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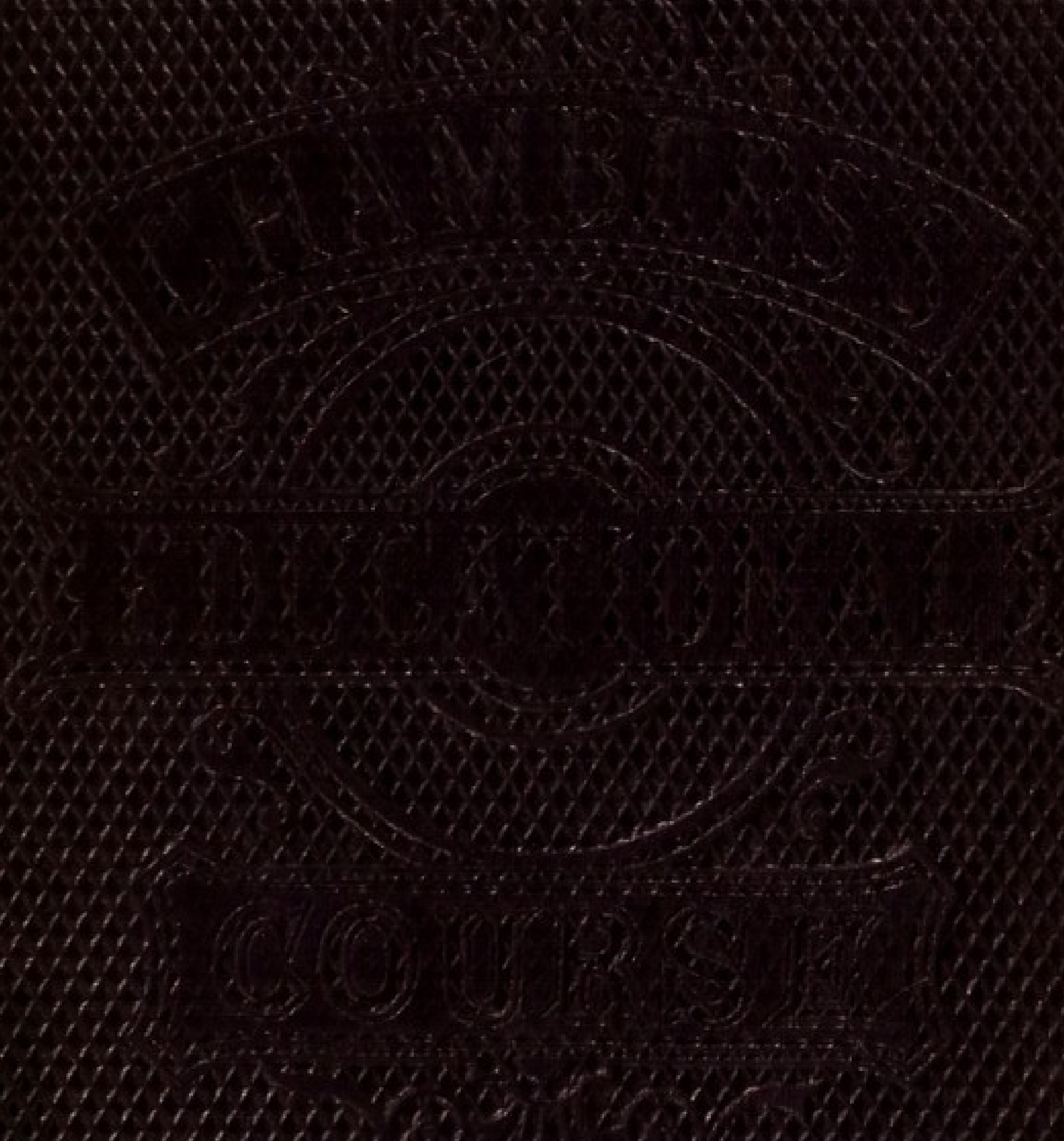

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[1865]

# PRACTICAL CHEMISTRY

BY

STEVENSON MACADAM, PH.D., F.R.S.E., F.C.S.

LECTURER ON CHEMISTRY IN THE MEDICAL SCHOOL, SURGEONS' HALL,
AND TO THE SCHOOL OF ARTS, EDINBURGH, ETC.

Illustrated by Wood-cuts.

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# PREFACE.

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This Treatise is intended for the use of students of Medicine and of Arts, and of advanced pupils in Educational Institutions. It is arranged in as simple a manner as possible, and the tests and processes given in the work are restricted to those substances which are to be met with in everyday life. The Treatise may be regarded as introductory to the larger works on the same subject, and in the hands of an intelligent teacher will serve as a guide to the conduction of classes in Practical Chemistry.

The special object contemplated in the issue of this little volume is to supply an elementary work which would be as serviceable in the laboratory or testing-room, as the companion Treatise on Chemistry has been found to be in the lecture-room. The subjects comprehended in the following pages are of a general nature, and the students of Medicine and of Arts, who wish to examine more fully the materials which specially pertain to those departments of knowledge, are recommended to make themselves familiar with the contents of this volume, and thereafter to consult the larger text-books on Practical and Analytical Chemistry.

# CONTENTS.

# PRACTICAL CHEMISTRY.

## Introduction.

1. The department of Chemistry which relates to the examination of substances in order to determine their nature and composition is designated Practical and Analytical Chemistry; and the pursuit of this branch of science necessitates that the student or pupil has command of various vessels and pieces of apparatus, as well as a number of chemical substances which may be employed in the course of testing.

2. Practical Chemistry, in the widest sense of the term, comprehends all the processes by which materials may be joined together to form definite compounds, and the methods which may be followed in separating simpler bodies from compound substances; but in the restricted sense in which it will be used in this treatise, it will simply relate to those properties of substances which distinguish the many chemical elements and compounds from each other.

3. Analytical Chemistry is the branch of Practical Chemistry which specially takes cognizance of the

characters and tests of the simple and compound substances, and of the processes which enable us to separate bodies from each other, and to determine the relative quantities of each. When the analytical operations are merely confined to the testing of the nature of the ingredients, it is called *Qualitative Analysis*, whilst when the quantity of each component is determined, the process is then known as *Quantitative Analysis.* The former must always precede the latter, as we must first know the quality or nature of the ingredients of a compound before we can proceed to estimate the quantity of each. The present treatise will be confined to Qualitative Analysis.

4. In the examination or testing of substances it is found that each material may be recognised by certain chemical properties, which are as distinctive as the signs or appearances commonly used for recognising bodies. Thus, ordinary water is generally known to us by being a clear transparent liquid, without odour or colour, and having little or no taste; and the chemist can recognise water by compelling it to dissolve certain salts, and by separating from it the two gases oxygen and hydrogen. Again, common salt is popularly known as a white substance, in larger or smaller crystals, and which has a *salt* taste; whilst the chemist can more certainly recognise it by the addition of testing solutions which give indications with common salt, and which they yield with no other material.

5. The simple or elementary substances which enter into the composition of the many thousand chemical compounds are sixty-four in number; and two, three, or more of these, are joined together in each compound substance. The following table gives the names of the chemical elements, with the symbols by means of which they are shortly indicated, and the equivalents or proportions in which they unite together:

## Table of the Elementary Substances.

| Names of Elements. | Symbols. | Equivalents H = 1. |
|---|---|---|
| ALUMINUM, | Al | 13·7 |
| ANTIMONY (Stibium), | Sb | 120·3 |
| ARSENIC, | As | 75 |
| BARIUM, | Ba | 68·5 |
| Beryllium or Glucinum, | Be | 7 |
| BISMUTH, | Bi | 210 |
| * BORON, | B | 10·9 |
| * BROMINE, | Br | 80 |
| Cadmium, | Cd | 56 |
| Cæsium, | Cs | 133 |
| CALCIUM, | Ca | 20 |
| * CARBON, | C | 6 |
| Cerium, | Ce | 46 |
| * CHLORINE, | Cl | 35·5 |
| CHROMIUM, | Cr | 26·7 |
| COBALT, | Co | 29·5 |
| COPPER (Cuprum), | Cu | 31·7 |
| Didymium, | Di | 48 |
| Erbium, | E | ... |
| * FLUORINE, | F | 19 |
| GOLD (Aurum), | Au | 197 |
| * HYDROGEN, | H | 1 |
| * IODINE, | I | 127 |
| Iridium, | Ir | 99 |
| IRON (Ferrum), | Fe | 28 |
| Lanthanum, | Ln | 46·4 |
| LEAD (Plumbum), | Pb | 103·5 |
| Lithium, | Li | 7 |
| MAGNESIUM, | Mg | 12 |
| MANGANESE, | Mn | 27·5 |
| MERCURY (Hydrargyrum), | Hg | 100 |
| Molybdenum, | Mo | 48 |
| NICKEL, | Ni | 29·5 |
| Niobium or Columbium, | Nb | ... |
| * NITROGEN, | N | 14 |
| Norium, | No | ... |
| Osmium, | Os | 99·6 |
| * OXYGEN, | O | 8 |
| Palladium, | Pd | 53·3 |
| * PHOSPHORUS, | P | 31 |
| PLATINUM, | Pt | 98·7 |
| POTASSIUM (Kalium), | K | 39·1 |
| Rhodium, | R | 52·2 |

| Names of Elements. | Symbols. | Equivalents H = 1. |
|---|---|---|
| Rubidium, | Rb | 85·4 |
| Ruthenium, | Ru | 52·2 |
| * Selenium, | Se | 39·7 |
| * SILICON or Silicium, | Si | 14 |
| SILVER (Argentum), | Ag | 108 |
| SODIUM (Natrium), | Na | 23 |
| STRONTIUM, | Sr | 43·8 |
| * SULPHUR, | S | 16 |
| Tantalum, | Ta | 68·8 |
| Tellurium, | Te | 64 |
| Terbium, | Tr | ... |
| Thallium, | Tl | 204 |
| Thorium, | Th | 59·6 |
| TIN (Stannum), | Sn | 59 |
| Titanium, | Ti | 25 |
| Tungsten (Wolfram), | W | 92 |
| Uranium, | U | 60 |
| Vanadium, | V | 68·6 |
| Yttrium, | Y | 32·2 |
| ZINC, | Zn | 32·6 |
| Zirconium, | Zr | 33·6 |

6. In the foregoing table, the more commonly occurring elements, and those which will be specially referred to in this treatise, are printed in capital letters, whilst the rarer elements are printed in ordinary type. The elementary substances are divided into fifty-one metals and thirteen non-metals, and the latter are distinguished from the former in the table by an asterisk.

7. In analytical chemistry the student or pupil has comparatively little to do with the simple substances or elements, excepting in the case of the metals which are used in commerce, such as aluminum, zinc, nickel, iron, lead, silver, mercury, copper, bismuth, cadmium, gold, platinum, antimony, tin, and arsenic. In the greater number of instances the substance under examination is a salt, such as sulphate of magnesia (Epsom salts), $MgO,SO_3$, which contains the oxide of magnesium or

magnesia, MgO, in combination with sulphuric acid, $SO_3$; and in the testing for this salt, the experimenter first detects the characters or properties of magnesia, and thereafter of sulphuric acid.

8. In the prosecution of the testing operations, the student must bear in recollection that it is absolutely necessary that the utmost cleanliness be preserved in all the vessels and other apparatus which he employs; and that every used glass be thoroughly washed out before it is again employed for any purpose. Saline substances, which adhere to the side of the glass, and which will not come off by water, will generally be detached by the addition of a few drops of hydrochloric acid, HCl; and oily matters may be removed by a little potash, KO, solution; and in either case, thorough washing with water must be resorted to thereafter. If the vessels are well cleaned with water, there is no necessity for drying the interior with a towel, as, unless clean on every occasion, the latter is apt to soil the glasses.

9. The manipulator must always keep in recollection that the properties and characters of substances, which are given in this treatise as their tests, have been acknowledged by chemists to be correct, and that if all the conditions required for the performance of the experiments are carried out by him, the stated result must be brought about. He should on no account pass over a single test until satisfied that the reaction or property has been correctly obtained.

10. The general plan of the treatise is (1.) To describe the various articles of apparatus required in the operations, and to state their uses; (2.) To explain the various processes which are employed in the chemical operations; (3.) To name the reagents or chemical substances, and give the methods for preparing the solutions of proper strength; (4.) To give the tests or characters of the

various groups of bodies; and (5.) To describe the methods which may be followed in the systematic testing of unknown substances.

11. For the more clear understanding of the difference in the results of the tests applied to the many substances, I have prefaced the consideration of each group of bodies by a tabulated statement of the principal tests, and have thereafter given very shortly a more full explanation of the changes which occur, and the conditions required for the successful working out of the tests.

### 12. Vessels and Apparatus required for Testing.

(1.) Six or eight test-glasses with lip (fig. 1), which are employed in mixing the liquids and observing the reactions.

Fig. 1.

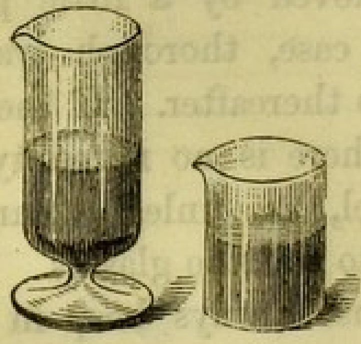

Fig. 2.

(2.) Two or three pieces of glass rod, about 3 inches long, and rounded at the ends, which can be used in stirring the mixtures in the test-glasses, &c.

(3.) Several glass jars and beakers of various sizes (fig. 2), for holding solutions, &c.

(4.) A dozen of glass test-tubes, large and small, in a test-tube rack (fig. 3), for heating small portions of liquids, and flasks for making solutions (fig. 4).

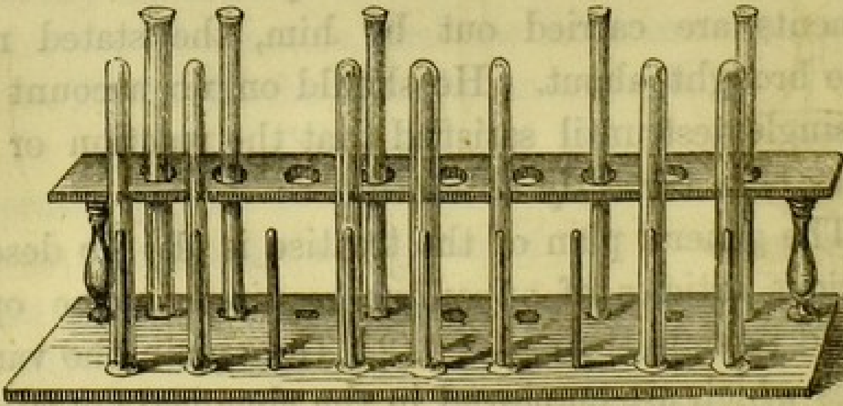

Fig. 3.

(5.) Several porcelain basins and capsules of different sizes (fig. 5), which are serviceable in heating larger quantities of liquids, and in the preparation of solutions.

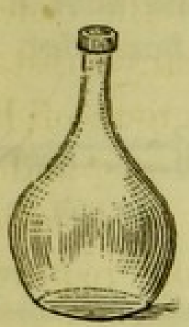

Fig. 4.

Fig. 5.

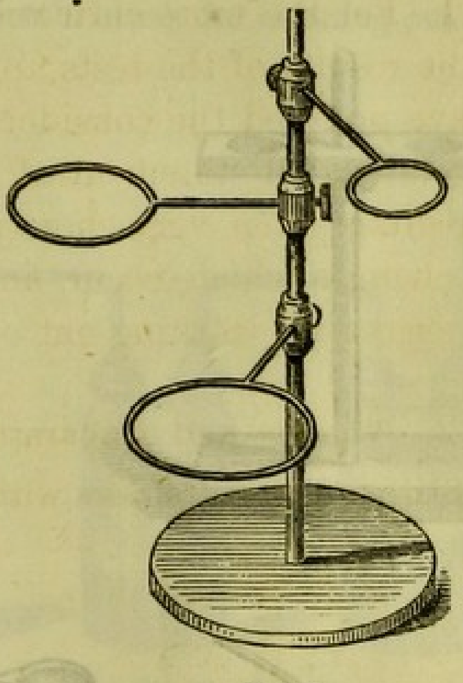

Fig. 6.

(6.) A retort-stand with several rings (fig. 6), for supporting the flasks and basins over the lamp.

(7.) Spirit-lamp, with cotton wick and alcohol (fig. 7), or Bunsen lamp (fig. 8), supplied with gas and air, admitted below, for heating vessels.

Fig. 7.

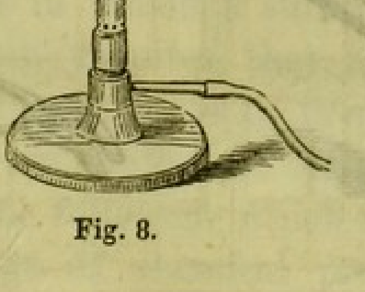

Fig. 8.

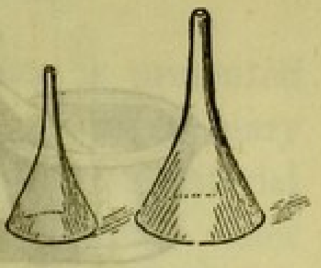

Fig. 9.

(8.) Several glass funnels of various sizes (fig. 9), and funnel-stand (fig. 10), for filtering liquids, and fine white filtering paper.

(9.) Two retorts for the distillation of liquids (fig. 11).

(10.) A washing-bottle (fig. 12), for pouring water on filters, &c., and a large bottle for holding distilled water.
(11.) Several watch-glasses and pieces of glass tubing.
(12.) Platinum capsule for heating solids (fig. 13).

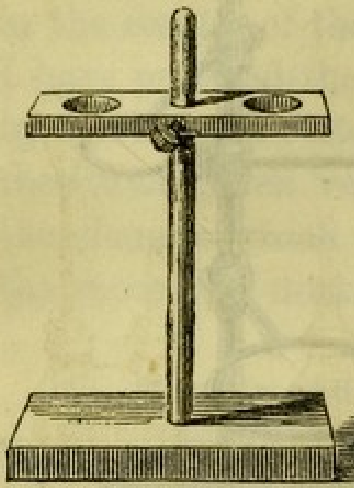
Fig. 10.

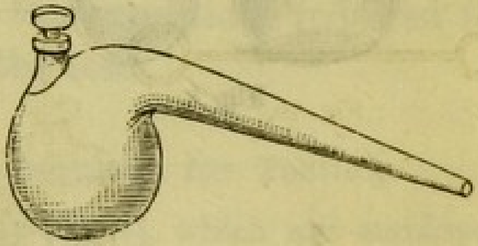
Fig. 11.

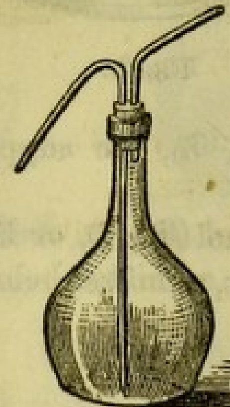
Fig. 12.


Fig. 13


Fig. 14.

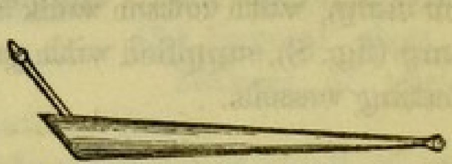
Fig. 15.

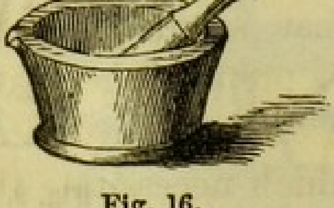
Fig. 16.

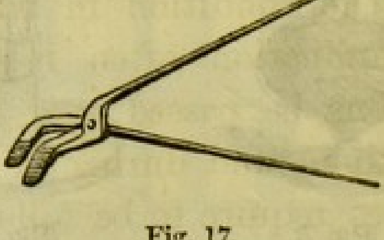
Fig. 17.

(13.) Platinum wire for blow-pipe experiments (fig. 14).
(14.) Pieces of charcoal for supports in blow-pipe testing.
(15.) A blow-pipe (fig. 15).
(16.) A small porcelain mortar (fig. 16).

(17.) Pair of iron forceps (fig. 17), a test-tube holder (fig. 18), and a wire holder (fig. 19).
(18.) Several triangles for supporting small vessels, &c., on retort-stand (fig. 20).
(19.) A tube cleaner, or small bottle brush for cleaning out test-tubes and small bottles.


Fig. 18.


Fig. 19.

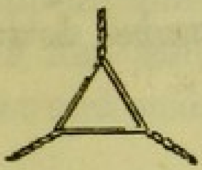
Fig. 20.

