and containing about five parts in the hundred of vegetable matter. I could not detect in it any phosphate or sulphate of lime, so that its fertility must have depended principally upon its power of attracting principles of vegetable nourishment from water and the atmosphere.*

Mr. Tillet, in some experiments made on the composition of soils at Paris, found that a soil composed of three-eighths of clay, two-eighths of river sand, and three-eighths

* This soil was sent to me by T. Poole, Esq. of Nether Stoway. It is near the opening of the river Parret into the British Channel; but, I am told, is never overflowed.

of the parings of lime stone, was very proper for wheat.

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 potatoe soil, from Varfal, in Cornwall, afforded me seven-eighths of siliceous sand; and its absorbent power was so small, that one hundred parts lost only two by drying at 400° Fahrenheit.

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 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.
Silex	54
Alumine	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 causes 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 1, (at the top of page) *a, b, c, d, e, f.* 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 or weather,

and frequently contains shells. Shell marl is called either the earthy or the indurated, abounding with shells.

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 loses 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 into 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 analysed 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 judged by drying it, after being washed well: when being kneaded together, dried and burnt, it will harden and form a brick.

Sandy marls usually lose the same quantity of carbonic acid, and frequently still less.

ANALYSIS OF ORES.

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 great part of the ore, even of those which are called very rich.

Process I.—Take one part of the ore, freed as much as possible from its matrix or stony matter, reduce it to an impalpable powder, mix it with four times its weight of subcarbonate of potash and one of glass of borax, melt the mixture in an earthen crucible (fig. 15, pl. 1.), and after having fused it for half an hour, pour it out on a stone

slab, suffer it to cool, and reduce it to powder.

II.—Transfer the mass into a Florence 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 muriatic solution.

III.—Transfer the fluid obtained in the foregoing processes into a glass bason (fig. 4, pl. 1.), and evaporate it slowly, over a lamp, to dryness (fig. 4, pl. 1.).

IV.—Pour upon the residue obtained in the last process so much boiling distilled water as is sufficient to dissolve it, and filtre the solution through paper placed in a funnel.

V.—Having done this, precipitate the solution with green sulphate of iron, 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 199).

VI.—Decant the fluid from this powder carefully, collect the latter, which is metallic gold, by putting it upon a filtre, and, when 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, when separated by the filtre, and perfectly dried, contain 75 parts of silver, which may be obtained from it, as shall be noticed more fully under the article of 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 contains 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 but a slight excess of acid.

When gold is found interspersed amongst sand, or earthy substances, in the state of so minute particles that it cannot be distinguished by the mere 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 conical 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 sulphate of iron, as directed, page 199.

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 mineralising 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 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 of silver, which may be obtained from it in the manner directed page 141.

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 448, and immerse into 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 only have 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 ensues, 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 30 of metallic lead.

III.—The presence of iron may be investigated by dropping into the solution prussiate of potash or tincture of galls.

Analysis of Bismuthic Silver Ore.

Process I.—Digest the ore repeatedly in nitric acid, till this fluid exercises no further action on the ore.

II.—Pour the nitric solution into a large quantity of water; a precipitate falls down,

which is oxide of bismuth; 123 parts of it, when dry, indicate 100 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 muriate 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 450, 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: ammonia will indicate it (see page 231); a cylinder of iron will precipitate the copper.

VIII.—The residue may again be digested repeatedly in muriatic acid, and assayed for lead by sulphuric acid. If a precipitate ensues, 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 or Common Sulphuret of Copper.

Process I.—Digest one part of the pulverised 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 acquires no blue colour it contains no copper.

II.—Evaporate this solution to dryness, re-dissolve it 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 filtre, wash, dry, and ignite it.

IV.—Mingle the fluid from which the iron has been separated with a solution of pot-

ash, 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 muriate of silver, and leaves the lead; by subtracting the weight which the precipitate has lost by this treatment, the quantity of both metals will be found. If antimony was 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 analysing all copper ores,

with a view to ascertain the quantity of copper.