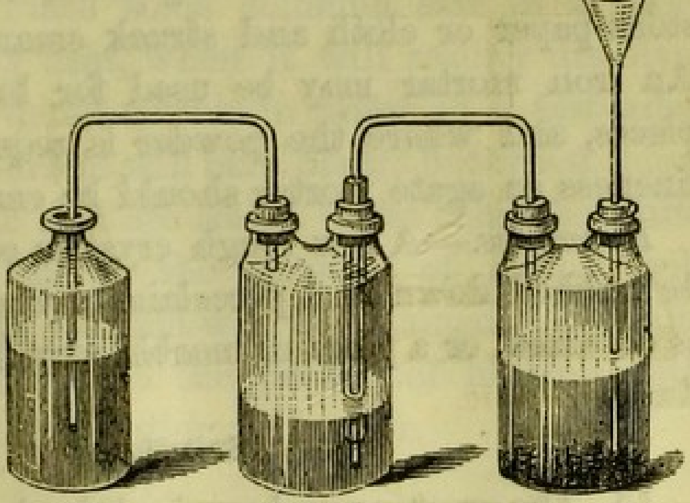
Fig. 21.

(20.) Bottle for generating hydrosulphuric acid (fig. 21).
(21.) Pieces of cobalt blue glass and of green glass.
(22.) Bottles and contents as enumerated under reagents.

## Operations in Analysis.

13. The condition in which a substance is presented for examination often requires that some preliminary operations be passed over, so as to prepare the material for testing; and during the course of the analysis other processes require to be followed, which necessitate that a little prior knowledge of chemical processes has been acquired. In order, therefore, that the several modes of operating may be distinctly understood, the student should familiarise himself with the following operations :

### Pulverisation.

14. Crystalline substances and bodies in small pieces should be broken down into powder before being subjected to the process of solution. For general purposes, an ordinary porcelain mortar (see fig. 16) is suitable, and where the substance is very hard, it may be placed in stout paper or cloth and struck smartly with a hammer. An iron mortar may be used for breaking down large pieces, and where the powder is required to be of great fineness an agate mortar should be employed.

*Examples.*—A few rough crystals of common salt may be rubbed down in a porcelain mortar till a fine powder is obtained, or a piece of marble may be pounded down to dust.

### Solution.

15. The greater number of solid substances are dissolved on the addition of a liquid, and the process is facilitated by the application of the heat of a lamp. Water is generally the solvent or liquid substance employed; and where

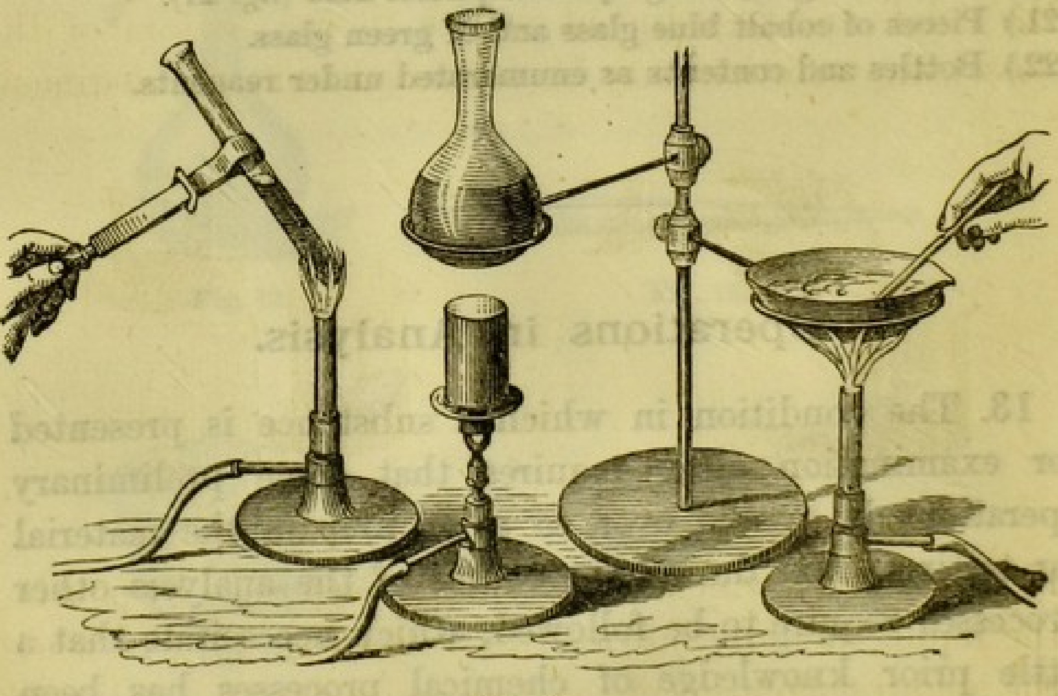

Fig. 22.

water fails to dissolve the material, an acid may be added. A few substances resist the action of water and of acids. The apparatus employed in effecting the solution is either a test-tube, a glass flask, or a porcelain basin, and these may be supported on holders or on retort-stands, and heated by lamps (fig. 22).

*Examples.*—(1.) Place some common salt in a tube, add water, and apply heat, when it will readily dissolve. (2.) Place some powdered marble in water in a test-tube, then heat, and no solution will take place; but when a few drops of hydrochloric acid are added to the tube, the white cloudy appearance due to the particles of marble will disappear, and a clear solution will be obtained. (3.) Take some fine sand and repeat the process of heating with water and acid, and no solution will occur.

### Decantation.

16. When a liquid does not dissolve the whole of the solid, and a sediment settles to the bottom of the vessel, the solution may be separated from the sediment by decantation, which is most simply performed by pouring the liquid carefully into another vessel (fig. 23); or where the slightest agitation of the fluid might raise the sediment, a siphon or piece of bent glass tube may be filled with water, the finger placed on the extremity of the longer limb, and the shorter limb introduced into the liquid, when on

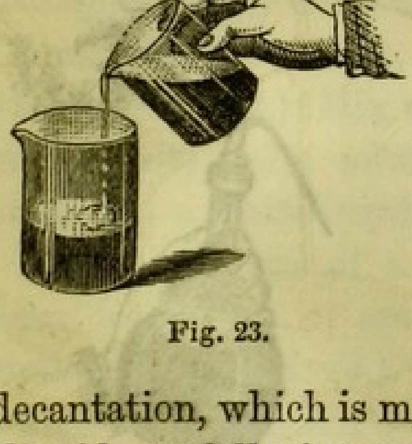

Fig. 23.

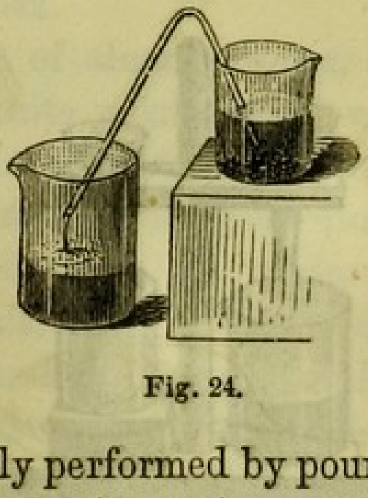

Fig. 24.

the withdrawal of the finger from the outer arm, the liquid will be drawn out of the vessel containing the sediment, and be run into another glass (fig. 24).

*Example.*—Place some sand or pulverised chalk in water, and decant the clear liquid from the sediment by the two methods stated above.

### Filtration.

17. This operation is intended for the more complete separation of a liquid from a solid, and consists in throwing both on a piece of fine white bibulous or blotting paper. The latter should leave only a mere trace of ash when it is burned, and should be free from all visible holes. The paper is folded twice at right angles, and is inserted into a glass funnel set in a filtering-stand, and with a beaker placed below (fig. 25). The liquid or *filtrate* passes through the paper filter into the vessel underneath, and the sedimentary matter is left on the filter. When the solid substance is required perfectly free from the liquid, it is advisable to wash the sediment subsequently by water, which can be directed upon it by a washing bottle (fig. 26).

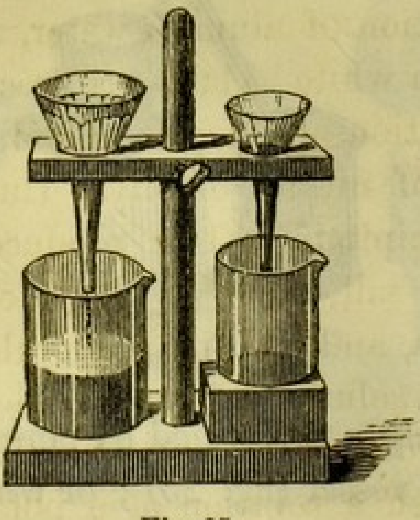

Fig. 25.

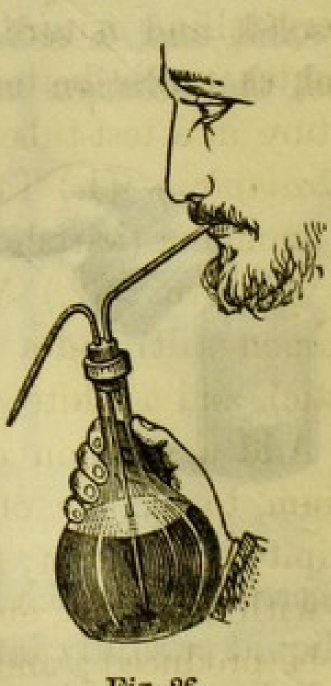

Fig. 26.

*Examples.*—Mix some common salt and sand together in a beaker, add water, and stir with a glass rod. The water will dissolve the common salt, and leave the sand, so that when the mixture is thrown on a filter, the water containing the salt will pass through, and may be recognised by its salt taste, while the sand will be left on the filter.

### Precipitation.

18. When the solutions of certain saline substances are brought together, it often occurs that a finely-divided solid substance is formed, which may remain suspended in the liquid for some time, imparting to it a milky or cloudy appearance, or it may quickly fall to the bottom of the vessel. The production of the solid substance or *precipitate* is due to the materials employed in the experiment being capable of forming a substance which is insoluble in the liquid, and the precipitate may be in appearance, of a gelatinous, curdy, pulverulent, flocculent, or crystalline nature. In many cases the precipitate separates much better on the application of heat to the mixture in a test-tube, basin, or flask.

*Examples.*—(1.) Take a solution of alum in water, and add ammonia (hartshorn), and a white gelatinous precipitate will form; (2.) Mix a solution of chloride of sodium (common salt) and a solution of nitrate of silver (lunar caustic), and a white curdy precipitate will be produced; (3.) Add a solution of a lime salt, such as chloride of calcium, to oxalate of ammonia, and a white pulverulent precipitate will form; (4.) Mix a solution of perchloride of iron with ammonia, and a red-brown flocculent precipitate will be produced; and (5.) When a solution of a potash salt, such as the nitrate of potash (saltpetre), is treated with excess of tartaric acid, and the mixture is well stirred, a white crystalline precipitate is formed, which quickly settles to the bottom of the vessel.

### Evaporation.

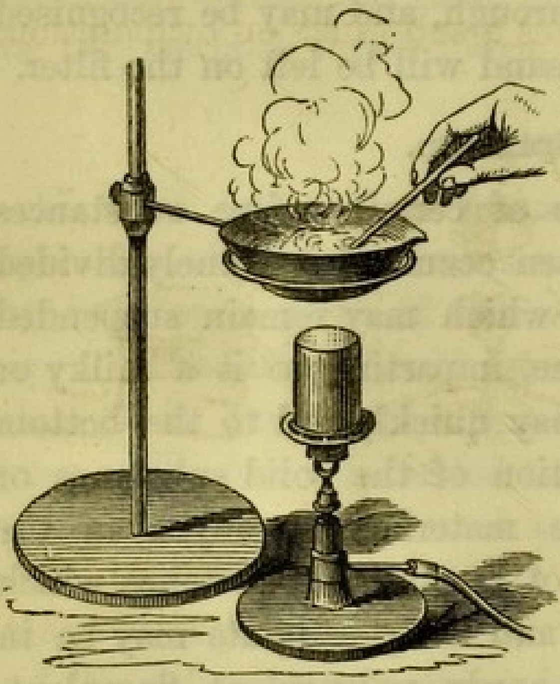

Fig. 27.

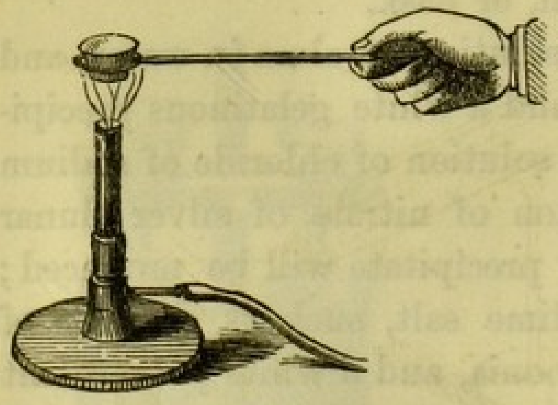

Fig. 28.

19. During the course of testing a solution it is occasionally desirable that the liquid be decreased in bulk, with the object either of obtaining a stronger and more concentrated solution; of procuring some crystals; or of leaving a saline residue. When the liquid is in considerable volume, it may be evaporated in a porcelain basin supported on a retort-stand and heated by a lamp (fig. 27); and when the quantity of fluid is small, it may be placed in a platinum or porcelain capsule, and held by a wire holder over the lamp (fig. 28).

*Examples.*—(1.) Take some sea-water, or a dilute solution of common salt, and evaporate a portion down to one-half of its bulk, when the concentrated liquid will be found to possess a stronger saline taste, and give a more abundant precipitate with nitrate of silver; (2.) Evaporate a solution of alum or chromate of potash to small bulk, and allow the liquid to cool, when crystals will separate; and (3.) Heat a solution of sulphate of magnesia (Epsom salts) till the water is evaporated, and a residue of the salt will be obtained.

### Distillation.

20. This process is carried on when it is desirable to retain the liquid which leaves a substance on evaporation. The apparatus which is employed for the purpose may either consist of a retort and receiver (fig. 29), where the material to be distilled is placed in the bulb of the retort, and when heat is applied, the liquid rises in vapour and passes over into the receiver; or where larger quantities of liquids are to be distilled very carefully, Liebig's condenser (fig. 30) is used, and the substance to be operated upon being placed in the flask or retort, A, and heat being applied, the vapours rise and pass by the tube, BB, to the receiver, D, while a current of cold water is allowed to flow from a tank through an outer tube, CC.

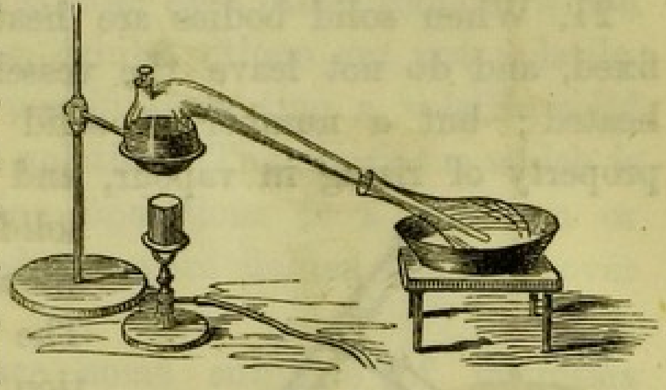

Fig. 29.

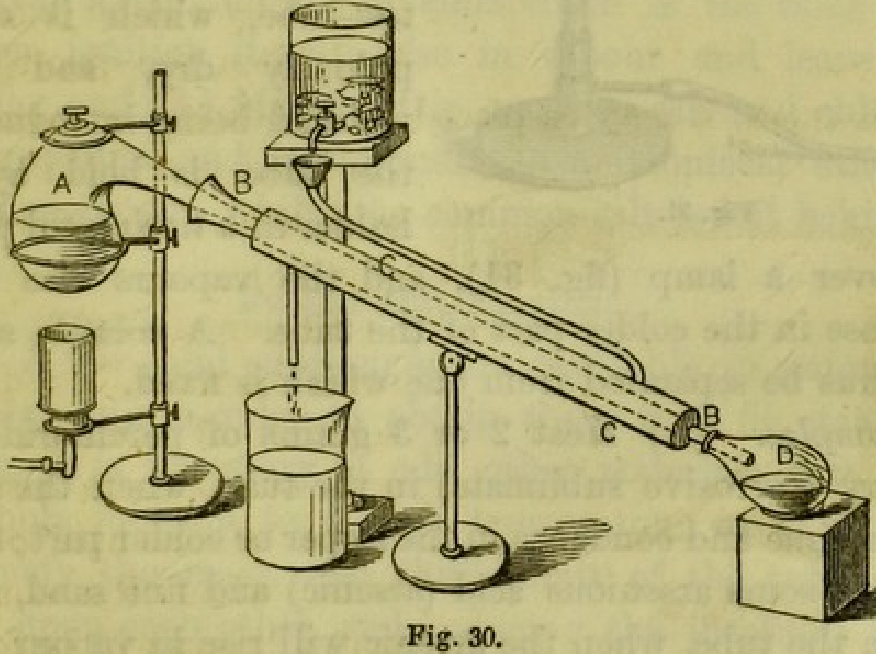

Fig. 30.

*Example.*—Place some beer in the retort or flask, and apply heat, when alcohol will distil over; or use sea-water, and all the water will distil over, whilst the saline matter will be left behind.

### Sublimation.

21. When solid bodies are heated, the majority are fixed, and do not leave the vessel in which they are heated; but a number of solid substances have the property of rising in vapour, and once again becoming solid when the vapour is allowed to cool down. The process is a distillation of solids. The most convenient apparatus for the sublimation of small quantities is an ordinary test-tube, which is scrupulously dry, and the material being introduced, the tube is held by a holder in a horizontal position over a lamp (fig. 31), and the vapours rise and condense in the colder part of the tube. A volatile solid may thus be separated from one which is fixed.

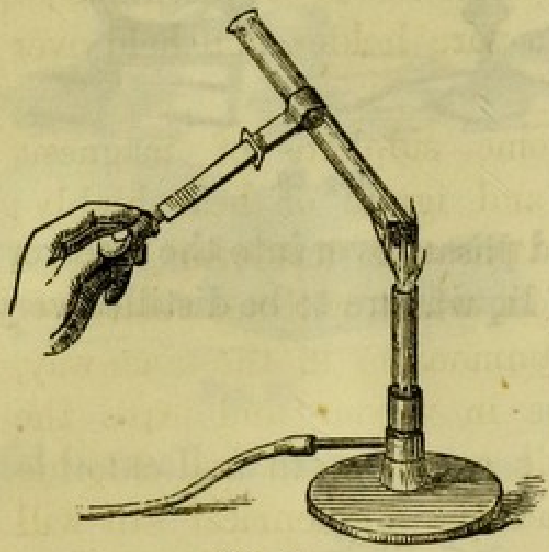

Fig. 31.

*Examples.*—(1.) Heat 2 or 3 grains of perchloride of mercury (corrosive sublimate) in the tube, when the salt will sublime and condense in the upper or colder part; and (2.) Mix some arsenious acid (arsenic) and fine sand, and heat in the tube, when the arsenic will rise in vapour and condense on the sides of the tube, leaving the sand still fixed at the closed end.

### Ignition.

22. This operation is the application of a high temperature to solid substances, for the purpose of observing if they will become volatile, and pass off in vapour. It is the evaporation of solids, and is serviceable for distinguishing many substances from each other, some of which are volatile on ignition, whilst others are not volatile. The process is also of use in separating a volatile solid from one which is not volatile. The apparatus which is employed in the testing operations is a platinum or porcelain capsule, placed on a wire holder, and held over the lamp (see fig. 28).

*Examples.*—(1.) Place some sulphate of magnesia (Epsom salts) in a capsule, and ignite or heat highly; and after the water of crystallisation has evaporated, a white saline residue will be left, which will not volatilise; (2.) Heat some chloride of ammonium in the same way, and on ignition it will rise in vapour and leave the capsule; and (3.) Mix a little common salt and chloride of ammonium, and ignite, and the ammoniacal salt will escape as vapour, whilst the common salt is left behind.

### Fusion and Fluxing.

23. A few solid substances are insoluble in water and in acids; and in order to obtain these in a fit state for testing, it is necessary to add other materials, and raise the whole mixture to a high temperature, so as to fuse or liquefy the mass, and thus admit of the substances acting upon each other, and reducing the insoluble body to a condition in which it is soluble in water and in acids. The apparatus required when small quantities are being worked upon, is a platinum capsule; and the insoluble substance, being previously mixed with a flux, is introduced into the capsule, and the whole is heated over the

lamp for some time after it has been observed to liquefy. The heat may be increased by directing the blow-pipe flame against the capsule, and when very small quantities are being operated upon, the mixture may be held in the loop of a platinum wire, and heated before the blow-pipe (fig. 32).

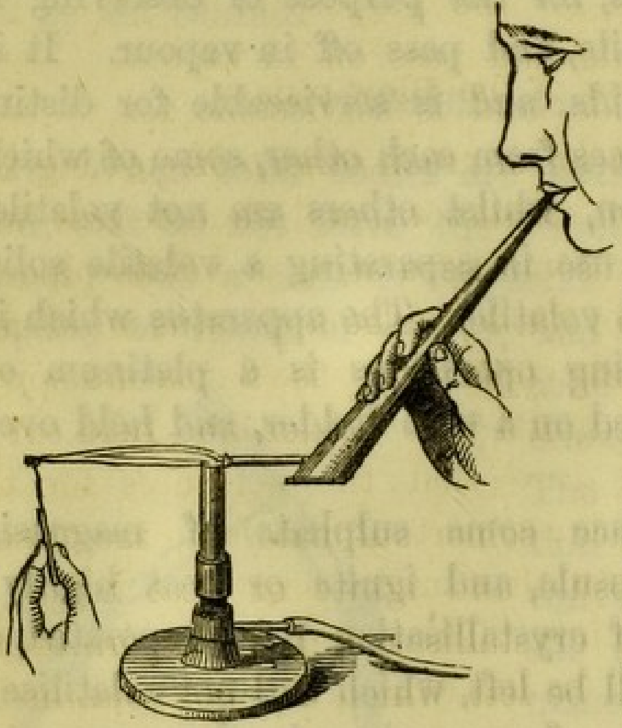

Fig. 32.

*Example.* — Take a little of the powder of sulphate of baryta, and heat with water and hydrochloric acid, and it will be found to be insoluble; after which take another portion of the powder, and mingle it with three times its weight of white flux (a mixture of carbonate of potash and carbonate of soda), and collecting some on the loop of the platinum wire, heat it strongly before the blow-pipe till the mass appears to liquefy; then digest in water, which will dissolve the sulphate of soda, leaving the carbonate of baryta, which is soluble in dilute hydrochloric acid.

### Deflagration.

24. When certain bodies are heated with a nitrate, such as nitrate of potash, or a chlorate, such as chlorate of potash, they give rise to slight detonations, and the process is called deflagration. It is resorted to for the oxidation of a few substances, and is also employed in indicating the presence of either a nitrate or a chlorate.

*Example.*—Heat a crystal of nitrate of potash (saltpetre) on a piece of charcoal before the blow-pipe, and the charcoal will deflagrate brilliantly.

### The Use of the Blow-pipe.

25. This instrument is of great service in testing the nature and qualities of substances, and the student will do well to practise for some time with the blow-pipe so as to be able to keep up a continuous stream of air. The blow-pipe may be directed against the flame of a spirit-lamp, or, still better, a gas-jet, such as the tube of a Bunsen lamp; taking care that the apertures for the admission of air at the lower part of the lamp are closed, and that the gas burns with a smoky flame to a height of from two to three inches. The extremity of the nozzle of the blow-pipe is laid on the edge of the gas-tube, and a gentle stream of air is directed through the blow-pipe. The result is, that the gas flame is diverted in a horizontal position (fig. 33), becomes non-luminous, and presents merely a blue-tinted flame, in which two distinct regions of combustion or divisions may be noticed. From the beginning of the flame to about two-thirds of its length, an *inner* flame will be observed; whilst from this point to the extremity of the burning gas, an *outer* flame will be recognised.

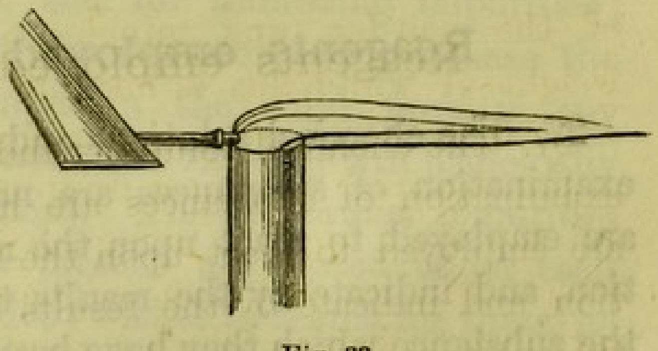

Fig. 33.

26. These two flames are of great service to the chemist, and they possess different and even opposite qualities. When substances, such as metallic oxides, are held by a platinum wire, or on a charcoal support, in

the *inner* flame, they are reduced to the metallic state, and hence it is often called the *reducing* flame; whilst when metals such as lead are held at the tip of the *outer* flame, they are oxidised, and hence it is generally called the *oxidising* flame. When a Bunsen lamp is burning with the admittance of air, and with a blue non-luminous flame, the inner and outer flames may be observed without the use of the blow-pipe; and substances held in the inner flame of the Bunsen lamp are reduced, whilst those placed in the outer part are oxidised.

*Example.*—Place some acetate of lead on a charcoal support, and heat in the inner flame of the blow-pipe, and beads of metallic lead will be obtained; whilst heat a portion of metallic lead in the outer flame, and it will become converted into oxide, and coat the charcoal with yellow oxide of lead.

## Reagents employed in Testing.

27. The chemical solutions and solids employed in the examination of substances are named reagents, as they are employed to react upon the material under examination, and indicate by the results they give the nature of the substance which they have been added to, or employed with.

28. The most essential material in chemical processes is pure water, which can be obtained by distillation (par. 20) from ordinary water, and which should be practically free from saline matter, and leave no residue upon evaporation. It should be colourless, odourless, and tasteless, and should not be altered by sulphide of ammonium, which would darken if lead, copper, or iron were present; by oxalate of ammonia, which would give a cloudiness if

lime was present; by nitrate of baryta, which would indicate sulphuric acid (sulphates) by giving a milky appearance; or by nitrate of silver, which would impart a milkiness if any chlorides, such as chloride of sodium, were dissolved in the water. The pure or distilled water is largely employed by the chemist to dissolve the substances which he is about to test, and it is also used occasionally during the course of testing.

29. The chemical substances which are used as reagents are numerous, but some are more often employed than others, and consequently should be placed immediately before the operator, whilst those reagents which are less often required may be put in some other convenient place. About thirty solutions and solids may be regarded as more generally important, whilst there are fifty other solutions and solids which are required more rarely. The following list gives the names of these reagents, with any special directions which may be required to prepare the substances or solutions, and for indicating impurities; it being understood that the operator can purchase the majority of the substances in the solid form in any pharmaceutical establishment, and his duty will principally consist in making solutions. The important impurities which are liable to be present are stated under each substance, and if the student wishes to search for these, he has merely to refer to the paragraphs further on, which give the tests for these impurities.

### The Reagents more commonly Used.

30. (1.) Alcohol, $C_4H_5O,HO$.

The spirits of wine of commerce will be found serviceable in all testing, and the methylated spirit (9 parts of grain alcohol, and 1 part of methyl alcohol) is suitable for all flame tests. Alcohol should leave no residue on evaporation.

31. (2.) Sulphuric Acid, concentrated, $+HO,SO_3$.

Use ordinary English oil of vitriol, which should be colourless, and evaporate on heating without leaving any residue.

*Impurities.*—Nitric acid, arsenic, and lead.

32. (3.) Sulphuric Acid, dilute, $-HO,SO_3$.

Add 1 part of ordinary oil of vitriol cautiously to 5 parts of water contained in a thin beaker, and agitate by stirring during the addition. Much heat is developed, and on cooling, the clear liquid may be decanted off from any sediment of sulphate of lead which may have separated.

33. (4.) Hydrochloric Acid, dilute, $-HCl$.

Add 1 part of concentrated hydrochloric acid (par. 57) to 5 parts of water, and stir.

34. (5.) Nitric Acid, dilute, $-HO,NO_5$.

Mingle 1 part of concentrated nitric acid (par. 58) with 5 parts of water, and stir.

35. (6.) Tartaric Acid, solution, $2HO,C_8H_4O_{10}=2HO,\overline{T}$.

Dissolve 1 part by weight of the solid tartaric acid in 3 parts by measure of water.

36. (7.) Acetic Acid, dilute, $HO,C_4H_3O_3 = HO,\overline{A}$.

Add 1 part of strong acetic acid to 5 parts of water. The acid should leave no residue when evaporated.

*Impurities.*—Sulphuric acid, hydrochloric acid, lead, copper, and iron.

37. (8.) Hydrosulphuric Acid (Sulphuretted Hydrogen), solution, $HS$.

In the preparation of a solution of this reagent, a gas-generating bottle is taken (see fig. 21), and sulphuret of iron, $FeS$, being placed in the bottle, and the tubes refixed, water, $HO$, and a little sulphuric acid, $HO,SO_3$, are added by the funnel-tube. The acid and water reacting upon the sulphuret of iron form sulphate of iron,

$FeO,SO_3$, and hydrosulphuric acid gas, HS, is evolved. The gas passes by the delivery-tube to a washing bottle containing water, and thereafter into the water contained in the ordinary solution bottle. The current of gas is passed through the water till the liquid smells strongly of the gas. The sulphuret of iron, FeS, used in this experiment is prepared by projecting by degrees a mixture of 30 parts of iron filings and 21 parts of sublimed sulphur into a red-hot crucible, and when the whole has passed into a state of fusion, it is allowed to cool, and may then be broken into fragments.

38. (9.) Potash, solution, $KO,HO$.

Dissolve 1 part by weight of the sticks of caustic potash in 20 parts by measure of water.

*Impurities.*—Sulphuric acid (sulphates), hydrochloric acid (chlorides), carbonic acid (carbonates), silica, and alumina.

39. (10.) Carbonate of Potash, solution, $KO,CO_2$.

Make a solution of 1 part by weight of this salt in 4 parts by measure of water.

*Impurities.*—Sulphuric acid (sulphates), hydrochloric acid (chlorides), silica, and alumina.

40. (11.) Ferrocyanide of Potassium, solution, $2K,Cfy$.

Dissolve 1 part by weight of the salt in 12 parts by measure of water.

41. (12.) Phosphate of Soda, solution, $2NaO,HO,PO_5$.

Add 1 part of the salt by weight to 10 parts of water by measure.

*Impurities.*—Sulphuric acid (sulphates), and carbonic acid (carbonates).

42. (13.) Hyposulphite of Soda, solution, $NaO,S_2O_2$.

Make a solution of 1 part by weight of the salt in 4 parts by measure of water.

43. (14.) Ammonia, dilute, —$NH_4O$.

Mix 1 part of strong ammonia (par. 59) with 5 parts of water. The solution should be colourless, and leave no residue on evaporation.

*Impurities.*—Carbonic acid, sulphuric acid, and hydrochloric acid.

44. (15.) Chloride of Ammonium, solution, $NH_4Cl$.

Dissolve 1 part by weight of this salt (commonly called sal-ammoniac) in 8 parts by measure of water. The salt should leave no residue on ignition in a spoon, and the solution should not darken with sulphide of ammonium (which would indicate the presence of iron).

45. (16.) Oxalate of Ammonia, solution, $NH_4O,\bar{O}$.

Take 2 parts by measure of water, and add 1 part by weight of oxalic acid. Heat gently till complete solution is obtained; then add a strong solution of ammonia till the liquid is neutral to test-papers (par. 54). When the mixture cools, crystals of oxalate of ammonia will separate, which may be purified by recrystallisation, and subsequently be dissolved in water in the proportion of 1 part of the salt by weight in 24 parts of water by measure. The oxalate of ammonia should volatilise completely when heated.

46. (17.) Sulphide of Ammonium, solution, $NH_4S,HS$.

This solution is prepared by passing a stream of hydrosulphuric acid, $HS$ (par. 37), into a solution of ammonia, $NH_4O$, so long as absorption of the gas takes place, and until the liquid loses the power of causing a precipitate, when a few drops are added to a solution of sulphate of magnesia. If the liquid ammonia which is used in the preparation of the sulphide of ammonium is the ordinary concentrated ammonia, then the prepared solution may be diluted with 10 times its volume of water. The solution of sulphide of ammonium should evolve strongly the fœtid odour of hydrosulphuric acid mingled with ammonia.

47. (18.) Nitrate of Baryta, solution, $BaO,NO_5$.

Dissolve 1 part by weight of the salt in 15 parts by volume of water.

*Impurity.*—A salt of lead, which is very commonly present, and can be got rid of by passing a stream of hydrosulphuric acid through the solution, which precipitates the lead, and thereafter, by filtering the liquid from the sulphide of lead, the solution may be boiled to disengage the excess of hydrosulphuric acid, refiltered, and allowed to cool. The liquid so obtained should not darken on addition of hydrosulphuric acid or of sulphide of ammonium.

48. (19.) Lime Water, solution, $CaO,Aq$.

Take some newly-slaked lime, add water, and agitate repeatedly; then filter through paper, when a clear solution of caustic lime will be obtained.

49. (20.) Chloride of Calcium, solution, $CaCl$.

Dissolve 1 part by weight of this salt in 5 parts by measure of water.

50. (21.) Sulphate of Lime, solution, $CaO,SO_3$.

Agitate some sulphate of lime with water, and filter, when a clear solution will be procured.

51. (22.) Nitrate of Silver, solution, $AgO,NO_5$.

Dissolve 1 part by weight of the sticks or crystals of lunar caustic in 20 parts by volume of water.

52. (23.) Sulphoindigotic Acid, $C_{16}N_4NO,HO,2SO_3$.

Some finely-powdered indigo is heated with a small proportion of concentrated sulphuric acid till a deep blue liquid is obtained, when it is allowed to cool, and is then projected into a large amount of cold water. The blue colour of the solution should be decided, but not too deep.

53. (24.) Lime, solid in powder, $CaO,HO$.

Take a piece of good lime-shell, add water sufficient to slake it, and when it crumbles into powder, place it in the bottle.

54. (25.) Test-Papers, Litmus and Turmeric.

These papers are of three kinds and tints.

*Blue Litmus.*—Take some chips of litmus, heat with water, dip into the liquid strips of white blotting-paper, and subsequently dry.

*Red Litmus.*—Add to litmus solution a few drops of dilute sulphuric acid till the blue colour changes to red, and then dip in the strips of paper, and dry.

*Yellow Turmeric.*—Infuse pieces of turmeric root with alcohol, which will give a yellow tincture, and then dip in the paper, and dry.

*Uses.*—(1.) When a strip of blue litmus-paper on being placed in a liquid has its blue colour changed to red, it indicates the presence of a free acid; (2.) When the red litmus is changed to blue, or when the yellow turmeric is altered to brown-red, it shews the presence of an alkali; and (3.) When neither the red litmus, blue litmus, nor turmeric papers are altered in tint when they are introduced into a liquid, then they indicate that the solution is neutral (neither acid nor alkaline).

55. (26.) Bichloride of Platinum, solution, $PtCl_2$.

Heat gently some scraps of the metal platinum in a mixture of 2 parts of concentrated hydrochloric acid and 1 part of concentrated nitric acid, evaporate to dryness, moisten with hydrochloric acid, and dissolve the residue in water. The solution of bichloride of platinum is of a yellow colour, and ought to give a yellow precipitate when a small quantity is added to a solution of nitrate of potash and the mixture stirred well. When used in testing, it ought to contain free hydrochloric acid.

56. (27.) Protonitrate of Cobalt, solution, $CoO,NO_5$.

Add equal portions of nitric acid and water to finely-divided oxide of cobalt, heat for some time, evaporate to dryness, and redissolve in water. The solution should be strong enough to be of a decided red colour.

57. (28.) Hydrochloric Acid, concentrated, $+ HCl$.

Pure hydrochloric acid of commerce, which, on evaporation, should leave no residue.

*Impurities.*—Organic matter and iron which impart a yellow colour, sulphuric acid, and nitric acid.

58. (29.) Nitric Acid, concentrated, $+ HO,NO_5$.

Pure commercial nitric acid, which should entirely volatilise on evaporation.

*Impurities.*—Sulphuric acid and hydrochloric acid.

59. (30.) Ammonia, concentrated solution, $+ NH_4O$.

The ordinary strong ammonia of commerce, which leaves no residue on evaporation.

*Impurities.*—Carbonic acid, sulphuric acid, and hydrochloric acid.

## The Reagents less commonly Used.

### FIRST SERIES.

60. (1.) Iodide of Potassium, solution, KI.

Dissolve 1 part by weight of the salt in 20 parts by measure of water.

61. (2.) Cyanide of Potassium, solution, KCy.

Add 1 part of this salt by weight to 20 parts of cold water by measure. The salt is white, and is completely soluble in water.

*Impurities.*—Carbonic acid (carbonate of potash) and oxalic acid (oxalate of potash).

62. (3.) Ferridcyanide of Potassium, solution, $3K,2Cfy$.

Make a solution of 1 part by weight of the salt in 12 parts of water by measure.

63. (4.) Sulphocyanide of Potassium, solution, $K,CyS_2$.

Dissolve 1 part of this salt in 12 parts of water.

64. (5.) Nitrate of Potash, solution, $KO,NO_5$.

Add 1 part of nitrate of potash to 5 parts of water.

*Impurities.*—Hydrochloric acid (chloride of potassium) and sulphuric acid (sulphate of potash).

65. (6.) Bichromate of Potash, solution, $KO,2CrO_3$.

Dissolve 1 part of the salt in 8 parts of water.

*Impurity.*—Sulphuric acid (sulphate of potash).

66. (7.) Bicarbonate of Soda, solution, $NaO,HO,2CO_2$.

Take 1 part of this salt and add 10 parts of water.

*Impurities.*—Sulphuric acid (sulphate of soda), and hydrochloric acid (chloride of sodium).

67. (8.) Molybdate of Ammonia, solution, $NH_4O,MoO_3$.

Dissolve 1 part of the salt in 20 parts of water acidulated with nitric acid.

68. (9.) Sulphate of Iron, solution, $FeO,SO_3$.

Dissolve the pure green crystals in 10 parts of cold water.

69. (10.) Perchloride of Iron, solution, $Fe_2Cl_3$.

Heat a small quantity of red oxide of iron in a mixture of equal parts of hydrochloric acid and water, evaporate to near dryness, add water, and filter; the colour of the solution should be decidedly yellow.

70. (11.) Ammonio-Nitrate of Silver, solution, $AgO,NO_5 + NH_3$.

Dissolve 1 part of nitrate of silver in 10 parts of water, and add dilute ammonia, drop by drop, till the light-brown precipitate which is given at first is almost entirely redissolved by the ammonia, then let the remaining sediment settle, and decant off the clear colourless liquid for use.

71. (12.) Acetate of Lead, solution, $PbO,\bar{A}$.

Add 1 part of the salt to 10 parts of water, and drop in dilute acetic acid till the liquid becomes clear.

72. (13.) Chloride of Mercury, solution, $HgCl$.

Dissolve 1 part of this salt (corrosive sublimate) in 20 parts of water.

73. (14.) Ammonio-Sulphate of Copper, solution, $CuO,SO_3 + NH_3$.

Make a solution of 1 part of sulphate of copper in 10 parts of water, and add dilute ammonia until the blue-green precipitate which is first thrown down is nearly dissolved, then allow the remaining precipitate to settle, and decant off the clear blue solution for use.

74. (15.) Protochloride of Tin, solution, $SnCl$.

Heat metallic tin with concentrated hydrochloric acid till the gas (hydrogen) ceases to be evolved, then dilute with 4 times the volume of water, filter, and keep the solution in a stoppered bottle containing a few fragments of metallic tin.

75. (16.) Starch, solution, $C_{12}H_{10}O_{10}$.

Add hot water to starch till a semi-transparent solution is obtained.

76. (17.) Terchloride of Gold, solution, $AuCl_3$.

Take gold leaf and heat in a flask with aqua regia (a mixture of 2 parts of concentrated hydrochloric acid and 1 part of concentrated nitric acid), evaporate nearly to dryness, add water, and filter if necessary. The solution is bright yellow in colour.

77. (18.) Ether (Sulphuric Ether), $C_4H_5O$.

78. (19.) Bicarbonate of Soda, solid, $NaO,HO,2CO_2$.

79. (20.) Zinc, granulated, $Zn$.

80. (21.) Iron, in strips and wire, $Fe$.

81. (22.) Copper, in foil and wire, Cu.

82. (23.) Sulphur, sublimed, S.

83. (24.) Oxalic Acid, solid, $HO,C_2O_3 = HO,\bar{O}$.

84. (25.) Bleaching Powder, solid, $CaCl + CaO,ClO$.