Process I.—Take 100 grains of the pulverised ore, digest it repeatedly in one ounce of nitro-muriatic acid, composed of equal parts of nitrous and muriatic acid, till all the copper is extricated, which may be known as directed already.

II.—The different solutions are then to be mingled, precipitated by the addition of sub-carbonate of potash, and the precipitate collected on a filtre.

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 analysing the most valuable ores of copper.—On considering the different proceedings, it will be seen that the totallity of the examination is exceedingly simple, and may be shortly stated, thus.

The ore being repeatedly digested in nitric acid, till all the copper and other metals

are extracted, and then precipitating from this solution the copper, 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 a muriate 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 a sulphate of lead. The presence of antimony may be detected by decomposing the solution of the ore by an alcali, 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 into the solution a cylinder of tin, which separates the copper only. Arsenic may be separated by acetate or nitrate of lead, which separates the arsenic in the form of arsenate of lead, and leaves the copper; 100 parts of it are equal to 33.66 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 into 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 muriate of lead, and also of muriate of silver, if the latter metal was contained in the ore.

IV.—To separate these two metals, digest the precipitate in liquid ammonia; the muriate of silver will be dissolved, and the muriate of lead left behind: or the muriate of lead may be separated by boiling the precipitate in 24 parts of water, which dissolves the muriate of lead, and leaves the muriate of silver: or the solution of the muriate of lead may still more easily be effected by digesting it in dilute nitric acid, which dissolves it readily, but does not touch the muriate 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 muriate of lead with half its weight of black flux; introduce 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 75.2 of metallic lead.

The muriate of lead may also be reduced, by immersing into 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 into 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, copper, with a minute portion of iron. It was thus analysed by Mr. Hatchett:

Process I.—Two hundred grains of the ore, finely pulverised, 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 red hot crucible, without residue.

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 filtred. 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 muriate 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 120.2 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 2.4 grains.

VI.—The fluid was next evaporated nearly to dryness, boiled with a strong so-

lution of potash till nearly dry, and, on washing it with water, the oxide of copper obtained weighed 32 grains.

In this analysis the metals are 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 120.2 of sulphate of lead, Mr. Hatchett estimates 85.24 of metallic lead, which is in the proportion of 70.9 in 100.

Analysis of Carbonate of Lead.

This ore may be analysed 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.—Into the obtained solution immerse a cylinder of zinc, which precipitates the

lead in a metallic state. 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 pulverised 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 of oxide, as it is in this state that the lead exists in the ore. This proportion, however, would give an increase of only 6.5 of oxigen upon 100 of lead.

ANALYSIS OF ORES OF TIN.

Analysis of Native Oxide of Tin.

Process **1.—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 filtre the fluid.

III.—Take the residue left on the filtre, 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.—Let the solutions, thus obtained, be mingled, and add to it muriatic acid till no more precipitate falls down, adding the

acid rather in excess; suffer the mixture to stand undisturbed till the precipitate is subsided, in order to collect it on a filtre.

V.—Dissolve this precipitate in muriatic acid, in excess; precipitate it again by the addition of carbonate of soda; collect the precipitate on a filtre; 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 silex), dilute the solution with two or three parts of water, immerse into 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 frequently associated with copper; its analysis may be accomplished in the following manner:

Process I.—Let one part of finely pulverised 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 sub-carbonate of potash, till no further precipitate ensues: collect the precipitate on a filtre.

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 pre-

cipitated 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 into 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 silex and alumine. It is not only attracted by the magnet, but it possesses itself polarity; hence it attracts iron filing. 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 six parts of potash or soda, and eighteen of water; 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 alcaline mass with water, transfer it into a flask, pour over it muriatic acid, previously diluted with two 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 silex, by the filtre.

IV.---To the fluid from which the silex 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 filtre, 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 changed into the perfect red oxide of iron; 100 parts of it indicate 52 of iron.

V.---If to the alcaline fluid, from which this oxide has been separated, nitric acid be added, just sufficient to render the solution neutral, the alumine may be separated, by adding to it benzoate of ammonia, till no farther cloudiness ensues. This precipitate, after having been heated to redness for half

an hour, gives the quantity of alumine that was present in the ore.

Magnetic iron sand, specular iron ore, miscaceous iron ore, red iron stone, and all its sub-species, may be analysed in a like manner.

Analysis of Black Iron Ore.

This ore differs from the latter, by containing a small portion of manganese.

Process I.---Treat the ore with potash or soda, as directed in page 469, process I.; separate the silex 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 suc-

cinate 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 adding to it, 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 470, process IV.

V.—To the remaining fluid now add soda till no further precipitate ensues: the precipitate obtained is oxide of manganese.

The ores called black hematite, brown iron ore, and all its sub-species, may be analysed in a like manner.

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, silex, and alumine, a considerable portion of oxide of manganese, and carbonate of lime, and sometimes, also, a small portion of carbonate 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 analysed 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 car-

bonic 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 acid that has acted upon it, and when rendered neutral by an alcali, blue or black.

III.—Mingle the obtained solutions, and having concentrated the whole by evaporation, decompose it whilst boiling hot, by soda, adding this alcali rather in excess, and boil the whole for about a quarter of an hour. The alumine will, by this means, become dissolved in the excess of the alcali. Separate the insoluble residue by the filtre.

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. The former earths will become dissolved, and the oxide of iron and manganese will be left untouched, which 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 sub-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 over it 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 sub-carbonate of potash. The precipitate obtained is sub-

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 sub-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, after being washed and dried at a low red heat, is carbonate of manganese; 100 parts of it are equal to 55 of metallic manganese.

Analysis of Common Argillaceous Iron Ore.

This ore is chiefly composed of oxide of iron, alumine, aud a small portion of silex, 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 portions of oxide of manganese, phosphate of iron, and silex; they may therefore be analysed thus:

Process I.—Digest one part 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 experiment I. with four times its weight of soda, for one hour; dissolve the mass in water, filtre it, and separate the silex from the alcaline solution, by the admixture of muriatic acid; collect and dry it.

IV.—To the fluid from which the silex has been obtained, add the solution from which the phosphate of iron has been separated (Experiment II.); supersaturate the whole with soda, and boil the mixture for about half an hour. The alumine, 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 filtre.

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 filtre.

VI.—Decompose the obtained nitric so-

lution 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 directed before.

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 pulverised, 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 muriate 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.

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

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 aciduated with nitrous acid, and carbonate of potash added to it, which will throw down the oxide of copper; and his, after being exposed to a low red heat, becomes converted to the state of brown oxide, 100 parts of which denote 85 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, specific gravity 1.25 one part, strong muriatic acid three 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 or white oxide 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, as long as any precipitate falls down, indicates the quantity of sulphur; after which, an excess of caustic potash, assisted by a boiling heat, will throw down the iron, and retain the alumine and silex, 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. and VII.

Of silver by IV.

Of lead by V.

Of copper by VI.

ANALYSIS

OF

METALLIC SUBSTANCES.

*Examination of a Metal the nature of which is unknown.**

Let us suppose a metal, the nature of which is unknown, when brought into contac with dilute sulphuric acid, produces a disengagement of hydrogen gas; we then may conclude that the metal may be iron, zinc, or manganese.

Iron is detected if the solution, mixed with a solution of potash, soda, or ammonia, produces a white or olive-green precipitate, which, by the contact of air, soon acquires a deep green, and afterward a reddish yellow or brown colour; and if, after having added to it a small quantity of oxy-

* From Thenard's Traite de Chemie, tome IV. p. 55.

muriatic acid, it acquires the property of forming a blue precipitate with prussiate of potash, and a black precipitate with tincture of gall-nuts.

Zinc, if a solution of potash, soda, or ammonia produces in the metallic solution a white precipitate, which does not alter its colour by contact with air, and which is soluble in an excess of alcali; and if the solutions of prussiate of potash and hydro-sulphuret of potash produce in it a grey or white precipitate.