### The Reagents less commonly Used.

#### SECOND SERIES.

85. (26.) Sulphate of Potash, solution, $KO,SO_3$.
Dissolve 1 part of the salt in 12 parts of water.

86. (27.) Acetate of Potash, solution, $KO,\bar{A}$.
Make a solution of 1 part of the salt in 10 parts of water.

87. (28.) Antimoniate of Potash, solution, $KO,SbO_5$.
Take a mixture of 4 parts of nitrate of potash and 1 part of antimony, and deflagrate in a crucible. Boil the fused residue in 12 parts of water for several hours, and filter, when a clear solution of antimoniate of potash will be obtained.

88. (29.) Soda, Caustic, in solution, $NaO,HO$.
Place 3 parts of the crystals of carbonate of soda in 15 parts of water, boil, and add 1 part of quicklime, which has been previously treated with 3 parts of hot water; reboil, and let cool and settle. The clear solution of caustic soda can be afterwards decanted off from the lime precipitate. The solution of soda should not effervesce on the addition of hydrochloric acid.

89. (30.) Sulphide of Sodium, solution, $NaS$.
This liquid is prepared in a similar manner to the sulphide of ammonium (par. 46), substituting a solution of caustic soda for the ammonia.

90. (31.) Sulphite of Soda, solution, $NaO,SO_2$.
Dissolve 1 part of the salt in 5 parts of water.

91. (32.) Bitartrate of Soda, solution, $NaO,HO,\overline{T}$.

Take two portions of tartaric acid, dissolve one part in water, neutralise with carbonate of soda, and add the second part of the tartaric acid, thereafter evaporate and crystallise. The crystals dissolve in 10 parts of water.

92. (33.) Yellow Sulphide of Ammonium, solution, $NH_4S + S$.

Heat the ordinary solution of sulphide of ammonium (par. 46) with a little sublimed sulphur, and filter, when a yellow solution will be obtained.

93. (34.) Carbonate of Ammonia, solution, $3NH_4O,2CO_2$.

Dissolve 1 part of this salt in 4 parts of water.

94. (35.) Baryta, Caustic, in solution, BaO,Aq.

Heat 1 part of caustic baryta with 20 parts of water, filter, and bottle immediately the clear solution.

95. (36.) Chloride of Barium, solution, BaCl.

Dissolve 1 part of the salt in 10 parts of water.

*Impurity.*—Salt of lead, which may be separated in the same manner as from the nitrate of baryta (par. 47).

96. (37.) Sulphate of Magnesia, solution, $MgO,SO_3$.

Make a solution of 1 part of the salt in 10 parts of water.

97. (38.) Subnitrate of Mercury, solution, $Hg_2O,NO_5$.

Treat a few globules of metallic mercury with concentrated nitric acid in a vessel kept as cold as possible, and when the mercury has formed a white crystalline salt of the subnitrate of mercury, add water to dissolve the salt, and place in a bottle containing some metallic mercury.

98. (39.) Sulphate of Copper, solution, $CuO,SO_3$.

Dissolve 1 part of the crystals in 10 parts of water.

99. (40.) Hydrofluosilicic Acid, solution, $HF,SiF_2$.

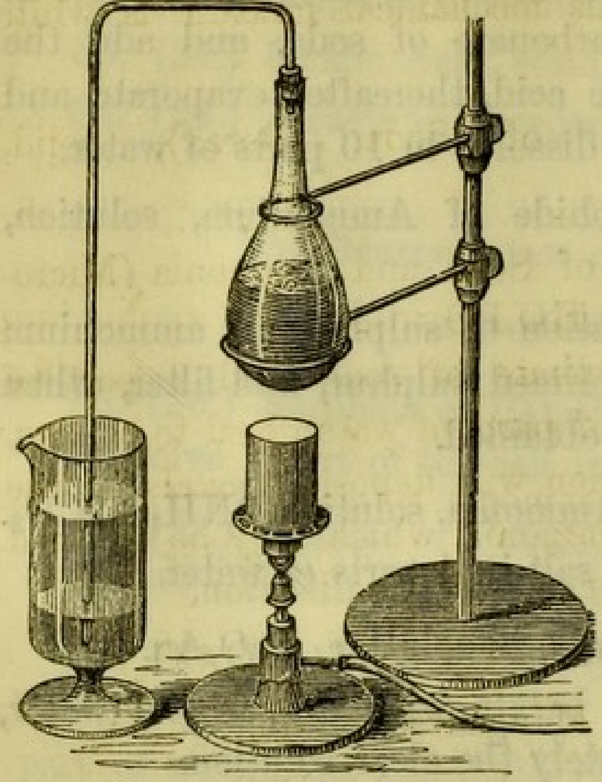

Fig. 34.

Take a mixture of equal parts of powdered fluor spar and glass, and introduce into a flask with bent tube dipping into a receiving jar (fig. 34). Some mercury is placed in the receiving vessel so as to cover the end of the glass tube, and water is then added. The gas evolved from the flask is decomposed when it enters the water. Gelatinous silica is separated, and on filtration through paper, a clear solution of hydrofluosilicic acid is obtained.

100. (41.) Chlorine, solution, $Cl,Aq$.

Heat a mixture of concentrated hydrochloric acid and black oxide of manganese in a retort, and receive the vapours of chlorine gas in the receiver containing water. The solution has a greenish-yellow colour and a suffocating odour.

101. (42.) Charcoal in powder, $C$.

102. (43.) Potash, caustic, in sticks, $KO,HO$.

103. (44.) Cyanide of Potassium, solid in powder, $KCy$.

*Impurities.*—Carbonate of potash and oxalate of potash.

104. (45.) White Flux, powder, $KO,CO_2 + NaO,CO_2$.

Dry some bicarbonate of potash and bicarbonate of soda, mix the dry substances in the proportion of 13 parts of the former with 10 parts of the latter, and pulverise very fine. This mechanical mixture is white flux.

105. (46.) Biborate of Soda (Borax), solid, $NaO,HO,2BO_3$.

106. (47.) Phosphate of Soda and Ammonia (Microcosmic Salt), $NaO,NH_4O,HO,PO_5$.

Add 6 parts of phosphate of soda and 1 part of chloride of ammonium to 2 parts of water, heat to boiling, and on cooling, the solution will deposit crystals of the phosphate of soda and ammonia, which may be purified by re-solution in hot water and recrystallisation.

107. (48.) Carbonate of Baryta, solid, $BaO,CO_2$.

108. (49.) Binoxide of Manganese, powder, $MnO_2$.

109. (50.) Binoxide of Lead, powder, $PbO_2$.

Digest the red oxide of lead in concentrated nitric acid for some time, then add much water, filter, and wash well. The brown powder on the filter is the binoxide of lead, and when dried it is fit for use.

## Testing of Known Substances by Reagents.

110. The majority of compounds which are employed in commerce and in medicine partake of the nature of a salt, and consist of a base and an acid. For example, nitrate of potash, $KO,NO_5$, contains the base or metallic oxide potash, KO, and the acid, nitric acid, $NO_5$. In the same list there are included for the purposes of testing, compounds such as chloride of sodium (common salt), NaCl, which contains merely the metal sodium, Na, in combination with chlorine, Cl, because in solution

with water, the elements of the chloride of sodium, $NaCl$, and water, $HO$, become associated, and the substance gives the tests and indications of soda, $NaO$, and hydrochloric acid, $HCl$. A similar remark applies to all the compounds of chlorine with the metals, as also the compounds of iodine, $I$, bromine, $Br$, fluorine, $F$, and cyanogen, $Cy$. Comparatively a small number of the substances commonly met with, consist of a base or metallic oxide alone, such as potash, $KO$, and lime, $CaO$, or of an acid alone, such as sulphuric acid, $SO_3$, and nitric acid, $NO_5$.

111. For the more ready and thorough understanding of the tests of the various substances, it will be necessary first to learn the characters of each metallic oxide, and of each acid separately; and for this purpose, solutions and solids *known* to contain these particular bodies are experimented upon. Each group of substances will be introduced by a table, in which all the principal tests will be exhibited at a glance, so that the differences in the mode of action of the reagents upon the various members of the group, and which constitute the special characters, may be readily observed. Thereafter a more full statement will be made of the tests, and an explanation given of their mode of action. Having personally performed the tests characteristic of each group of substances, the student ought to have placed in his hands a series of solutions and solids which will contain the bodies he has already passed over, but the names of such are not to be communicated to him, and he should be requested to test the *unknown* substances, and report as to their nature.

112. In the testing of *known* as well as of *unknown* substances, the experimenter must apply the reagents in the order in which they occur in their respective places, as in many cases the test is only applicable for the

detection of a particular body, when previous trials have shewn that other substances are not present. In all cases the tests which are given under each metallic oxide and acid are only those which may be regarded as characteristic, and other tests of less value in the detection of each kind of material have not been referred to. In making the trials, care should be taken that the reagent is thoroughly mingled with the substance under examination, and wherever a precipitate is not indicated at once on the addition of the reagent, the whole mixture should be thoroughly incorporated by lengthened stirring.

## Testing of the Metallic Oxides.

113. There are fifty-one known metals, and each forms at least one oxide, but the number of commonly occurring metallic oxides, either single or combined, does not exceed twenty-eight. These may be divided into four distinct groups, which are characterised by the reactions given on the addition of certain testing solutions.

These groups of metallic oxides are given in the following table :

## 114. Table of the Group Tests for the Metallic Oxides.

| FIRST GROUP. | SECOND GROUP. | THIRD GROUP. | FOURTH GROUP. |
|---|---|---|---|
| Hydrochloric Acid, $HCl$, and Hydrosulphuric Acid, $HS$,………… *No precipitate.* | $HCl$ and $HS$,……… *No precipitate.* | $HCl$ and $HS$,……… *No precipitate.* | $HCl$ and $HS$,………………*A precipitate.* |
| Ammonia, $NH_4O$, and Sulphide of Ammonium, $NH_4S,HS$,……… *No precipitate.* | $NH_4O$ and $NH_4S,HS$, *No precipitate.* | $NH_4O$ and $NH_4S,HS$, *A precipitate.* | |
| Phosphate of Soda, $2NaO,HO,PO_5$, and Ammonia, $NH_4O$,………… *No precipitate.* | $2NaO,HO,PO_5$ and $NH_4O$,….. *A pre.* | | |
| MEMBERS OF THE GROUP.<br>Potash,……..$KO$.<br>Soda,………..$NaO$.<br>Ammonia,…..$NH_4O$. | MEMBERS OF THE GROUP.<br>Baryta,……….$BaO$.<br>Strontia,……..$SrO$.<br>Lime,…………$CaO$.<br>Magnesia,…….$MgO$. | MEMBERS OF THE GROUP.<br>Alumina,…….$Al_2O_3$.<br>Chromia,…….$Cr_2O_3$.<br>Zinc,…………$ZnO$.<br>Manganese,…$MnO$.<br>Nickel,………$NiO$.<br>Cobalt,………$CoO$.<br>Iron, protoxide,…….$FeO$.<br>Iron,peroxide,$Fe_2O_3$. | MEMBERS OF THE GROUP.<br>Silver,……….$AgO$.<br>Lead,…………$PbO$.<br>Mercury, suboxide,………$Hg_2O$.<br>Mercury, peroxide,……..$HgO$.<br>Copper,………$CuO$.<br>Bismuth,…….$BiO_3$.<br>Cadmium,……$CdO$.<br>Gold,….. …….$AuO_3$.<br>Platinum,……$PtO_2$.<br>Tin, protoxide, $SnO$.<br>Tin, peroxide, $SnO_2$.<br>Antimony,…..$SbO_3$.<br>Arsenious Acid,………$AsO_3$.<br>Arsenic Acid, $AsO_5$. |

The experimenter should satisfy himself as to the distinction between the above groups of metals, by selecting at least one example of each group and applying the reagents thereto. Thus, he may take a solution of nitrate of potash, $KO,NO_5$, for the first group; sulphate of lime, $CaO,SO_3$, for the second group; sulphate of iron, $FeO,SO_3$, for the third group; and sulphate of copper, $CuO,SO_3$, for the fourth group. Having observed the above classification, the student is then in a position to enter on the study of the various groups, and the substances contained in each, and to notice the special characters by means of which the individual metallic oxides may be recognised from each other.

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## Metallic Oxides.—First Group.

115. *Preliminary Remarks.*—This may be called the group of the Alkalies, and the substances are characterised by giving no precipitates with the group tests; and the negative reaction indicates the absence of a member of any other group of metallic oxides, whilst the residue which is obtained on the evaporation of any of the solutions of potash, soda, or ammonia, demonstrates that one or other of these substances are likely to be present. A residue may be obtained, however, on evaporation, when no metallic oxide is present, as may be observed in solutions of free phosphoric, boracic, and silicic acids.

### 116. Table of the First Group of Metallic Oxides.

| | | |
|---|---|---|
| Characters of the Group. | HCl and HS, | *No precipitate.* |
| | $NH_4O$ and $NH_4S,HS$, | *No precipitate.* |
| | $2NaO,HO,PO_5$ and $NH_4O$, | *No precipitate.* |

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**Special Characters.**

| Metallic Oxides. | Bichloride of Platinum, $PtCl_2$. | Tartaric Acid, $HO,HO,\bar{T}$. | |
|---|---|---|---|
| Potash, KO, | *Yellow pre...* | *White pre.....* | Heat, *not volatile.*<br>Alcohol and blowpipe flames, *violet.* |
| Soda, NaO,.. | *No pre.........* | *No pre.........* | Heat, *not volatile.*<br>Alcohol and blowpipe flames, *yellow.* |
| Ammonia, $NH_4O$,.. | *Yellow pre...* | *White pre....* | Heat, *volatile.*<br>Lime, CaO, or potash, KO, added to compounds of ammonia, evolves *gaseous ammonia*, $NH_3$, which is recognised by (1.) its odour, (2.) its alkaline action on test-papers, and (3.) the formation of dense white flames on the approach of a rod dipped in concentrated hydrochloric acid, +HCl. |

### 117. Potash, KO.

Nitrate of Potash, $KO,NO_5$, may be employed in testing.

1. *Bichloride of Platinum*, $PtCl_2$, produces in neutral and acid solutions a *yellow crystalline precipitate* of the double chloride of platinum and potassium, $KCl + PtCl_2$,

which is insoluble in alcohol. The formation of the precipitate is promoted by stirring.

2. *Tartaric Acid*, $HO,HO,\bar{T}$, gives in neutral or alkaline solutions a *white crystalline* precipitate of the bitartrate of potash (cream of tartar), $KO,HO,\bar{T}$, which is soluble in free acids and alkalies, and in hot water. Bitartrate of soda, $NaO,HO,\bar{T}$, may be advantageously employed instead of tartaric acid.

3. *Heat* a small quantity of the solid potash compound in a capsule or spoon, or evaporate a portion of the potash solution, and heat the residue, when it will be *fixed* or *not volatile.*

4. *Alcohol* added to the potash solution, in a small basin or capsule, slightly heated, and then set fire to, burns with a *violet flame*, which is due to the disengagement and combustion of metallic potassium, K. The violet tint is better observed on looking through a piece of cobalt blue glass.

5. *Blow-pipe test.* When potash and its compounds are supported on a platinum wire, and held in the inner flame of the blow-pipe, they communicate a *violet colour* to the outer flame. The tint is best seen on looking through the cobalt blue glass. Potash compounds held in the flame of the Bunsen lamp also exhibit the violet flame.

### 118. Soda, NaO.

**Sulphate of Soda, $NaO,SO_3$, may be employed in testing.**

1. *Bichloride of Platinum*, $PtCl_2$, gives *no precipitate* with soda or its salts, as the double chloride of platinum and sodium, $NaCl + PtCl_2$, is soluble in water and in alcohol.

2. *Tartaric Acid*, $HO,HO,\bar{T}$, produces *no precipitate* in ordinary solutions, and the bitartrate of soda,

$NaO,HO,\overline{T}$, equally fails to give a precipitate, owing to the solubility of the salt. With saturated solutions of carbonate of soda and tartaric acid a white precipitate may be obtained.

3. *Heat* the solid salt, or the residue obtained from the solution on evaporation, and it is *fixed* or *not volatile.*

4. *Alcohol* mingled with the soda solution, and the mixture heated and set fire to, burns with a *strong yellow flame*, which is due to the combustion of the metal sodium, $Na$, and is best seen on looking through a piece of green glass.

5. *Blow-pipe test.* Soda and its compounds held on a platinum wire in the inner flame of the blow-pipe, tinge the outer flame of a *decided yellow colour.* The Bunsen lamp will also exhibit this flame when soda is held in it.

6. *Antimoniate of Potash*, $KO,SbO_5$, yields with neutral or alkaline solutions a *white crystalline precipitate* of the antimoniate of soda, $NaO,SbO_5$. Active stirring promotes the formation of the precipitate.

### 119. Ammonia, $NH_4O$.

Chloride of Ammonium, $NH_4Cl$, may be used in testing.

1. *Bichloride of Platinum*, $PtCl_2$, produces in neutral and acid solutions a *yellow crystalline precipitate* of the double chloride of platinum and ammonium, $NH_4Cl + PtCl_2$, which is insoluble in alcohol.

2. *Tartaric Acid*, $HO,HO,\overline{T}$, gives with difficulty a *white crystalline precipitate* of the bitartrate of ammonia, $NH_4O,HO,\overline{T}$, which is soluble in acids and alkalies, and in hot water. When the tartaric acid is added to acid reaction, to caustic ammonia, or a solution of carbonate of ammonia, the white precipitate is readily obtained.

3. *Heat* the solid ammoniacal compound, or the residue left on evaporation, and it will *entirely volatilise.*

4. *Lime*, CaO, or *Potash*, KO, when added to solutions of salts of ammonia, such as the chloride of ammonium, which have no odour of hartshorn, liberate the gaseous ammonia, $NH_3$, which can be recognised as escaping from the mixture by (1.) The odour of hartshorn; (2.) The alkaline action of the escaping vapours on test-papers held above the liquid; and (3.) By the formation of dense white fumes of chloride of ammonium, $NH_4Cl$, when a glass rod moistened with concentrated hydrochloric acid, $+$ HCl, is held over the liquid.

120. *Concluding Remarks.*—When the experimenter has passed over the tests for the first group of metallic oxides, and observed all the reactions correctly, he should have four or more solutions placed in his hands which may contain either potash, soda, ammonia, or be merely water, and he should be able to detect by a systematic application of the foregoing tests what the solution consists of. The order of applying the tests, which will be found most satisfactory, is indicated at pars. 203 and 217; and it will facilitate the examination of the *unknown substances*, if the tests are applied as stated. After the detection of a few unnamed solutions, the second group of metallic oxides may be proceeded with.

## Metallic Oxides.—Second Group.

121. *Preliminary Remarks.*—The group of the Alkaline Earths is distinguished from the first group by its members giving a precipitate with phosphate of soda, $2NaO,HO,PO_5$, and ammonia, $NH_4O$; and the second group is separated from the after groups by its giving no precipitate with the other group tests. The sulphate

of lime, $CaO,SO_3$, serves to divide this group into two divisions, as it precipitates the solutions of baryta and strontia, and does not precipitate the solutions of lime and magnesia.

### 122. Table of the Second Group of Metallic Oxides.

| | | |
|---|---|---|
| Characters of the Group. | $HCl$ and $HS$, | *No precipitate.* |
| | $NH_4O$ and $NH_4S,HS$, | *No precipitate.* |
| | $2NaO,HO,PO_5$ and $NH_4O$, | *White precipitate.* |

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Special Characters.

| Metallic Oxides. | Sulphate of Lime, $CaO,SO_3$. | |
|---|---|---|
| Baryta, $BaO$, | *White pre.* | Hyposulphite of Soda, $NaO,S_2O_2$, *white pre.*<br>Alcohol flame, *yellow green.* |
| Strontia, $SrO$, | *White pre.* | Hyposulphite of Soda, $NaO,S_2O_2$, *no pre.*<br>Alcohol flame, *carmine red.* |
| Lime, $CaO$, | *No pre.* | Oxalate of ammonia, $NH_4O,\bar{O}$, *white pre.*<br>Alcohol flame, *brick red.* |
| Magnesia, $MgO$, | *No pre.* | Oxalate of ammonia, $NH_4O,\bar{O}$, *no pre.*<br>Magnesian salts moistened with protonitrate of cobalt, $CoO,NO_5$, and heated on charcoal in the outer flame of the blow-pipe, become of a *flesh tint.* |

### 123. Baryta, BaO.

Nitrate of Baryta, $BaO,NO_5$, may be employed in testing.

1. *Phosphate of Soda,* $2NaO,HO,PO_5$, and *Ammonia,* $NH_4O$, give a *white precipitate* of phosphate of baryta, $3BaO,PO_5$, which is soluble in free acids.

2. *Sulphate of Lime* produces readily a *white precipi-*

*tate* of sulphate of baryta, $BaO,SO_3$, the formation of which is promoted by stirring.

3. *Hyposulphite of Soda*, $NaO,S_2O_2$, yields on stirring a white precipitate of *hyposulphite of baryta*, $BaO,S_2O_2$.

4. *Oxalate of Ammonia*, $NH_4O,\bar{O}$, throws down a *white precipitate* of oxalate of baryta, $BaO,\bar{O}$.

5. *Hydrofluosilicic Acid*, $HF,SiF_2$, forms a *white crystalline precipitate* of silicofluoride of barium, $BaF,SiF_2$, which is insoluble in alcohol.

6. *Alcohol* added to the solution of baryta, slightly heated, and then set fire to, burns with a *yellow-green flame.*

7. *Blow-pipe flame.* Baryta and its salts held in the inner flame of the blow-pipe, colour the outer flame of a *yellow-green tint.* The same result is observed in the Bunsen lamp.

### 124. Strontia, SrO.

Nitrate of Strontia, $SrO,NO_5$, may be employed in testing.

1. *Phosphate of Soda*, $2NaO,HO,PO_5$, and *Ammonia*, $NH_4O$, produce a *white precipitate* of phosphate of strontia, $3SrO,PO_5$, which is soluble in free acids.

2. *Sulphate of Lime*, $CaO,SO_3$, yields on prolonged stirring a *white precipitate* of sulphate of strontia, $SrO,SO_3$.

3. *Hyposulphite of Soda*, $NaO,S_2O_2$, gives *no precipitate* with the compounds of strontia.

4. *Oxalate of Ammonia*, $NH_4O,\bar{O}$, throws down a *white precipitate* of oxalate of strontia, $SrO,\bar{O}$.

5. *Hydrofluosilicic Acid*, $HF,SiF_2$, gives no precipitate with the compounds of strontium.

6. *Alcohol* mingled with the solution of strontia, and the whole gently heated and set fire to, burns with a *carmine-red flame.*

7. *Blow-pipe flame.* A small portion of strontia, or its salts, held on the platinum wire in the inner flame,

colours the outer flame of an intense *carmine-red tint.* The same colour is formed when the salt is held in the Bunsen lamp.

### 125. Lime, $CaO$.

Chloride of Calcium, $CaCl$, may be used in testing.

1. *Phosphate of Soda*, $2NaO,HO,PO_5$, and *Ammonia*, $NH_4O$, throw down from salts of lime a *white precipitate* of the phosphate of lime, $3CaO,PO_5$, which is readily dissolved on the addition of a free acid.

2. *Sulphate of Lime*, $CaO,SO_3$, gives *no precipitate* with a solution containing lime.

3. *Hyposulphite of Soda*, $NaO,S_2O_2$, gives *no precipitate* with solutions of lime.

4. *Oxalate of Ammonia*, $NH_4O,\bar{O}$, produces an abundant *white pulverulent precipitate* of oxalate of lime, $CaO,\bar{O}$, which is soluble in hydrochloric acid, $HCl$, or nitric acid, $HO,NO_5$, but is not soluble in acetic acid, $\bar{A}$, or in oxalic acid, $\bar{O}$.

5. *Hydrofluosilicic Acid*, $HF,SiF_2$, does *not precipitate* lime solutions.

6. *Alcohol* added to the lime solution, heated and kindled, burns with a *brick-red flame.*

7. *Blow-pipe flame.* When lime salts, and especially the chloride of calcium, are held in the inner flame of the blow-pipe, they tinge the outer flame of a *brick-red tint.* The same colour may be observed on placing the lime salt in the Bunsen flame.

### 126. Magnesia, $MgO$.

Sulphate of Magnesia, $MgO,SO_3$, may be employed in testing.

1. *Phosphate of Soda*, $2NaO,HO,PO_5$, and *Ammonia*, $NH_4O$, produce a *white crystalline precipitate* of the double phosphate of magnesia and ammonia,

$2MgO,NH_4O,PO_5$, which is soluble in free acids, including acetic acid, $\overline{A}$.

2. *Sulphate of Lime*, $CaO,SO_3$, does *not precipitate* the salts of magnesia.

3. *Hyposulphite of Soda*, $NaO,S_2O_2$, yields *no precipitate.*

4. *Oxalate of Ammonia*, $NH_4O,\overline{O}$, produces *no precipitate.*

5. *Hydrofluosilicic Acid*, $HF,SiF_2$, gives *no precipitate.*

6. *Alcohol* in burning is *not coloured* by magnesian salts.

7. *Blow-pipe* and *Bunsen flames* are *not tinged* by magnesia or its compounds.

8. *Blow-pipe test.* When magnesia and its salts are moistened with protonitrate of cobalt, $CoO,NO_5$, on a charcoal support, and heated in the outer flame of the blow-pipe, the saline mass assumes a *skin colour.*

127. *Concluding Remarks.*—The phosphate of soda is alone required for the precipitation of baryta, strontia, and lime in neutral or alkaline solutions, but when a free acid is present, the ammonia is useful in neutralising the acid. In testing for magnesia, the phosphate of soda produces a precipitate with great difficulty; but when ammonia is associated with it, a precipitate is readily obtained. The hyposulphite of soda is intended to distinguish between baryta and strontia, and the oxalate of ammonia separates lime from magnesia. The student should now test six or more solutions which may contain the metallic oxides of the first or second groups, and the systematic application of the tests for the purpose of distinguishing these *unknown solutions* may be observed at pars. 202 and 215.

## Metallic Oxides.—Third Group.

128. *Preliminary Remarks.*—The substances in this group are distinguished from the two preceding groups by giving precipitates with ammonia, $NH_4O$, and sulphide of ammonium, $NH_4S,HS$, and are recognised from the metallic oxides of the fourth group by yielding no precipitate on the addition of hydrochloric and hydrosulphuric acids. The precipitates which the members of this group give with ammonia and sulphide of ammonium are variously coloured, and hence these reagents are not only useful in distinguishing the group, but are also of value in denoting the individual substances of the group. The remaining special characters are introduced into the table in a very condensed form, so as to enable the contrast between the different reactions to be more readily observed, and the reading of the table will be facilitated at first by constant reference to the detailed statement of the tests under the individual substances.

### 129. Table of the Third Group of Metallic Oxides.

Characters of the Group. { HCl and HS,........................................ ........*No precipitate.*
{ $NH_4O$ and $NH_4S,HS$,..........................................*A precipitate.*

---

Special Characters.

| Metallic Oxides. | Sulphide of Ammonium, $NH_4S,HS$. | Ammonia, $NH_4O$. | |
|---|---|---|---|
| **Alumina, $Al_2O_3$,..................** | *White precipitate*....... | *White pre.*, insol. in excess,............ | KO,HO gives *white pre.*, soluble in excess, and reprecipitated by $NH_4Cl$.<br>$CoO,NO_5$. Blow-pipe test on charcoal, C, gives *sky-blue residue.* |
| Chromium, oxide, $Cr_2O_3$,..... | *Blue-green pre*.......... | *Blue-green pre*.......... | KO,HO gives *blue-green pre.*, sol. in excess, and repre. by $NH_4Cl$.<br>$KO,NO_5$ and $KO,CO_2$, ignite $= CrO_3$, which on addition of $PbO,\bar{A}$ gives *yellow pre.* |
| Zinc, oxide, ZnO,............... | *White pre*............... | *White pre.*, sol. in excess,............ | KO,HO gives *white pre.*, sol. in excess, and repre. by HS.<br>$CoO,NO_5$. Blow-pipe test on C gives *green residue.* |

**Special Characters—Continued.**

| Metallic Oxides. | Sulphide of Ammonium, $NH_4S,HS$. | Ammonia, $NH_4O$. | |
|---|---|---|---|
| Manganese, protoxide, MnO, | *Skin-coloured pre*...... | *Skin-coloured pre*...... | KO,HO gives a *skin-coloured pre.*, insol. in excess.<br>$NaO,HO,2CO_2$. Blow-pipe test on Pt gives *emerald-green bead.* |
| Nickel, oxide, NiO,............ | *Black pre.*, insol. in —HCl,............ | *Light-green pre.*, sol. in excess,............ | KO,HO gives a *light-green pre.*, insol. in excess.<br>KCy yields a *yellow-green pre.*, sol. in excess. |
| Cobalt, oxide, CoO,............ | *Black pre.*, insol. in —HCl,............ | *Blue pre.*, sol. in excess,................ | KO,HO gives a *blue pre.*, insol. in excess.<br>Blow-pipe tests with $Al_2O_3$ and ZnO. |
| Iron, protoxide, FeO,.......... | *Black pre.*, sol. in —HCl,............ | *Green pre.*, insol. in excess,................ | KO,HO gives a *green pre.*, insol. in excess.<br>2K,Cfy yields a *light-blue pre.*<br>3K,2Cfy produces *dark Prussian blue.* |
| Iron, peroxide, $Fe_2O_3$......... | *Black pre.*, sol. in —HCl,............ | *Red-brown pre.*, insol. in excess,............ | KO,HO yields a *red-brown pre.*, insol. in excess.<br>2K,Cfy gives a *dark Prussian blue.*<br>3K,2Cfy produces a *brown colour.*<br>$K,CyS_2$ forms a *blood-red solution.* |

### 130. Alumina, $Al_2O_3$.

Sulphate of Alumina, $Al_2O_3,3SO_3$, may be used in testing.

1. *Ammonia*, $NH_4O$, and *Sulphide of Ammonium*, $NH_4S,HS$, throw down a *white gelatinous precipitate* of the hydrate of alumina, $Al_2O_3,3HO$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, added by itself gives the *same precipitate.*

3. *Ammonia*, $NH_4O$, yields the *same precipitate.*

4. *Potash*, $KO,HO$, when added in small quantity, gives a *white gelatinous precipitate* of the hydrate of alumina, $Al_2O_3,3HO$, which redissolves when excess of potash solution is added, and is reprecipitated on the subsequent addition of the solution of chloride of ammonium, $NH_4Cl$. No reprecipitation occurs when hydrosulphuric acid, $HS$, is added to the potash solution.

5. *Blow-pipe test.* When a solid salt of alumina is placed on a charcoal support, and is moistened with protonitrate of cobalt, $CoO,NO_5$, and heated in the outer flame of the blow-pipe, the saline matter becomes coloured of a fine *sky-blue tint.*

### 131. Sesquioxide of Chromium, $Cr_2O_3$.

Sesquichloride of Chromium, $Cr_2Cl_3$, may be employed in testing.

1. *Ammonia*, $NH_4O$, and *Sulphide of Ammonium*, $NH_4S,HS$, produce a *bluish-green precipitate* of the hydrate of the sesquioxide of chromium, $Cr_2O_3,3HO$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, employed by itself gives the *same precipitate.*

3. *Ammonia*, $NH_4O$, yields the *same precipitate.*

4. *Potash*, $KO,HO$, throws down at first a *bluish-green precipitate* of the hydrate of the sesquioxide of chromium, $Cr_2O_3,3HO$, which is soluble in excess of potash, and is reprecipitated on the addition of chloride of ammonium, $NH_4Cl$.

5. *Nitrate of Potash*, $KO,NO_5$, and *Carbonate of Potash*, $KO,CO_2$, when added to the solution of chromium, and the mixture evaporated and ignited, yield a *yellow residue* of chromate of potash, $KO,CrO_3$. On dissolving this residue in water, and adding the acetate of lead, $PbO,\bar{A}$, a *yellow precipitate* of the chromate of lead, $PbO,CrO_3$, is obtained.

### 132. Oxide of Zinc, ZnO.

**Sulphate of Zinc, $ZnO,SO_3$, may be used in testing.**

1. *Ammonia*, $NH_4O$, and *Sulphide of Ammonium*, $NH_4S,HS$, yield a *white precipitate* of the hydrated sulphide of zinc, $ZnS,HO$, which is soluble in hydrochloric acid, $HCl$, or in nitric acid, $HO,NO_5$, but not in acetic acid, $\bar{A}$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, gives the *same precipitate.*

3. *Ammonia*, $NH_4O$, throws down a *white precipitate* of the hydrated oxide of zinc, $ZnO,HO$, which is soluble in excess of ammonia.

4. *Potash*, $KO,HO$, produces a *white precipitate* of the hydrated oxide of zinc, $ZnO,HO$, which is readily soluble in excess of the potash, and is reprecipitated on the addition of hydrosulphuric acid, $HS$, as the hydrated sulphide of zinc, $ZnS,HO$. Chloride of ammonium, $NH_4Cl$, does not reprecipitate the zinc from its potash solution.

5. *Blow-pipe test.* When a salt of zinc is placed on a charcoal support, moistened with protonitrate of cobalt, $CoO,NO_5$, and heated in the outer flame of the blow-pipe, it gives a *green coloured residue*, which is best observed when cold.

6. The *metal Zinc* is hard, has a blue tinge of colour, and may be tested by placing it in water acidulated

with a few drops of concentrated sulphuric acid, when the zinc will speedily dissolve, and form the sulphate of zinc, which can then be employed in testing by the above reagents.

### 133. Protoxide of Manganese, MnO.

Chloride of Manganese, MnCl, may be employed in testing.

1. *Ammonia*, $NH_4O$, and *Sulphide of Ammonium*, $NH_4S,HS$, throw down a *skin-coloured precipitate* of the hydrated sulphide of manganese, $MnS,HO$, which darkens on exposure to the air, and is soluble in acids.

2. *Sulphide of Ammonium*, $NH_4S,HS$, produces the *same precipitate.*

3. *Ammonia*, $NH_4O$, yields a *skin-coloured precipitate* of the hydrated protoxide of manganese, $MnO,HO$, which on exposure to the air acquires a dark-brown colour, owing to its conversion into a higher oxide of manganese, $Mn_3O_4$.

4. *Potash*, $KO,HO$, produces the *same precipitate* as ammonia.

5. *Blow-pipe tests.* When bicarbonate of soda, $NaO,HO,2CO_2$, is moistened with the solution of manganese, and held by a platinum wire in the outer flame of the blow-pipe, the whole fuses, and on cooling, an *emerald green bead* is obtained of the manganate of soda, $NaO,MnO_3$.

6. *Microcosmic Salt*, $NaO,NH_4O,HO,PO_5$, and *Borax*, $NaO,HO,2BO_3$, when moistened with manganese solution, and heated on a platinum wire in the outer flame of the blow-pipe, yield on cooling *amethyst red beads.*

### 134. Protoxide of Nickel, NiO.

Sulphate of Nickel, $NiO,SO_3$, may be used in testing.

1. *Ammonia*, $NH_4O$, and *Sulphide of Ammonium*, $NH_4S,HS$, produce a *black precipitate* of the hydrated

sulphide of nickel, NiS,HO, which is insoluble in dilute hydrochloric acid, —HCl.

2. *Sulphide of Ammonium*, $NH_4S,HS$, yields the *same precipitate.*

3. *Ammonia*, $NH_4O$, gives a *green precipitate* of the hydrated oxide of nickel, NiO,HO, which is soluble in excess of ammonia.

4. *Potash*, KO,HO, throws down a *light-green precipitate* of the hydrated oxide of nickel, NiO,HO, which is insoluble in excess of the precipitant.

5. *Cyanide of Potassium*, KCy, when added in small quantity, produces a *yellow-green precipitate* of the cyanide of nickel, NiCy, which dissolves in an excess of the cyanide of potassium.

6. The *metal Nickel* may be dissolved in diluted nitric acid, which will give the nitrate of nickel, $NiO,NO_5$, and to which the above tests can be applied.

### 135. Oxide of Cobalt, CoO.

**Protonitrate of Cobalt, $CoO,NO_5$, may be employed in testing.**

1. *Ammonia*, $NH_4O$, and *Sulphide of Ammonium*, $NH_4S,HS$, yield a *black precipitate* of the hydrated sulphide of cobalt, CoS,HO, which is insoluble in dilute hydrochloric acid, —HCl.

2. *Sulphide of Ammonium*, $NH_4S,HS$, throws down the *same precipitate.*

3. *Ammonia*, $NH_4O$, produces a *blue precipitate* of a basic salt of cobalt, which changes to a *red-brown solution* when the ammonia is added in excess.

4. *Potash*, KO,HO, gives a *blue precipitate* of a basic salt of cobalt, which is insoluble in excess of the potash, but turns *green* on exposure to the air.

5. *Cyanide of Potassium*, KCy, yields a *brownish-white precipitate* of the cyanide of cobalt, CoCy, which is soluble in excess of cyanide of potassium.

6. *Blow-pipe tests.* When a salt of alumina is moistened with a solution of cobalt, and heated on charcoal in the outer flame, a *light-blue residue* is obtained. A salt of zinc treated in a similar way produces a *green residue.*

7. *Borax*, $NaO,HO,2BO_3$, moistened with the solution of cobalt, and heated on a platinum wire before the blow-pipe, gives a *blue-coloured bead.* Microcosmic salt, $NaO,NH_4O,HO,PO_5$, acts in a similar manner.

### 136. Protoxide of Iron, FeO.

Sulphate of Iron, $FeO,SO_3$, may be employed in testing.

1. *Ammonia*, $NH_4O$, and *Sulphide of Ammonium*, $NH_4S,HS$, throw down a *black precipitate* of the hydrated sulphide of iron, $FeS,HO$, which is readily soluble in dilute hydrochloric acid, —HCl, and other acids, and changes to *reddish-brown* on exposure to the air, owing to the precipitate becoming oxidised into the hydrated red or sesquioxide of iron, $Fe_2O_3,HO$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, produces the *same precipitate.*

3. *Ammonia*, $NH_4O$, yields a *green precipitate* of the hydrated protoxide of iron, $FeO,HO$, which is insoluble in excess, and which on exposure to the air becomes oxidised into the reddish-brown hydrated sesquioxide of iron, $Fe_2O_3,HO$.

4. *Potash*, $KO,HO$, gives the *same precipitate* as ammonia.

5. *Ferrocyanide of Potassium*, 2K,Cfy, throws down a *light-blue precipitate* of the ferrocyanide of potassium and iron, K,3Fe,2Cfy, which on exposure to the air becomes oxidised into a deeper blue colour.

6. *Ferridcyanide of Potassium*, 3K,2Cfy, yields a *deep Prussian blue precipitate* of ferridcyanide of iron, 3Fe,2Cfy,

which is not altered by dilute hydrochloric acid, —HCl, but is changed into a ruddy colour by an excess of potash, KO,HO. If the solution of iron is very dilute, the result of the test may be merely a blue-green solution.

7. *Sulphocyanide of Potassium*, $K,CyS_2$, produces *no colour or precipitate* when it is added to the pure protosalts of iron; but as all these salts are liable to be oxidised on exposure to the air, a certain proportion of the sesquisalt of iron is formed, and is coloured red by the sulphocyanide of potassium.

8. *Metallic Iron* may be tested for by dissolving it in water acidulated with sulphuric acid, when the protosulphate of iron, $FeO,SO_3$, is formed, and the above tests may be applied to the solution so obtained.

### 137. Sesquioxide of Iron, $Fe_2O_3$.

**Sesquichloride of Iron, $Fe_2Cl_3$, may be used in testing.**

1. *Ammonia*, $NH_4O$, and *Sulphide of Ammonium*, $NH_4S,HS$, yield a *black precipitate* of the protosulphide of iron, FeS,HO, which is soluble in dilute hydrochloric acid, —HCl, and becomes ruddy brown when exposed to the air, owing to the oxygen of the atmosphere converting the precipitate in part into the hydrated sesquioxide of iron, $Fe_2O_3,HO$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, produces the *same precipitate.*

3. *Ammonia*, $NH_4O$, throws down a *bulky red-brown precipitate* of the hydrated sesquioxide of iron, $Fe_2O_3,HO$, which is insoluble in excess of the ammonia.

4. *Potash*, KO,HO, gives the *same precipitate* as ammonia.

5. *Ferrocyanide of Potassium*, 2K,Cfy, throws down a *deep Prussian blue precipitate* of ferrocyanide of iron, 4Fe,3Cfy, which is insoluble in dilute hydrochloric

acid, —HCl, but is decolorised to a brown tint when alkalies, such as potash, are added in excess.

6. *Ferridcyanide of Potassium*, 3K,2Cfy, gives only a *brown colour* with the sesquisalts of iron.

7. *Sulphocyanide of Potassium*, K,Cy$S_2$, yields a *blood-red colour* when added to the solutions of the sesquisalts of iron. The test is very delicate, and is due to the formation of the soluble sulphocyanide of iron.