Manganese, if the addition of potash, or of soda, produces in the metallic solution a white precipitate, which is insoluble in an excess of alcali, and changeable to a chesnut brown colour, by contact with air; and if alcaline prussiates and hydro-sulphurets also produce with it white or grey precipitates. Lastly, if, by drying the oxide which is separated by the alcaline solutions, having mixed it with five or six times its weight of sub-carbonate of potash, and then exposing the mixture to the action of a red heat for

15 or 20 minutes, a green mass is obtained, possessing all the properties of the mineral cameleon.*

Let us now suppose that the metal has

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* By exposing to a red heat nitrate of potash, with a 6th or 7th of its weight of the protoxide of manganese, a green compound is obtained, possessing remarkable properties.† In effect, this compound, put in contact with cold or warm water, dissolves and colours it green: a little afterward the solution, whether in contact with the air or not, deposits reddish yellow flakes, which appear to be a hydrate or tetroxide of manganese, 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 at length abandons all the oxide that it contains, and 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*. The cameleon is evidently formed of potash and oxide of manganese; for it is most commonly prepared by heating to redness 7 or 8 parts of potash made caustic by lime, or 9 or 10 parts of the potash of commerce, with 1 part of oxide of manganese.

† See Accum's Chemical Amusement, Fourth Edit. 1819, p. 188.

no action on sulphuric acid, diluted with water, at the common temperature, but that it is susceptible of being dissolved by nitric acid at that temperature, or at least with the assistance of heat; it will make part of the following series: tin, antimony, molybdena, arsenic, cobalt, uranium, copper, nickel, palladium, mercury, bismuth, tellurium, lead, silver.

Cobalt, uranium, copper, nickel, and palladium, being the only metals of these fourteen which colour nitric acid, they cannot, therefore, be confounded with one another: they are to be distinguished by this property of the liquid.—The metal is

Cobalt, if the liquor is of a violet-red or rose colour; if it forms a precipitate of a violet-blue with alcalies, green with alcaline prussiates, black with alcaline hydrosulphurets, and particularly if the oxide which is separated from it by the alcalies is capable, at a red heat, of colouring a great quantity of borax, and producing with it a blue glass.

Palladium, if it is red; if the proto-sulphate of iron quickly reduces the metal; if muriate of tin throws down from it a black precipitate, and prussiate 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 is blue, or of a greenish blue colour; if it forms with potash and soda a blue precipitate, insoluble in an excess of alcali; with ammonia, a bluish-white precipitate, which an excess of ammonia dissolves immediately, imparting an azure blue colour to the solution; with prussiate of potash, a brown precipitate; lastly, if by immersing polished iron into it, the iron becomes covered with a coat of copper.

Nickel, if it is of a grass-green colour; if potash and soda precipitate from it an oxide of a green colour; if ammonia changes the colour of it to a violet-blue; if prussiate of potash produces an apple-green precipitate,

hydro-sulphuret of potash a black precipitate, and if polished iron does not at all reduce the metal.

Uranium, if the solution is yellow or inclining to yellow; if by proper evaporation and cooling, crystals of a citron-yellow colour are separated; if potash, soda, or ammonia produces a pale yellow precipitate, insoluble in an excess of an alcali; if prussiate of potash produces a blood-coloured precipitate; and lastly, if iron does not reduce the solution containing the oxide.

*A Metallic Compound being given, how to ascertain its Nature.**

1.—The first step to be taken is to put the mixture in contact with water, to determine whether it contains potassium, sodium, barium, strontium, or calcium: if it

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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.

contains any of these substances, hydrogen gas will be disengaged, and the liquid will become alcaline; then an excess of sub-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, strontium, and lime, are insoluble, whilst those of potash and soda are on the contrary very soluble, the filtred liquid and the precipitate well washed, if any is 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 sub-carbonates of potash, and of soda, which is held in solution. Let them be re-dissolved in water; then, after having decomposed them by sulphuric acid, to convert them into sulphates, the latter are to be separated by crystallization. In the case where the concentrated liquid is incapable of rendering a concentrated solution of platinam at all turbid, it would be useless

to crystallize the salts: they would consist of sulphate of soda only.