8. *Tincture of Galls* produces with the sesquisalts of iron a *black solution* of the tannogallate of iron (black writing-ink).

9. *Ordinary rust*, or *Red Oxide of Iron*, $Fe_2O_3$, may be dissolved readily in water acidulated with hydrochloric acid, HCl, when the sesquichloride of iron, $Fe_2Cl_3$, is formed, and may be tested for as above. Heat promotes the solution of the rust in the acid.

138. *Concluding Remarks.*—The members of the third group of metallic oxides are acted upon in two ways, on the addition of ammonia and sulphide of ammonium. The solutions of alumina and the oxide of chromium are precipitated as hydrated oxides, and not as sulphides, whilst the solutions of the oxides of zinc, manganese, nickel, cobalt, and iron are precipitated as sulphides. In the testing for the sesquioxide of iron, it will be observed that it is not a sesquisulphide which is thrown down, but a protosulphide, and in this respect the two oxides of iron agree in regard to the reaction with sulphide of ammonium. The white precipitates given by alumina and oxide of zinc on the addition of sulphide of ammonium, serve to distinguish these substances from the other members of the group, and the reaction with potash, which in either case gives a white precipitate soluble in excess, and the subsequent reprecipitation of the alumina by chloride of ammonium, and the zinc by hydrosulphuric acid, serves as an excellent

mode of distinguishing between these substances. The sulphide of ammonium produces four black precipitates—namely, when added to solutions of the protoxide of nickel, protoxide of cobalt, protoxide of iron, and sesquioxide of iron; and the subsequent addition of dilute hydrochloric acid to the black precipitates serves to divide the four substances into those which are insoluble in the acid—nickel and cobalt; and those which are soluble in the acid—the two salts of iron. The student should now proceed to test ten or more *unknown solutions*, which may contain the substances belonging to this and the previous groups, and the systematic mode of applying the tests for the identification of the individual substances will be found at pars. 201 and 210.

## Metallic Oxides.—Fourth Group.

139. *Preliminary Remarks.*—The fourth and last group of metallic oxides contains a large number of important substances, alike from their medicinal use and from their commercial value. It includes all the more costly as well as the more poisonous metals. The test of the group is the production of a precipitate on the addition of hydrochloric acid, $HCl$, and hydrosulphuric acid, $HS$; in other words, by the use of hydrosulphuric acid in an acidified solution. The group contains eleven metals, and as three of these have each two distinct oxides, there are altogether fourteen metallic oxides to be tested for. The various coloured precipitates, however, given by the hydrosulphuric acid enable several of these metallic oxides to be distinguished from each other, and to be separated into minor classes. Thus, the hydrosulphuric acid forms yellow precipitates with arsenious acid, arsenic acid,

cadmium and binoxide of tin; an orange precipitate with antimony; a brown precipitate with protoxide of tin; and a black precipitate with each of the remaining eight metallic oxides. Hydrochloric acid precipitates the solutions of three of the members of the group—namely, silver, suboxide of mercury, and oxide of lead—but this does not interfere with the subsequent addition of the hydrosulphuric acid. The reactions given in the table are much curtailed, but the after-explanations will suffice to render the table completely intelligible.

### 140. Table of the Fourth Group of Metallic Oxides.

Character of the Group,..................HCl and HS,.................................*A precipitate.*

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Special Characters.

| Metallic Oxides. | Hydrochloric Acid, HCl, and Hydrosulphuric Acid, HS. | Ammonia, $NH_4O$. | |
|---|---|---|---|
| Silver, oxide, $AgO$,............ | *Black pre.*, insol. in $-NO_5$,......... | *Brown pre.*, sol. in excess,................ | HCl gives *white pre.*, sol. in $NH_4O$.<br>KO,HO produces a *light-brown pre.*, insol. in excess. |
| Lead, oxide, $PbO$,.............. | *Black pre.*, insol. in $-NO_5$,......... | *White pre.*, insol. in excess,................ | HCl yields *white pre.*, insol. in $NH_4O$.<br>KO,HO gives *white pre.*, difficultly sol. in excess.<br>$HO,SO_3$ produces a *white pre.*, sol. in KO,HO.<br>KI gives a *yellow pre.*<br>$KO,2CrO_3$ yields a *yellow pre.* |
| Mercury, suboxide, $Hg_2O$,... | *Black pre.*, insol. in $-NO_5$,......... | *Black pre.*, insol. in excess,................ | HCl produces a *white pre.*, which blackens on addition of $NH_4O$.<br>KO,HO yields a *black pre.*, insol. in excess.<br>SnCl gives a *gray pre.*<br>Mercury solution on metallic copper, Cu, yields a *silver stain.* |

| | | | |
|---|---|---|---|
| Mercury, peroxide, HgO,..... | *White*, passing to *yellow*, *orange*, *brown*, and lastly *black pre*.......... | *White pre.*, insol. in excess,......... | KO,HO gives a *yellow pre.*, insol. in excess.<br>SnCl yields a *gray pre.*<br>KI produces a *scarlet pre.*, sol. in excess of either solution.<br>Mercury solution on metallic copper, Cu, gives a *silver stain.* |
| Copper, oxide, CuO,........... | *Black pre.*, insol. in —$NO_5$,......... | *Green-blue pre.*, sol. in excess to azure-blue solution,............... | KO,HO yields a *green-blue pre.*, insol. in excess.<br>2K,Cfy produces a *ruddy-brown pre.*<br>Copper solution on bright iron, Fe, gives a *copper deposit.* |
| Bismuth, teroxide, $BiO_3$,...... | *Black pre.*, insol. in —$NO_5$,........ | *White pre.*, insol. in excess,............... | KO,HO forms a *white pre.*, insol. in excess.<br>Water produces a *white pre.*, insol. in $\overline{T}$.<br>KO,$2CrO_3$ gives a *yellow pre.* |
| Cadmium, oxide, CdO,......... | *Yellow pre.*, insol. in $NH_4O$,......... | *White pre.*, sol. in excess,............... | KO,HO gives a *white pre.*, insol. in excess.<br>KO,$CO_2$ yields a *white pre.*, insol. in excess. |
| Gold, teroxide, $AuO_3$,......... | *Black pre.*, insol. in —$NO_5$,........ | *Red yellow pre.*, in strong solutions,... | SnCl gives a *purple solution* or *pre.*<br>FeO,$SO_3$ precipitates metallic gold as a *brown powder.* |
| Platinum, binoxide, $PtO_2$,.... | *Black pre.*, insol. in —$NO_5$,........ | *Yellow pre.*, sol. in excess,.............. | SnCl yields a *red solution* or *pre.*<br>KO,$NO_5$ gives a *yellow crystalline pre.* |

Special Characters—Continued.

| Metallic Oxides. | Hydrochloric Acid, HCl, and Hydrosulphuric Acid, HS. | Ammonia, $NH_4O$. | |
|---|---|---|---|
| Antimony, teroxide, $SbO_3$,... | *Orange-red pre.*, insol. in $-NO_5$,. | *White pre.*, insol. in excess,............... | KO,HO produces a *white pre.*, sol. in excess.<br>HCl gives a *white pre.*, sol. in excess.<br>Zn and $HO,SO_3$ yield a *black pre.* of Sb, and evolve as gas $SbH_3$. |
| Tin, protoxide, SnO,....... ... | *Brown pre.*, insol. in $-NO_5$,......... | *White pre.*, insol. in excess,............... | KO,HO gives a *white pre.*, sol. in excess.<br>$AuCl_3$ produces a *purple solution* or *pre.*<br>HgCl yields a *gray pre.* |
| Tin, binoxide, $SnO_2$,............ | *Yellow pre.*, insol. in $NH_4O$,......... | *White pre.*, slightly sol. in excess,....... | KO,HO forms a *white pre.*, sol. in excess.<br>$KO,CO_2$ gives a *white pre.* |
| Arsenious Acid, $AsO_3$,......... | *Yellow pre.*, sol. in $NH_4O$,......... | *No pre*............... | Ammonio-sulphate of copper throws down a *green pre.*, sol in $NH_4O$ and acids.<br>Ammonio-nitrate of silver yields a *yellow pre.*, sol. in $NH_4O$ and acids. |
| Arsenic Acid, $AsO_5$,........... | *Yellow pre.*, sol. in $NH_4O$,......... | *No pre*............... | Ammonio-sulphate of copper gives a *green pre.*, sol. in $NH_4O$ and acids.<br>Ammonio-nitrate of silver produces a *red-brown pre.*, sol. in $NH_4O$ and acids. |

### 141. Oxide of Silver, $AgO$.

**Nitrate of Silver, $AgO,NO_5$, may be employed in testing.**

1. *Hydrosulphuric Acid*, $HS$, throws down the *black precipitate* of sulphide of silver, $AgS$, which is insoluble in dilute nitric acid, $HO,NO_5$, and other acids.

2. *Sulphide of Ammonium*, $NH_4S,HS$, produces the *same precipitate*.

3. *Ammonia*, $NH_4O$, yields in strong solutions of silver a *brown precipitate* of the oxide of silver, $AgO$, which is readily soluble in excess of the precipitant.

4. *Hydrochloric Acid*, $HCl$, gives a *white curdy precipitate* of the chloride of silver, $AgCl$, which is insoluble in nitric acid, $HO,NO_5$, but readily soluble in ammonia, $NH_4O$.

5. *Potash*, $KO,HO$, forms a *light-brown precipitate* of the oxide of silver, $AgO$, which is insoluble in excess.

6. *Blow-pipe test.* Compounds of silver, mingled with a little bicarbonate of soda, $NaO,HO,2CO_2$, and heated on charcoal in the inner flame of the blow-pipe, yield *globules of metallic silver*, $Ag$. Occasionally a dark-red incrustation forms on the charcoal.

7. The *metal Silver* is the well-known white metal, and may be dissolved in nitric acid, $HO,NO_5$, diluted with water, and heat applied in a test-tube. A solution of nitrate of silver, $AgO,NO_5$, is obtained, which can be tested as above.

### 142. Oxide of Lead, $PbO$.

**Acetate of Lead, $PbO,\bar{A}$, may be used in testing.**

1. *Hydrosulphuric Acid*, $HS$, yields a *black precipitate* of the sulphide of lead, $PbS$, which is insoluble in dilute acids and alkalies. When free acid is present in the lead solution, the precipitate appears at first of a red tint, but the addition of more hydrosulphuric acid, converts the whole into a black precipitate.

2. *Sulphide of Ammonium*, $NH_4S,HS$, gives the *same precipitate* of sulphide of lead, PbS.

3. *Ammonia*, $NH_4O$, produces a *white precipitate* of a basic salt of lead, which is insoluble in excess.

4. *Hydrochloric Acid*, HCl, throws down from strong solutions of lead an abundant *white precipitate* of the chloride of lead, PbCl, which is soluble in much water, but is insoluble in ammonia, $NH_4O$. In a very dilute solution of lead the hydrochloric acid fails to cause a precipitate.

5. *Potash*, KO,HO, gives a *white precipitate* of a basic salt of lead, which is insoluble in excess.

6. *Sulphuric Acid*, $HO,SO_3$, yields a *white precipitate* of the sulphate of lead, $PbO,SO_3$, which is insoluble in dilute acids, and is difficultly soluble in an excess of potash, KO,HO.

7. *Iodide of Potassium*, KI, produces a *yellow precipitate* of the iodide of lead, PbI, which is soluble in a large excess of water.

8. *Bichromate of Potash*, $KO,2CrO_3$, gives a *yellow precipitate* of the chromate of lead, $PbO,CrO_3$, which is nearly insoluble in dilute nitric acid, $HO,NO_5$, but is readily dissolved by potash, KO,HO.

9. *Blow-pipe test.* When a compound of lead is mixed with bicarbonate of soda, $NaO,HO,2CO_2$, and heated on charcoal in the inner flame of the blow-pipe, *globules of metallic lead* are obtained, which, on cooling, are soft and can be readily cut with a knife. The charcoal is found incrusted with the yellow oxide of lead, PbO.

10. The *metal Lead* is a soft metal, with a blue tinge of colour, and dissolves readily when heated with diluted nitric acid, $HO,NO_5$, in a test-tube, when the nitrate of lead, $PbO,NO_5$, is obtained in solution, and can be employed in giving the above tests.

### 143. Suboxide of Mercury, $Hg_2O$.

**Subnitrate of Mercury, $Hg_2O,NO_5$, may be employed in testing.**

1. *Hydrosulphuric Acid*, HS, throws down a *black precipitate* of the subsulphide of mercury, $Hg_2S$, which is insoluble in dilute acids.

2. *Sulphide of Ammonium*, $NH_4S,HS$, forms the *same precipitate.*

3. *Ammonia*, $NH_4O$, produces a *black precipitate*, consisting mainly of the suboxide of mercury, $Hg_2O$.

4. *Hydrochloric Acid*, HCl, gives a *white precipitate* of the subchloride of mercury, $Hg_2Cl$, which is insoluble in dilute acid, and is changed to a black precipitate on the addition of ammonia, $NH_4O$.

5. *Potash*, KO,HO, forms a *black precipitate* of the suboxide of mercury, $Hg_2O$, which is insoluble in excess.

6. *Protochloride of Tin*, SnCl, throws down a *gray precipitate* of metallic mercury, Hg, in a finely-divided state.

7. *Polished Copper*, Cu, when moistened with a solution of mercury, and thereafter burnished, acquires a *silver white coating*, owing to the deposition of metallic mercury on the surface of the copper.

8. The *metal Mercury* dissolves in cold nitric acid, $HO,NO_5$, and yields a crystalline mass of the subnitrate of mercury, $Hg_2O,NO_5$, which readily dissolves in water, and yields a solution which will give the above tests.

### 144. Peroxide of Mercury, HgO.

**Chloride of Mercury, HgCl, may be used in testing.**

1. *Hydrosulphuric Acid*, HS, added in small quantity to this solution of mercury gives a *white precipitate*, which consists of a double compound of the sulphide of mercury and chloride of mercury, $HgCl + 2HgS$. When more hydrosulphuric acid is added, the white precipitate becomes

*yellow*, *orange*, *brown*, and lastly *black*, as the mercury is more completely acted upon by the reagent; and when the black precipitate has been attained, the whole of the mercury salt has been converted into sulphide of mercury, HgS, which is insoluble in dilute acids. The series of colours which the solutions of the peroxide of mercury give with hydrosulphuric acid are quite characteristic of the substance.

2. *Sulphide of Ammonium*, $NH_4S,HS$, yields the *same precipitate* of sulphide of mercury, HgS.

3. *Ammonia*, $NH_4O$, gives a *white precipitate* of the double amidide and chloride of mercury, $HgCl + HgNH_2$, which is insoluble in excess of the precipitant.

4. *Potash*, KO,HO, produces a *yellow precipitate* of the hydrated oxide of mercury, HgO,HO, which is insoluble in excess. When the potash is sparingly added, the precipitate is of a reddish-brown tint, and consists of a basic salt.

5. *Protochloride of Tin*, SnCl, when added in small quantity, throws down a white precipitate of the subchloride of mercury, $Hg_2Cl$, but when more freely added it yields a *gray precipitate* of finely-divided metallic mercury, Hg.

6. *Iodide of Potassium*, KI, forms a *bright scarlet precipitate* of iodide of mercury, HgI, when added in about equal proportions; and if the solution containing this scarlet precipitate is divided into two, and excess of chloride of mercury is poured into one of these portions, and excess of iodide of potassium is added to the second portion, it will be found that the precipitate is soluble in excess of either of the substances which form it.

7. *Polished Copper*, Cu, when treated with the solution of chloride of mercury, and thereafter subjected to gentle friction, acquires a coating of metallic mercury of a *silver-white appearance*.

8. *Metallic Mercury*, Hg, treated with nitric acid, $HO,NO_5$, in a test-tube, and heated, yields a solution of the pernitrate of mercury, $HgO,NO_5$, which will give the tests mentioned above.

### 145. Oxide of Copper, CuO.

Sulphate of Copper, $CuO,SO_3$, may be employed in testing.

1. *Hydrosulphuric Acid*, HS, throws down a *black precipitate* of the sulphide of copper, CuS, which is insoluble in dilute acids.

2. *Sulphide of Ammonium*, $NH_4S,HS$, yields the *same precipitate.*

3. *Ammonia*, $NH_4O$, produces at first a *greenish-blue precipitate* of the hydrated oxide of copper, CuO,HO, which dissolves in excess of ammonia to an *azure-blue solution.*

4. *Potash*, KO,HO, forms a *greenish-blue precipitate* of the hydrated oxide of copper, CuO,HO, which is insoluble in excess, and which when heated in a tube loses part of its water of hydration, and becomes a *brownish-black precipitate* of the hydrated oxide of copper, 3CuO,HO.

5. *Ferrocyanide of Potassium*, 2K,Cfy, yields a *bulky reddish-brown precipitate* of the ferrocyanide of copper, 2Cu,Cfy, which is insoluble in dilute acids, but is decomposed by potash, KO,HO. This is the most delicate test for copper in solution, and when the amount of copper is very minute, a *ruddy-tinted liquid* is only obtained.

6. *Carbonate of Potash*, $KO,CO_2$, produces a *greenish-blue precipitate* of the double carbonate and hydrate of copper, $CuO,CO_2 + CuO,HO$, which, on boiling in a test-tube, is converted into the brownish-black hydrated oxide of copper, 3CuO,HO.

7. *Bright Iron*, Fe, placed in a solution of copper, speedily acquires a *coating of metallic copper* with its characteristic red colour.

8. *Blow-pipe test.* When a salt of copper is mixed with bicarbonate of soda, $NaO,HO,2CO_2$, and heated on charcoal in the inner flame of the blow-pipe, *metallic copper* is formed.

9. *Blow-pipe flame* and *Bunsen flame.* When a platinum wire is dipped into a solution of copper, or has some powder of a salt of copper attached to it, and is then held in the inner blow-pipe or Bunsen flame, the outer flame becomes tinted of an *emerald-green colour.* When the copper salt is heated on charcoal in the inner flame of the blow-pipe, the *emerald-green tint* is observed, and the charcoal is not incrusted with any coloured oxide.

10. *Metallic Copper*, Cn, is the well-known red metal, and is readily soluble in diluted nitric acid, $HO,NO_5$, especially on heating in a test-tube, and a solution of nitrate of copper, $CuO,NO_5$, is obtained, which gives all the above tests.

## 146. Teroxide of Bismuth, $BiO_3$.

Ternitrate of Bismuth, $BiO_3,3NO_5$, may be used in testing.

1. *Hydrosulphuric Acid*, HS, produces a *black precipitate* of the tersulphide of bismuth, $BiS_3$, which is insoluble in dilute acids.

2. *Sulphide of Ammonium*, $NH_4S,HS$, gives the *same precipitate.*

3. *Ammonia*, $NH_4O$, yields a *white precipitate* of the hydrated teroxide of bismuth, $BiO_3,HO$, which is insoluble in excess.

4. *Potash*, KO,HO, also gives a *white precipitate* of the hydrated teroxide of bismuth, $BiO_3,HO$, which is not dissolved in excess.

5. *Water*, added in considerable quantity to the solution of the ternitrate of bismuth, throws down a *dazzling white precipitate* of the subnitrate of bismuth,

$5BiO_3,4NO_5 + 9HO$, which is insoluble in tartaric acid, $HO,HO,\overline{T}$, and turns black on the addition of hydrosulphuric acid, HS.

6. *Bichromate of Potash*, $KO,2CrO_3$, produces a *yellow precipitate* of the chromate of bismuth, $BiO_3,2CrO_3$, which is readily dissolved by nitric acid, $HO,NO_5$, and is insoluble in potash, KO,HO.

7. *Carbonate of Potash*, $KO,CO_2$, gives a *white precipitate* of the basic carbonate of bismuth, $BiO_3,CO_2$, which is insoluble in excess.

8. *Sulphuric Acid*, $HO,SO_3$, gives *no precipitate* with salts of bismuth.

9. *Blow-pipe test.* When the compound of bismuth is mixed with bicarbonate of soda, $NaO,HO,2CO_2$, and heated on charcoal in the inner flame of the blow-pipe, little *globules of metallic bismuth* are obtained, which, on cooling, may be observed to be brittle. The charcoal is more or less coated with the fine powder of teroxide of bismuth, $BiO_3$, which is *yellow* when cold, and *orange* whilst hot.

10. *Metallic Bismuth*, Bi, is a brittle, crystalline metal, with a shade of red, and is dissolved by a mixture of equal parts of nitric acid, $HO,NO_5$, and water, HO, which, when heated with bismuth in a test-tube, readily yield a solution of the ternitrate of bismuth, $BiO_3,3NO_5$, which can be used in giving the above tests.

### 147. Oxide of Cadmium, CdO.

Chloride of Cadium, CdCl, may be employed in testing.

1. *Hydrosulphuric Acid*, HS, yields a *yellow precipitate* of the sulphuret of cadmium, CdS, which is insoluble in ammonia, $NH_4O$, and in dilute acids.

2. *Sulphide of Ammonium*, $NH_4S,HS$, gives the *same precipitate*.

3. *Ammonia*, $NH_4O$, throws down a *white precipitate* of the hydrated oxide of cadmium, CdO,HO, which is readily soluble in excess of the ammonia.

4. *Potash*, KO,HO, produces a *white precipitate* of the hydrated oxide of cadmium, CdO,HO, which is insoluble in excess.

5. *Carbonate of Potash*, $KO,CO_2$, gives a *white precipitate* of the carbonate of cadmium, $CdO,CO_2$, insoluble in excess.

6. *Blow-pipe test.* When a compound of cadmium is mixed with bicarbonate of soda, $NaO,HO,2CO_2$, and heated on a charcoal support in the inner flame of the blow-pipe, the metal cadmium, Cd, is produced; but it instantly volatilises, and merely leaves, on cooling, a *red-brown incrustation* of the oxide of cadmium, CdO.

7. *Metallic Cadmium*, Cd, is readily dissolved in diluted hydrochloric acid, —HCl, when heated in a test-tube, and a *solution of chloride of cadmium*, CdCl, is obtained, which will give the above tests.

### 148. Teroxide of Gold, $AuO_3$.

Terchloride of Gold, $AuCl_3$, may be used in testing.

1. *Hydrosulphuric Acid*, HS, throws down in the cold a *black precipitate* of the tersulphide of gold, $AuS_3$, which is insoluble in dilute acids, but soluble in yellow sulphide of ammonium, $NH_4S + S$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, yields a *black precipitate* of tersulphide of gold, $AuS_3$, which is soluble in a larger quantity of sulphide of ammonium containing an excess of sulphur, $NH_4S + S$.

3. *Ammonia*, $NH_4O$, gives in strong solutions of gold a *reddish-yellow precipitate* of aurate of ammonia.

4. *Protochloride of Tin*, SnCl, produces a *purple precipitate* or *solution* of the double stannate of gold and

tin (purple of Cassius) $SnO,SnO_2 + AuO,SnO_2$. The shade of purple varies much, and if a little bichloride of tin be present in the protochloride of tin the reaction is more decided.

5. *Protosulphate of Iron*, $FeO,SO_3$, gives with solutions of gold a *brown precipitate* of metallic gold, Au, in a very fine state of powder. The precipitate appears of a *brown colour* by reflected light, and of a *blue tint* by transmitted light.

6. *Metallic Gold*, Au, is insoluble in nitric acid, $HO,NO_5$, or hydrochloric acid, HCl, taken separately; but in a mixture of 2 parts of hydrochloric acid and 1 part of nitric acid (forming aqua regia) the gold dissolves, and yields a solution of the terchloride of gold, $AuCl_3$. The same substance can be prepared by suspending gold-leaf in water, and passing a stream of chlorine gas, Cl, through the water, when the terchloride of gold, $AuCl_3$, is formed, and may be employed for testing as above.

### 149. Binoxide of Platinum, $PtO_2$.

Bichloride of Platinum, $PtCl_2$, may be employed in testing.

1. *Hydrosulphuric Acid*, HS, gives a *black precipitate* of the bisulphide of platinum, $PtS_2$, which is insoluble in dilute acids, but soluble in yellow sulphide of ammonium, $NH_4S + S$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, yields a *black precipitate* of bisulphide of platinum, $PtS_2$, which is soluble in yellow sulphide of ammonium, $NH_4S + S$.

3. *Ammonia*, $NH_4O$, produces with a solution of platinum, when the mixed liquids are acidified by hydrochloric acid, HCl, a *yellow crystalline precipitate* of the double chloride of platinum and ammonium, $NH_4Cl + PtCl_2$, which is soluble in excess of ammonia, but insoluble in acids.

4. *Protochloride of Tin*, $SnCl$, yields a *red solution* or *precipitate* of the double stannate of platinum and tin, $SnO,SnO_2 + PtO,SnO_2$,

5. *Nitrate of Potash*, $KO,NO_5$, forms a *yellow crystalline precipitate* of the double chloride of platinum and potassium, $KCl + PtCl_2$, which is insoluble in acids, but soluble in alkalies.

6. *Metallic Platinum*, Pt, is not soluble in either hydrochloric acid, $HCl$, or nitric acid, $HO,NO_5$, taken separately, but in aqua regia (2 parts of hydrochloric acid and 1 part of nitric acid) the platinum dissolves, and yields a *solution of bichloride of platinum*, $PtCl_2$, which can be tested as above.

### 150. Teroxide of Antimony, $SbO_3$.

Tartrate of Potash and Antimony (Tartar Emetic), $KO,SbO_3,\overline{T}$, may be used in testing.

1. *Hydrosulphuric Acid*, $HS$, throws down an *orange-red precipitate* of the tersulphide of antimony, $SbS_3$, the formation of which is promoted by the addition of hydrochloric acid, $HCl$, or other mineral acid, and retarded by the presence of an alkali, such as potash, $KO,HO$, or ammonia, $NH_4O$. The precipitate is soluble in yellow sulphide of ammonium, $NH_4S + S$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, gives an *orange-red precipitate* of tersulphide of antimony, $SbS_3$, which is more abundantly formed on the addition of an acid, and is soluble in yellow sulphide of ammonium, $NH_4S + S$.

3. *Ammonia*, $NH_4O$, produces a *white precipitate* of teroxide of antimony, $SbO_3$, which is insoluble in excess of ammonia. This precipitate is not readily obtained from the solution of tartar emetic, but is abundantly thrown down from the terchloride of antimony, $SbCl_3$.

4. *Potash*, KO,HO, produces the *same precipitate* as ammonia, but it is soluble in excess of potash.

5. *Hydrochloric Acid*, HCl, yields a *white precipitate* of a basic salt of antimony, which readily dissolves in an excess of the acid.

6. *Metallic Zinc*, Zn, and a few drops of *Sulphuric Acid*, $HO,SO_3$, added to a solution containing antimony, give rise to a *black precipitate* of fine particles of metallic antimony, Sb, and to the disengagement of antimoniuretted hydrogen, $SbH_3$, as a gas with a peculiar odour, and possessing poisonous properties.

7. *Blow-pipe test.* When the compound of antimony is mixed with bicarbonate of soda, $NaO,HO,2CO_2$, and cyanide of potassium, KCy, and heated on charcoal in the inner flame of the blow-pipe, *globules of metallic antimony* are obtained, which on cooling may be observed to be brittle.

8. *Metallic Antimony*, Sb, is a crystalline metal, somewhat resembling bismuth, but with a shade of blue. It is not dissolved by hydrochloric acid, HCl; and nitric acid, $HO,NO_5$, converts it into a *yellowish-white insoluble powder* of antimonic acid, $SbO_5$; but if the antimony be heated with aqua regia (2 parts of hydrochloric acid and 1 part of nitric acid) a *solution* is obtained which mainly consists of the *terchloride of antimony*, $SbCl_3$.

9. *Water*, HO, added to the terchloride of antimony, produces a *white precipitate* of a basic chloride of antimony, $2SbO_3 + SbCl_3$, which is soluble in tartaric acid, $HO,HO,\overline{T}$, and gives an *orange-red precipitate* with hydrosulphuric acid, HS.

### 151. Protoxide of Tin, SnO.

Protochloride of Tin, SnCl, may be used in testing.

1. *Hydrosulphuric Acid*, HS, throws down a *dark-brown precipitate* of the protosulphide of tin, SnS, which

is insoluble in dilute acids, but dissolves in yellow sulphide of ammonium, $NH_4S + S$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, produces the *same precipitate.*

3. *Ammonia*, $NH_4O$, gives a *white precipitate* of the hydrated protoxide of tin, $SnO,HO$, which is insoluble in excess of ammonia.

4. *Potash*, $KO,HO$, yields a *white precipitate* of the hydrated protoxide of tin, $SnO,HO$, which is soluble in excess of potash.

5. *Terchloride of Gold*, $AuCl_3$, produces a *purple solution* or *precipitate* of the stannate of gold and tin (purple of Cassius), $SnO,SnO_2 + AuO,SnO_2$.

6. *Perchloride of Mercury*, $HgCl$, gives a *gray precipitate* of finely-divided metallic mercury, $Hg$.

7. *Blow-pipe test.* If the compound of tin be mixed with bicarbonate of soda, $NaO,HO,2CO_2$, and cyanide of potassium, $KCy$, and heated on charcoal in the inner blow-pipe flame, minute *globules of metallic tin*, $Sn$, will be obtained, which may be separated more readily by triturating the whole in a mortar, and washing off the lighter particles of charcoal, &c. When cold, the globules will be found intermediate in hardness between lead and silver.

8. *Metallic Tin*, $Sn$, is a white metal, of medium softness, and readily dissolves in diluted hydrochloric acid, $HCl$, yielding *a solution of the protochloride of tin*, $SnCl$, which can be employed in trying the above tests.

### 152. Binoxide of Tin, $SnO_2$.

Bichloride of Tin, $SnCl_2$, may be employed in testing.

1. *Hydrosulphuric Acid*, $HS$, throws down a *yellow precipitate* of the bisulphide of tin, $SnS_2$, which is insoluble in dilute acids, but is soluble in yellow sulphide of ammonium, $NH_4S + S$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, produces the *same precipitate*, and it dissolves in excess of the precipitant.

3. *Ammonia*, $NH_4O$, gives a *white precipitate* of hydrated binoxide of tin, $SnO_2,HO$, which is slightly soluble in excess.

4. *Potash*, $KO,HO$, yields a *white precipitate* of hydrated binoxide of tin, $SnO_2,HO$, which is readily soluble in excess.

5. *Carbonate of Potash*, $KO,CO_2$, forms a *white precipitate* of hydrated binoxide of tin, $SnO_2,HO$, which is soluble in potash.

6. *Metallic Zinc*, Zn, placed in a solution of the bichloride of tin with excess of hydrochloric acid, HCl, throws down *metallic tin*, Sn, in the form of a *grayish-black powder*, *scales*, or *spongy mass*.

7. *Blow-pipe test*. Compounds of the binoxide of tin, when mixed with the bicarbonate of soda, $NaO,HO,2CO_2$, and cyanide of potassium, KCy, placed on a charcoal support, and held in the inner flame of the blow-pipe, give *globules of metallic tin*, Sn.

### 153. Arsenious Acid, $AsO_3$.

**Arsenious Acid (Arsenic), $AsO_3$, may be used in testing.**

1. *Hydrosulphuric Acid*, HS, yields in acid solutions a *yellow precipitate* of sulph-arsenious acid, $AsS_3$. The presence of hydrochloric acid, HCl, greatly facilitates the formation of the precipitate, whilst there is no precipitation in an alkaline solution. The precipitate is insoluble in dilute acids, but is readily soluble in ammonia, $NH_4O$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, gives *no precipitate* with the solution of arsenious acid, until a free acid, such as hydrochloric acid, HCl, is added, when the

*yellow precipitate* of the sulph-arsenious acid, $AsS_3$, is thrown down.

3. *Ammonia*, $NH_4O$, produces *no precipitate.*

4. *Potash*, KO,HO, forms *no precipitate.*

5. *Ammonio-Sulphate of Copper*, $CuO,SO_3+NH_3$, when added in small quantity, throws down a *bright-green precipitate* of the arsenite of copper (Scheele's green), $2CuO,HO,AsO_3$, which is soluble in free acids and in free alkalies.

6. *Ammonio-Nitrate of Silver*, $AgO,NO_5 + NH_3$, forms a *yellow precipitate* of the arsenite of silver, $3AgO,AsO_3$, which is soluble in free acids and alkalies.

7. *Polished Copper*, Cu, introduced into a solution of arsenious acid, acidulated with hydrochloric acid, HCl, and heat applied, obtains an *iron-gray deposit*, which consist of a film of an alloy of copper and arsenic, $Cu_5,As$, and which readily separates in scales. When the film or scales are washed in water, dried, and then gently heated in a dry narrow test-tube, *minute crystals of arsenious acid*, $AsO_3$, are obtained in the upper part of the tube, which may be dissolved in water, and the three principal tests applied to the solution. The principal liquid tests are —*Hydrosulphuric Acid*, *Ammonio-Sulphate of Copper*, and *Ammonia-Nitrate of Silver.*

8. *Metallic Arsenic*, As, may also be obtained by mixing the arsenical compounds with bicarbonate of soda, $NaO,HO,2CO_2$, and cyanide of potassium, KCy, and heating the whole in the bulb of a Berzelius reduction tube (fig. 35), when *metallic arsenic*, As, will be formed, and will deposit in the upper part of the restricted

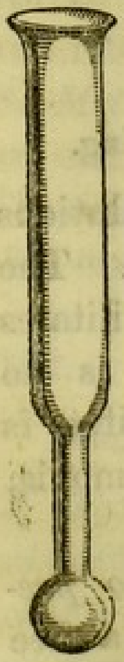

Fig. 35.

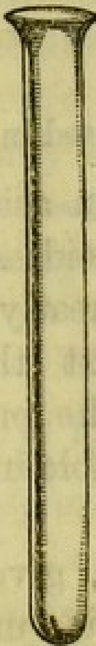

Fig. 36.

portion of the tube. The piece of glass with the deposit of the metal arsenic may be cut away, and being placed in an ordinary dry test-tube (fig. 36), will yield *crystals of arsenious acid*, $AsO_3$, which can be dissolved in water, and the liquid tests applied.

9. *Blow-pipe test.* When arsenious acid, $AsO_3$, or similar arsenical compound, is heated on charcoal in the inner flame of the blow-pipe, the vapours of *metallic arsenic*, As, are evolved, and a *strong garlic odour* is observed.

## 154. Arsenic Acid, $AsO_5$.

Arsenic Acid, $AsO_5$, may be employed in testing.

1. *Hydrosulphuric Acid*, HS, added to solutions of arsenic acid, along with hydrochloric acid, HCl, causes in course of time a *yellow precipitate* of sulph-arsenious acid, $AsS_3$, with the separation of 2 atoms of sulphur, $S_2$. The precipitate is not formed in alkaline or neutral solutions, and when produced in an acid solution, it is found to be insoluble in dilute acids, but is readily soluble in ammonia, $NH_4O$.

2. *Sulphide of Ammonium*, $NH_4S,HS$, causes *no precipitate* with the solution of arsenic acid, but if *hydrochloric acid*, HCl, be subsequently added, a *yellow precipitate* of the sulph-arsenic acid, $AsS_5$, is formed, which is insoluble in dilute acids, but is quickly dissolved by ammonia, $NH_4O$, or other alkaline solution.

3. *Ammonia*, $NH_4O$, produces *no precipitate*.

4. *Potash*, KO,HO, yields *no precipitate*.

5. *Ammonio-Sulphate of Copper*, $CuO,SO_3 + NH_3$, gives a *greenish-blue precipitate* of the arsenate of copper, $2CuO,HO,AsO_5$, which is soluble in acids and alkalies.

6. *Ammonio-Nitrate of Silver*, $AgO,NO_5 + NH_3$, forms a *reddish-brown precipitate* of the arsenate of silver, $3AgO,AsO_5$, which is soluble in acids and alkalies.

7. *Polished Copper*, Cu, placed in a solution of arsenic acid acidulated with hydrochloric acid, HCl, does not readily become coated with a stain or film; but if the acid be added till it is equal to twice the bulk of the liquid, then, on heating, the copper will acquire a coating of an alloy of copper and arsenic similar to that given by arsenious acid (par. 153, 7).

8. *Metallic Arsenic*, As, may be obtained from arsenic acid and its compounds by heating them with a mixture of bicarbonate of soda, $NaO,HO,2CO_2$, and cyanide of potassium, KCy, in the manner stated under arsenious acid (par. 153, 8).

9. *Blow-pipe test.* If arsenic acid, $AsO_5$, and its compounds are placed on a charcoal support and heated in the inner flame of the blow-pipe, the *strong garlic odour* of the escaping vapours of the *metal arsenic* will be observed.

155. *Concluding Remarks.*—The fourth group of metallic oxides is the last of the series relating to metals; for although there are more metals than those which have been considered under these four groups, yet they are not common, and are not likely to be encountered either pure or as compounds, except by chemists who devote much time to the examination of the rarer minerals, &c. During the course of the testing for the fourth group, it will have been observed that hydrochloric acid causes a precipitate when added to solutions of oxide of silver, oxide of lead (strong), suboxide of mercury, and also of teroxide of antimony (tartar emetic). As the latter precipitate disappears when more acid is added, care should always be taken that an excess of hydrochloric acid be employed, and when a precipitate is given and remains, it can only refer to oxide of silver, oxide of lead (strong), or the suboxide of mercury. The subsequent

addition of ammonia in excess to the precipitate, distinguishes between these three metallic oxides. A dilute solution of lead is not indicated by giving a precipitate with hydrochloric acid, but readily gives the other tests. In the systematic application of the tests, care should be taken to add in every case the hydrosulphuric acid till the mixed liquids smell strongly of the acid, as otherwise a lighter-coloured precipitate may be obtained than what the full action will yield, and the experimenter be thus led into error. The yellow precipitates given on the addition of the hydrosulphuric acid to the solutions of the oxide of cadmium, the peroxide of tin, arsenious acid and arsenic acid, may readily be divided into two subclasses by the addition of ammonia in excess, which dissolves at once the arsenical precipitates, but leaves undissolved the precipitates given by tin and cadmium. These and other distinctions between the various metallic oxides of this group are fully stated in the systematic course at pars. 200 and 204—209, and the student should now have placed in his hands a number of solutions of metallic oxides belonging to the fourth and preceding groups, and should examine these by the systematic course, so that he may fully understand the mode of the application of the tests in the most ready and certain manner. Having become familiar with the detection of the metallic oxides, he may then enter on the consideration of the acids.

## Testing of the Acids.

156. The acid substances which form the second half of the majority of compounds are classified under two divisions: 1st, the *Inorganic Acids*, or those which are

derived from the mineral kingdom; and 2d, the *Organic Acids,* or those which are directly or indirectly obtained from the vegetable or animal kingdoms. The acids belonging to either class, and which are known to chemists, are numerous; but there are many of these which are not common, and indeed are very rare, and we shall only refer to those which are likely to be encountered in everyday-life. Generally, the Organic Acids may be recognised from the Inorganic Acids by the charring or decomposition which occurs on the application of heat, and a special table will be devoted to the consideration of these Organic Acids; but there are two acids of organic origin, oxalic acid and hydrocyanic acid, which, alike from the non-charring which many of their compounds exhibit when heated, and also from their giving indications in testing which are similar to some of the inorganic acids, render it necessary that they should be associated with the inorganic acids during the course of testing.

157. Two of the inorganic acids have already been discussed under the metallic oxides—viz., arsenious acid and arsenic acid—and we have now to consider other seventeen acid substances which must be treated of under the inorganic division. These acids are capable of being classified into groups according to the mode in which certain group tests act upon them, and the reagents which are serviceable in arranging the inorganic acids are a solution of a salt of barium, such as the nitrate of baryta or the chloride of barium, and a solution of silver, such as the nitrate of silver. The classification of the inorganic acids will be observed from the following table:

## 158. Table of the Group Tests for the Inorganic Acids.

| FIRST GROUP. | SECOND GROUP. | THIRD GROUP. |
|---|---|---|
| Nitrate of Baryta, $BaO,NO_5$, to neutral solution,.........*A precipitate.* | Nitrate of Baryta, $BaO,NO_5$, to neutral solution,........*No precipitate.* | Nitrate of Baryta, $BaO,NO_5$, to neutral solution,.......*No precipitate.* |
| If the solution under examination is acid to test-papers, it must be rendered neutral by the addition of a few drops of ammonia before the nitrate of baryta can be applied. | Nitrate of Silver, $AgO,NO_5$, to solution acidified with Nitric Acid, *A precipitate.* | Nitrate of Silver, $AgO,NO_5$, to solution acidified with Nitric Acid, *No precipitate.* |
| MEMBERS OF THE GROUP. | MEMBERS OF THE GROUP. | MEMBERS OF THE GROUP. |
| Chromic Acid,......................$CrO_3$. | Hydrochloric Acid,...........HCl. | Nitric Acid,.........................$NO_5$. |
| Sulphuric Acid,......................$SO_3$. | Hydrocyanic Acid,............HCy. | Chloric Acid,.........................$ClO_5$. |
| Phosphoric Acid,...................$PO_5$. | Hydriodic Acid,................HI. | |
| Boracic Acid,.........................$BO_3$. | Hydrobromic Acid,........ ..HBr. | |
| Oxalic Acid,.........................$\bar{O}$. | Hydrosulphuric Acid,........HS. | |
| Hydrofluoric Acid,.................HF. | Hydroferrocyanic Acid,.....2H,Cfy. | |
| Carbonic Acid,......................$CO_2$. | Hydroferridcyanic Acid,....3H,2Cfy. | |
| Silicic Acid,.........................$SiO_2$. | | |

In order that the above classification of the inorganic acids may be firmly impressed on the memory, several acids from the first, second, and third groups should be taken, and the group tests applied to each.