With regard to the precipitate, it must be re-dissolved in muriatic acid, the solution evaporated to dryness, the residue digested repeatedly in boiling alcohol, which has no action on muriate of barytes, but which readily dissolves muriate of lime and muriate of strontia: after which, the alcoholic solution is to be diluted with water, and sub-carbonate of potash added to it; this immediately precipitates the lime and strontia of these muriates in the state of carbonates. Then if any precipitate is thrown down, let it be again dissolved, not however in muriatic but in nitric acid; and lastly, the solution must again be evaporated to dryness, in order that the residue may be digested in boiling and highly rectified alcohol, which has no action on nitrate of strontia, but has a very powerful action on nitrate of lime.

II.—When water has no action on the mixture, it is to be put in contact with

weak sulphuric acid, and the temperature of that acid raised to ebullition. 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, as in the case, page 483.

The mixture contains

Iron, if the solution forms, with prussiate of potash, a precipitate which becomes blue with oxy-muriatic acid, or on exposure to the air.

Nickel, if, after having poured an excess of oxy-muriatic acid into the solution to oxidize highly the iron, it becomes blue on adding ammonia.

Zinc, if the iron of the solution being highly oxidized, the addition of carbonates of potash and 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 a nitrate of zinc will be produced, which will exhibit, with alcalies, with hydro-sulphurets, and the alcaline prussiates, all the phenomena that we have pointed out in speaking of zinc. (See page 484.)

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 afterward on the remaining mass, a solution is obtained, which furnishes, by evaporation, a residue, capable of forming mineral cameleon with potash. (See note, page 485.)

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 results; if the liquid precipitates a solution of gold, brown or purple; if, by pouring into it subcarbonates of potash or of soda, a precipi-

tate is obtained, which, treated with nitric acid, leaves a white residue, it is proved that 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, and palladium; and will not sensibly attack, or will attack with difficulty, chromium, tungsten, columbium, titanium, cerium, osmium, rhodium, platinam, gold, and iridium. If the solution is incapable of being made turbid by water, a certain quantity of this liquid is to be added; then it is to be filtred, and the residue washed; but if it is capable of being rendered turbid, it must be diluted with weak nitric acid (which will produce no alteration in it), filtred as usual, and the residue washed with weak nitric acid.

The residue, being well washed, should

be put in contact with muriatic acid, and exposed to the action of heat, in order to dissolve the metals which nitric acid may have only oxygenized; namely, antimony, 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 arsenite 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, assaying

it with hydro-sulphuret 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 contains 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 contains arsenic acid, it will be sufficient for the purpose of ascertaining it 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 belong but to that series which we have 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, and uranium. It contains

Bismuth, if, on dilution with water, it deposits a white precipitate, which, well washed, is capable of becoming black, with sulphuretted hydrogen, of melting before the blow-pipe into a yellowish mass; and lastly, of being reduced by heating it with a blow-pipe in a cavity of charcoal, and of affording a brittle and very fusible metal.

Lead, if, after having diluted it with water, it forms 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, or 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 becomes turbid by adding muriatic acid, and if the precipitate is white, flaky, insoluble in an excess of acid, but soluble in ammonia, and if it becomes black on exposure to light.

Palladium, if the proto-sulphate of iron speedily separates from it a brilliant white metal, forming with nitric acid a red solution, capable of being precipitated in a brown powder by muriate of tin, and if it yields a precipitate by prussiate of mercury.

Copper, if a polished iron plate, immersed into it, becomes 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 produces with it a precipitate partly soluble in caustic potash; if, saturating afterward the alcaline solution with an acid, a white oxide subsides; lastly, if that oxide, mixed with oil, and heated to

redness in a retort, sublimes in bluish-white metallic globules.

Mercury, if on heating to redness in a retort, or glass tube, the part of the precipitate of the preceding experiment which resisted the action of the alcali, yields globules of mercury; or still better, if similar globules are obtained by heating the metals before treating them with nitric acid.

Cobalt, if, after having diluted it with water, and immersed into it a plate of iron, to precipitate the bismuth, lead, silver, palladium, copper, tellurium, and mercury, a liquid is obtained, from which an oxide can be precipitated, capable of forming a blue glass with borax: to this effect, the liquid must be first mixed with muriatic acid, and next with an excess of ammonia; afterwards the liquid is to be filtered, and then boiled with caustic potash: and the precipitate formed by the action of this alcali, melted with 20 or 25 times its weight of glass of borax, will colour it intensely blue.

Uranium, if, by digesting in nitric acid

the precipitate formed with ammonia in the preceding experiment, evaporating the nitric solution to dryness, pouring water on the residue, and repeating these two operations for several times successively, a yellow liquid is obtained, possessing the same properties as that which is produced by the action of nitric acid on uranium. (See page 488.)

Let us now examine the second solution, (IV. pages 493 and 494.)

The muriatic solution should be concentrated like the nitric; and when it is so far concentrated as to have lost the greatest part of its excess of acid, a small excess of hydro-sulphuret 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 oxides, whatever they are, become precipitated in combination with the sulphuretted hydrogen, forming hydro-sulphurets, or sulphuretted hydro-sulphurets; then, after having filtered the liquid, it is to be treated as has

been stated (see page 493), in order to discover in it those two kinds of metallic acids. As for the precipitate, which is perhaps composed of hydro-sulphuret of antimony, hydro-sulphuret of tin, and sulphuret of bismuth, it is to be boiled with concentrated muriatic acid, which readily decomposes and dissolves the hydro-sulphurets, and has no action on the sulphuret of bismuth. If the new solution affords 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 contains tin, by producing a brown or purple precipitate.

Moreover, as the sulphuret of bismuth is acted on by nitric acid, and as by digesting it in that acid with the assistance of heat, a nitrate of bismuth, which is soluble, crystallizable, and decomposable by water, and a deposit of sulphur and sulphate is produced, it will always be easy to discover it.

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 bason; if the residue is 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 afterward with muriatic acid, and lastly with nitro-muriatic acid: three solutions will be thus obtained, one alcaline, and the two others acid. In the alcaline 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 becomes turbid, and submitting it to ebullition in a retort, a colourless liquid passes over into the receiver, possessing an odour of oxy-muriatic acid, susceptible of becoming blue with nut-galls, and depositing black flakes by the contact of zinc.

Chromium, if, after having poured unto it nitric acid, filtering it to separate the deposit, if any, and having saturated it with potash, soda, or ammonia, the acid nitrate of mercury produces a red precipitate, which becomes green when strongly heated.

Tungsten, if sulphuric, nitric, and muriatic acids form with it a white precipitate, and if the precipitate becomes yellow when boiled in one of these acids.

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

remains, possessing the same properties as that which is produced by digesting columbic acid in the same manner.

The titanium, cerium, and iridium, are to be found in the muriatic solution (see V. page 500). To determine whether it contains these metals, it must be concentrated, diluted with water, and filtered. A plate of iron must be immersed in it, and lastly 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 an oxide; the iron will precipitate the iridium in a black powder in the metallic state; and though it might at the same time precipitate a little platinum, and even a little rhodium, an effect that would occur if these last two metals could be attacked, at least in part, by nitre, the characteristic properties of iridium would not be so concealed as to prevent its being distinguished. The tartrate of potash will precipitate the cerium in the state of tartrate of cerium. By decomposing at a red

heat this salt, an oxide of cerium will be obtained of the colour of ochre, which, heated with muriatic acid, produces oxy-muriatic acid, and a solution which is sweet and colourless.

The nitro-muriatic solution must be examined for platinum and gold. If it contains 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 green sulphate of iron and muriate of tin. If it contains gold, this muriate will produce a precipitate of purple of Cassius, and green sulphate of iron will precipitate the gold immediately.

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.

Lastly.—As rhodium is not attacked by water, by acids, nor by nitrate of potash, this metal should be contained in the residue left after the action of those different reagents on the metallic mixture; the residue indeed should contain no other. However, if it should happen that there is no residue, it must not be concluded that the mixture contained no rhodium, because it is known that the presence of the other metals promotes the solution of the latter; it will be found, undoubtedly, in the muriatic or nitro-muriatic solution, from which it may be extracted by the methods pointed out in all systems of chemistry.

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* Iridium, osmium, palladium, rhodium, and platinum, are all extracted from the ore of platinum met with in commerce. The crude platina, or the ore of platinum, likewise contains some globules of mercury, which may be separated by heat.---See Accum's System of Chemistry.

*Analysis of a Metallic Compound consisting of Tin, Bismuth, Lead, Copper, and Silver.**

VI.—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 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 (see page 493), will give, by their weight, the quantities of tin and bismuth of the mixture. The quantities of silver, lead, and copper, are to be determined

* We shall content ourselves merely by indicating the general way of proceeding that should be followed in this analysis, as well as in those following. The washings, filtrations, desications, and all other operations practised in analyzing these different compounds, will not here again be considered. The reader being now, it is supposed, familiar with all these analytical details, more especially as they have been previously described.

by pouring into the solution, first, muriatic acid; afterward a solution of sulphate of potash or soda; and lastly, potash. The muriatic acid will precipitate the oxide of silver; the sulphuric acid of the alcaline sulphate will precipitate the oxide of lead; and the potash, the oxide of copper. In this manner there will be obtained muriate of silver, sulphate of lead, and of copper, of which it will be sufficient to take the weights, in order to ascertain those of the silver, lead, and copper.—See the Analyses of the alloy of tin and lead, of gold and silver, and of zinc and copper, for the estimation of the quantities of lead, silver, and copper. (See page 516.)

Analysis of a Metallic Compound consisting of Tin, Bismuth, Lead, Silver, Copper, and Zinc.

VII.—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 516): the alcali will precipitate both in the state of an oxide, it will re-dissolve the former, and leave the oxide of copper pure.

Analysis of a Metallic Compound consisting of Tin, Bismuth, Lead, Silver, Copper, Zinc, and Manganese.

VIII.—By always pursuing the same mode of analysis, the tin, bismuth, lead, silver, and zinc, will become isolated; but the copper and manganese remained combined. Now, since they are oxidized, and as ammonia readily dissolves oxide 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 oxide 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 supposed to be at the *maximum* of oxidizement.

Analysis of a Metallic Compound consisting of Tin, Bismuth, Lead, Silver, Copper, Zinc, Manganese, Gold, and Platinum.

IX.—Still treating this alloy like the preceding, you will separate the bismuth, lead, silver, copper, zinc, and manganese, and obtain a residue composed of oxide of tin, gold, and platinum; digesting afterward this residue with muriatic acid, the oxide of tin becomes dissolved, and may be precipitated by adding ammonia; you will then have remaining only gold and platinum, which may be converted into muriates with nitro-muriatic acid; then pouring sulphate of iron into the solution of these two metals, the gold will be reduced and gradually subside; now, passing a current of sulphuretted hydrogen through this

solution, thus freed from gold, you will combine the platinum with the sulphur; and lastly, heating in contact with air the sulphuret of platinum, which will appear in the form of black flakes, you will extract the platinum.

Analysis of a Metallic Compound consisting of pure Tin, Bismuth, Lead, Silver, Copper, Zinc, Manganese, Gold, Platinum, and Iron.

X.—If the bismuth, lead, silver, copper, and zinc, are separated, as before mentioned, the iron, in the state of oxide, 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 analyse 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 alcaline 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 sub-sulphate 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 sub-sulphate; 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 alcali, and when, on the contrary, it is made turbid by greater quantities of potash. The sub-sulphate 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, and consequently, the quantity of that metal: the weight of the oxide of manganese will give equally 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 afterward with water, and throw the whole upon a filtre, the oxide of iron remains upon the filtre, while the

oxide of manganese, combined with nitric acid, will pass through it, and may then be separated by the addition of potash.

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 into water. The mercury is volatilized and condenses into the receiver, while the other metal remains in the retort or tube. Every other alloy composed of mercury and a fixed metal, or which is not volatilized below a red heat, may be analysed in the same manner to dilute 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 decomposed, 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 filtre, 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 subtracting the quantity of oxigen which it contains, namely, 27.2 in 127.2, we shall have the quantity of tin of the alloy. Unite afterward 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, wash, dry, and weigh it, and observe that, in the sulphate of lead, the acid is to the oxide as 100 to 279.74; and that in the oxide, the oxygen is to the lead as 7.7 to 100, or rather 100 of sulphate of lead contains 68.39 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 oxide 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

deutoxide of copper; weigh it, and deduct from its weight the quantity of copper of the alloy, which is to be done by subtracting 20 per cent. of the weight.

Analysis of an Alloy of Lead and Antimony.

This analysis is performed exactly the same as that of tin and lead (see page 514), but instead of subtracting 27.20 from 127.20 of residue, 37.20 must be subtracted; because the peroxide of antimony of which that residue is composed, contains in 137.20 of oxide, 100 of metallic antimony, and 37.20 of oxygen.

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 decantation, till the washings no longer turn turmeric paper brown. Thus you will obtain the oxide of zinc in solution in the liquid; and the copper, in the state of deutoxide, will remain in the residue. It will be sufficient to dry and heat to redness and weigh this residue, and subtracting 20 per cent. from its weight, to have the quantity of copper in the alloy. But it will be necessary to perform a greater number of operations to have the quantity of the zinc. For this purpose, after having united the washings with the liquid, add an excess of muriatic or of sulphuric acid, which will convert the potash and oxide of zinc into sulphates or muriates of potash; then add sub-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, since that oxide is composed of 100 zinc and 24.4 oxygen.

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 muriate obtained by pouring muriatic acid into the liquid, washing, drying, and weighing the precipitate.

If the quantity of silver is very small, the nitric will not dissolve the alloy, or only in part. It will then be necessary to combine the alloy with a weighed quantity of silver, that 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 muriate: after which the liquid is to be filtered, and the precipitate washed, till 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 deutoxide. This oxide well washed, dried, and heated to redness, gives the quantity of copper; and so likewise the muriate 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 dis-

solve, and the gold remain behind. The weight of the gold is to be appreciated as in the article (see page 518); and the quantity of silver and of copper contained in the solution determined as aforementioned.—(See page 519.)

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 oxydizable, 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 bis-

muth, 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 68.39 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 this means, all the lead will be dissolved in the state of a 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, heat to redness, and to weigh the oxide of tin, to ascertain the quantity of the 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 the bismuth; and lastly, pour sulphate of potash into the solution of nitrate of lead, to collect, wash, dry, and weigh the sulphate of lead which will become precipitated: **127.2** of oxide of tin contain **100** of tin; **111.72** of oxide of bismuth contain **100** of bismuth; and **100** of sulphate of lead, **68.39** of lead.

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 into 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 basons, *c, c,* or a funnel ; 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.*

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 or cover 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 intended to be exposed to the action of the fire.

FIG. 10. *A Glass Capsule or Evaporating Bason.*—These basons 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 again be forcibly driven out by the breath: and if directed against the inner sides of the filtre, 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 pulverised substance does not stick to the sides.

FIG. 14. *A precipitating or decanting Jar.*

FIG. 15. *A Crucible and its Cover.*

PLATE II.

FIG. 1. *Apparatus for the Analysis of Soils.*

FIG. 2. *A specific gravity Bottle.*---It consists of a small short vial 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 expence of the spirit to supply the lamp for experimental purposes is quite inconsiderable. *a*, the lamp; *c*, 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 basons, &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 desication 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.*

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 easy manageable heat, which may be kept up for many hours.

FIG. 8. *Another Modification of the Tube described Fig.* 11, *pl. I.*

FIG. 9. *A Pair of Crucible Tongs.*

FIG. 10. *Dr. Wollaston's Pocket Blow-pipe.*

FIG. 11. *A Sand-bath, to fit the Portable Furnace, represented on the Title Page.*

FIG. 12, 13. *Rings to fit the same Furnace, for contracting the opening of it.*

FIG. 14. *A Flask and Bent Tube.*

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