## Inorganic Acids.—First Group.

159. *Preliminary Remarks.*—The acids in this group are distinguished from the acids in the remaining groups by the production of a precipitate on the addition of nitrate of baryta to a neutral solution. Several members of the group are likewise precipitated by nitrate of silver, but in every case the silver precipitates with the acids of this group are soluble in dilute nitric acid.

### 160. Table of the First Group of Inorganic Acids.

| | |
|---|---|
| Character of the Group. | Nitrate of Baryta, $BaO,NO_5$, added to neutral solution,............................*A precipitate.* |

---

**Special Characters.**

| Inorganic Acids. | Nitrate of Baryta, $BaO,NO_5$. | |
|---|---|---|
| Chromic Acid, $CrO_3$,............ | *Yellow pre.*, sol. in HCl,... | $AgO,NO_5$ gives a *purple-red pre.*, sol. in $NO_5$ and in $NH_4O$.<br>$PbO,\bar{A}$ yields a *yellow pre.*, sol. in $KO,HO$.<br>HS produces a *green solution, with separation of* S. |
| Sulphuric Acid, $SO_3$,............... | *White pre.*, insol. in HCl, | $NaO,HO,2CO_2$ and C, mingled with solution of $SO_3$, and heated in the inner flame of blow-pipe = NaS, which when placed in HCl *evolves* HS *as gas.* |
| Phosphoric Acid, $PO_5$,............... | *White pre.*, sol. in HCl, without effervescence,...... | $AgO,NO_5$ forms a *yellow pre.*, sol. in $NO_5$.<br>$MgO,SO_3$ and $NH_4O$ give a *white pre.*<br>$KO,CO_2$, then $\bar{A}$ and $Fe_2,Cl_3$, yield *white pre.*<br>$NH_4O,MoO_3$ and HCl, heat in tube, give *yellow sol.* or *pre.* |

**Special Characters—Continued.**

| Inorganic Acids. | Nitrate of Baryta, $BaO,NO_5$. | |
|---|---|---|
| Boracic Acid, $BO_3$, .............. | *White pre.*, sol. in HCl, without effervescence,........ | Add HCl, dip in turmeric paper and dry, = *bright-red colour.*<br>Add $SO_3$ and alcohol, heat in capsule, give *green flame.* |
| Oxalic Acid, $\overline{O}$,... | *White pre.*, sol. in HCl, without effervescence,...... | Add CaCl, which gives a *white pre.*, sol. in $NO_5$ or HCl.<br>Add $SO_3$ to solid in test-tube and heat; when gas escapes, set fire to, and it burns with *blue flame.* |
| Carbonic Acid, $CO_2$,............. | *White pre.*, sol. in HCl, with effervescence, | Add CaCl, which yields a *white pre.*, sol. in HCl, with effervescence. |
| Hydrofluoric Acid, HF,...... | *White pre.*, sol. in HCl, without effervescence,...... | Add CaCl, which gives a *gelatinous pre.*<br>Add $SO_3$ to solid in platinum or lead vessel, covered with glass, and heat, = *glass etched.* |
| Silicic Acid, $SiO_2$, | *White pre.*, sol. in HCl, with separation of silica in a gelatinous form. | |

## 161. Chromic Acid, $CrO_3$.

Bichromate of Potash, $KO,2CrO_3$, may be employed in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, added to neutral or alkaline solutions, yields a *yellow precipitate* of chromate of baryta, $BaO,CrO_3$, which is soluble in hydrochloric acid, HCl, and in nitric acid, $HO,NO_5$. If the solution is acid, it should be rendered neutral by ammonia, $NH_4O$, before the nitrate of baryta is added. *Chloride of Barium*, BaCl, produces the *same precipitate*.

2. *Nitrate of Silver*, $AgO,NO_5$, throws down a *purple-red precipitate* of the chromate of silver, $AgO,CrO_3$, which dissolves in nitric acid, $HO,NO_5$, and in ammonia, $NH_4O$.

3. *Acetate of Lead*, $PbO,\bar{A}$, gives a *yellow precipitate* of the chromate of lead, $PbO,CrO_3$, which is difficultly soluble in nitric acid, $HO,NO_5$, but is soluble in excess of potash, $KO,HO$.

4. *Hydrosulphuric Acid*, $HS$, produces slowly a *green solution, with separation of sulphur*, $S$, which is due to the reduction of the chromic acid, $CrO_3$, to the condition of oxide of chromium, $Cr_2O_3$. This reaction is so decided, as to lead to the detection of the chromic acid during the testing of the metallic oxides by the addition of hydrosulphuric acid.

## 162. Sulphuric Acid, $HO,SO_3$.

Sulphate of Soda, $NaO,SO_3$, may be used in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, throws down a *white precipitate* of *Sulphate of Baryta*, $BaO,SO_3$, which is insoluble in hydrochloric acid, $HCl$, and other acids, and in alkalies. *Chloride of Barium* produces the *same precipitate*.

2. *Bicarbonate of Soda*, $NaO,HO,2CO_2$, and *Charcoal*, $C$, mingled with sulphuric acid or a sulphate, and heated on a platinum wire in the inner flame of the blow-pipe till a clear drop of liquid is obtained, leave on cooling a bead of *fused sulphide of sodium*, $NaS$; and when this bead is introduced into a test-glass containing dilute hydrochloric acid, —$HCl$, minute bells of hydrosulphuric acid gas, $HS$, are disengaged. The escaping gas may be recognised by the *disagreeable odour* and by the *blackening* of a piece of paper dipped in a solution of acetate of lead, $PbO,\bar{A}$.

3. *Acetate of Lead*, $PbO,\bar{A}$, gives a *white precipitate* of the sulphate of lead, $PbO,SO_3$, which is soluble in excess of potash, $KO,HO$.

### 163. Phosphoric Acid, $PO_5$.

Ordinary tribasic Phosphate of Soda, $2NaO,HO,PO_5$, may be employed in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, throws down a *white precipitate* of the phosphate of baryta, $2BaO,HO,PO_5$, or $3BaO,PO_5$, which readily dissolves on addition of hydrochloric acid, $HCl$, or nitric acid, $HO,NO_5$. *Chloride of Barium*, $BaCl$, gives the *same precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, yields a *yellow precipitate* of the phosphate of silver, $3AgO,PO_5$, which is soluble in nitric acid, $HO,NO_5$, and in ammonia, $NH_4O$.

3. *Sulphate of Magnesia*, $MgO,SO_3$, and *Ammonia*, $NH_4O$, produce a *white precipitate* of the phosphate of magnesia and ammonia, $2MgO,NH_4O,PO_5$, which is readily soluble in acids.

4. *Carbonate of Potash*, $KO,CO_2$, *Acetic Acid*, $\bar{A}$, to slight acid reaction, and subsequently a few drops of *Sesquichloride of Iron*, $Fe_2Cl_3$, yield a *white gelatinous precipitate* of the phosphate of the sesquioxide of iron, $Fe_2O_3,PO_5 + 4Aq$.

5. *Molybdate of Ammonia*, $NH_4O,MoO_3$, added in very small quantity to the solution containing the phosphoric acid, and a few drops of *dilute Hydrochloric Acid*, $HCl$, give, on heating, a *yellow precipitate* or *solution* which contains molybdic acid, phosphoric acid, and ammonia. This test is very delicate, and will indicate very small quantities.

6. *Chloride of Calcium*, $CaCl$, or *Sulphate of Lime*, $CaO,SO_3$, yields in neutral or alkaline solutions *white precipitates* of the phosphate of lime, $2CaO,HO,PO_5$, or

$3CaO,PO_5$, which is soluble in acetic acid, $HO,\bar{A}$, and other acids.

### 164. Boracic Acid, $BO_3$.

Biborate of Soda (Borax), $NaO,HO,2BO_3$, may be used in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, gives a *white precipitate* of borate of baryta, $BaO,BO_3$, or $3BaO,5BO_3$, which is readily soluble in hydrochloric acid, HCl, and other acids, and in ammonia, $NH_4O$. *Chloride of Barium*, BaCl, forms the *same precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, throws down from strong solutions of borates a *white precipitate* of the borate of silver, $AgO,BO_3$, or $3AgO,4BO_3$, which readily dissolves in nitric acid, $HO,NO_5$, and ammonia, $NH_4O$.

3. *Chloride of Calcium*, CaCl, forms a *white precipitate* of the borate of lime, $CaO,BO_3$, which is soluble in acids, including acetic acid, $HO,\bar{A}$.

4. *Hydrochloric Acid*, HCl, added to a solution of a compound of a borate, liberates the boracic acid, $BO_3$, therefrom, and when *turmeric paper* is dipped into the mixture, and then dried, the paper acquires a *fine red tint.*

5. *Sulphuric Acid*, $HO,SO_3$, added to a borate, liberates the boracic acid, $BO_3$, and on the addition of alcohol, and heating the whole in a capsule, a decided *green flame* is obtained.

### 165. Oxalic Acid, $HO,C_2O_3 = HO,\bar{O}$.

Oxalate of Ammonia, $NH_4O,\bar{O}$, may be employed in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, produces in neutral or alkaline solutions a *white precipitate* of the oxalate of baryta, $BaO,\bar{O}$, which is soluble in hydrochloric acid, HCl, and other acids. *Chloride of Barium*, BaCl, will yield the *same precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, gives in neutral solutions a *white precipitate* of oxalate of silver, $AgO,\bar{O}$, which is soluble in nitric acid, $HO,NO_5$.

3. *Chloride of Calcium*, $CaCl$, or *Sulphate of Lime*, $CaO,SO_3$, forms a *white precipitate* of the *Oxalate of Lime*, $CaO,\bar{O}$, which is soluble in hydrochloric acid, $HCl$, and nitric acid, $HO,NO_5$, but is not soluble in acetic acid, $HO,\bar{A}$.

4. *Concentrated Sulphuric Acid*, $HO,SO_3$, added to solid oxalic acid, or an oxalate, and the mixture heated in a test-tube, gives rise to the disengagement of the *two gases*, carbonic acid, $CO_2$, and carbonic oxide, $CO$, and when set fire to, the latter burns with a *characteristic pale-blue flame.*

### 166. Carbonic Acid, $CO_2$.

Carbonate of Soda, $NaO,CO_2$, may be used in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, gives a *white precipitate* of the carbonate of baryta, $BaO,CO_2$, which is soluble in hydrochloric acid, $HCl$, with effervescence. *Chloride of Barium*, $BaCl$, yields the *same precipitate.*

2. *Chloride of Calcium*, $CaCl$, forms a *white precipitate* of the carbonate of lime, $CaO,CO_2$, which is soluble in hydrochloric acid, $HCl$, with effervescence.

3. *Hydrochloric Acid*, $HCl$, or other acid solution, added to the solid carbonate in a test-glass, evolves abundantly the carbonic acid gas, $CO_2$, and if this gas be allowed to flow over into a glass containing lime-water, $CaO,Aq$, or baryta-water, $BaO,Aq$, the latter becomes of a milky appearance, owing to the formation respectively of carbonate of lime, $CaO,CO_2$, or of carbonate of baryta, $BaO,CO_2$.

### 167. Hydrofluoric Acid, HF.

The Fluoride of Sodium, NaF, may be employed in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, produces a *white precipitate* of the fluoride of barium, BaF, which is soluble in hydrochloric acid without effervescence or separation of gaseous particles. *Chloride of Barium*, BaCl, gives the *same precipitate*.

2. *Chloride of Calcium*, CaCl, forms a *white gelatinous precipitate* of the fluoride of calcium, CaF.

3. *Concentrated Sulphuric Acid*, $HO,SO_3$, added to the solid fluoride, such as fluoride of calcium, or fluor spar, CaF, in a platinum or lead capsule, and slightly heated, evolves fumes of hydrofluoric acid, HF, which etch glass. The etching is best observed by coating the glass with bees-wax, and removing certain parts with a pencil; and when the fumes impinge upon the glass, they only act upon and eat into the exposed parts, whilst those portions which are covered with wax are unacted upon.

### 168. Silicic Acid, $SiO_2$.

Silicate of Soda, $NaO,SiO_2$, may be used in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, throws down a *white precipitate* of the silicate of baryta, $BaO,SiO_2$, which is decomposed on the addition of an excess of hydrochloric acid, HCl, and at the same time the silica, $SiO_2$, is separated in a gelatinous form.

169. *Concluding Remarks.*—The inorganic acids of the first group are readily separated from each other. The yellow colour of the solution of the compound of chromic acid is indicative of the presence of that acid, and the tests of nitrate of baryta giving a yellow precipitate, and hydrosulphuric acid yielding a green solution, are

confirmatory. Sulphuric acid is definitely recognised by the white precipitate with the nitrate of baryta being insoluble in hydrochloric acid. Phosphoric acid is recognised by giving a white precipitate with nitrate of baryta, which dissolves in hydrochloric acid without effervescence, and by yielding a yellow precipitate with nitrate of silver, which is soluble in nitric acid. Boracic is known by the white precipitate with nitrate of baryta being soluble in hydrochloric acid without effervescence, and by communicating the red tint to the turmeric paper when the paper has been dipped in the mixture of the solution of boracic acid and hydrochloric acid, and dried. Oxalic acid may be determined in the absence of phosphoric and boracic acids by the white precipitate with chloride of calcium, and by the sulphuric acid decomposing the salt and liberating carbonic acid and carbonic oxide, the latter burning with a blue flame. Carbonic acid is at once observed by the effervescence when hydrochloric acid is added; and the hydrofluoric and silicic acids, which are less commonly met with, by the special tests given under these acids.

## Inorganic Acids.—Second Group.

170. *Preliminary Remarks.*—The members of this group are not precipitated by nitrate of baryta under any circumstances, but they are precipitated by nitrate of silver in the presence of dilute nitric acid. They are thus distinguished from the acids of the first group, which are precipitated by nitrate of baryta, and whose precipitates with nitrate of silver are soluble in dilute nitric acid.

The second group is readily distinguished from the third group of inorganic acids, as the latter is not precipitated by nitrate of silver under any circumstances.

### 171. Table of the Second Group of Inorganic Acids.

| | | |
|---|---|---|
| Characters of the Group. | Nitrate of Baryta, $BaO,NO_5$,.... | *No precipitate.* |
| | Nitrate of Silver, $AgO,NO_5$,.. | *A precipitate,* insol. in dilute nitric acid —$NO_5$. |

---

**Special Characters.**

| Inorganic Acids. | Nitrate of Silver, $AgO,NO_5$. | |
|---|---|---|
| Hydrocyanic Acid, HCy,.... | *White pre.*, insol. in —$NO_5$, but sol. in $NH_4O$,......... | $FeO,SO_3$, $Fe_2Cl_3$, $KO,HO$, and HCl in excess, give a *Prussian-blue solution* or *precipitate.*<br>$NH_4S + S$, added to solution, and dried up, yields with $Fe_2Cl_3$ a *blood-red solution.*<br>Add $SO_3$ to solution, and the *odour of Prussic acid* is evolved. |
| Hydrochloric Acid, HCl,..... | *White pre.*, insol. in —$NO_5$, but sol. in $NH_4O$, ........ | $Hg_2O,NO_5$ gives a *white pre.*, insol. in —$NO_5$.<br>$MnO_2$ and $SO_3$, added to solution, and heated in test-tube, evolve *chlorine gas*, with *green colour* and *strong odour.* |
| Hydriodic Acid, HI,............... | *Yellow pre.*, insol. in —$NO_5$, and difficultly sol. in $NH_4O$, | $PbO,\bar{A}$ gives a *yellow pre.*<br>HgCl yields a *scarlet pre.*, soluble in either solution.<br>Starch and Cl (or $NO_5$) produce a *blue pre.*<br>$MnO_2$ and $SO_3$, added to solution, and heated in test-tube, evolve *iodine gas*, with *violet colour* and *strong odour.* |

**Special Characters—Continued.**

| Inorganic Acids. | Nitrate of Silver, $AgO,NO_5$. | |
|---|---|---|
| Hydrobromic Acid, HBr,..... | *Yellow - white pre.*, insol. in —$NO_5$, and difficultly sol. in $NH_4O$,..... | Starch and Cl (or $NO_5$) form a *yellow colour*.<br>$MnO_2$ and $SO_3$, added to solution, and heated in test-tube, evolve *bromine vapour*, with *brownish-red colour* and *strong odour*.<br>Add Cl to solution, then ether, and agitate, = *ethereal solution of bromine*. |
| Hydrosulphuric Acid, HS,...... | *Black pre.*, insol. in —$NO_5$ and $NH_4O$,... | $PbO,\bar{A}$ gives a *black pre.*<br>$PbO,\bar{A}$ and $NaO,HO$ give *black solution* in very dilute liquids.<br>Nitroprusside of sodium and soda give *reddish-violet solution* |
| Hydroferrocyanic Acid, 2H,Cfy,......... | *White pre.*, insol. in —$NO_5$ and $NH_4O$,... | $Fe_2Cl_3$ yields a *deep Prussian-blue pre.*<br>$CuO,SO_3$ produces a *ruddy-brown pre.*<br>$PbO,\bar{A}$ forms a *yellow-white pre.* |
| Hydroferridcyanic Acid, 3H,2Cfy,........ | *Orange pre.*, insoluble in —$NO_5$, but sol. in $NH_4O$, | $Fe_2Cl_3$ gives a *brown solution.*<br>$CuO,SO_3$ produces a *yellow-green pre.*<br>$FeO,SO_3$ forms a *deep Prussian-blue pre.*<br>$PbO,\bar{A}$ yields a *yellow-white pre.* |

### 172. Hydrocyanic Acid, $HC_2N = HCy$.

Cyanide of Potassium, KCy, may be employed in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, gives *no precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, produces a *white curdy precipitate* of the cyanide of silver, AgCy, which is

insoluble in dilute nitric acid, $HO,NO_5$, but is soluble in ammonia, $NH_4O$, and in cyanide of potassium, KCy.

3. *Sulphate of Iron*, $FeO,SO_3$, *Perchloride of Iron*, $Fe_2Cl_3$, *Potash*, KO,HO, and *Hydrochloric Acid*, HCl, added together to the solution containing hydrocyanic acid, give rise to the formation of Prussian-blue, 4Fe,3Cfy, which, if in very small quantity, may appear of a green tinge.

4. *Yellow Sulphide of Ammonium*, $NH_4S + S$, added in small quantity to the cyanide solution, and evaporated to dryness, leaves a residue of sulphocyanide of ammonium, $NH_4,CyS_2$, which yields, with perchloride of iron, $Fe_2Cl_3$, a *blood-red colour* of sulphocyanide of iron, which is readily *bleached* on the addition of chloride of mercury, HgCl.

5. *Sulphuric Acid*, $HO,SO_3$, added to a cyanide, liberates the hydrocyanic acid, $HC_2N$, *as gas*, which may be recognised by its peculiar bitter-almond odour, and by forming a *white film*, cyanide of silver, AgCy, on a watch-glass, which has been previously moistened with nitrate of silver, $AgO,NO_5$, and held over the testing vessel.

### 173. Hydrochloric Acid, HCl.

Chloride of Calcium, CaCl, may be used in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, yields *no precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, forms a *white curdy precipitate* of chloride of silver, AgCl, which is insoluble in dilute nitric acid, $HO,NO_5$, but is readily soluble in ammonia, $NH_4O$, and in cyanide of potassium, KCy.

3. *Protonitrate of Mercury*, $Hg_2O,NO_5$, produces a *white precipitate* of the subchloride of mercury (calomel), $Hg_2Cl$, which is insoluble in dilute nitric acid, $HO,NO_5$, and turns black on the addition of ammonia, $NH_4O$.

4. *Binoxide of Manganese*, $MnO_2$, and *concentrated*

*sulphuric acid*, $HO,SO_3$, added to a solution of a chloride in a test-tube, and gently heated, give rise to the *evolution of chlorine gas*, Cl, which is recognised by its *disagreeable suffocating odour*, and, when in quantity, by its *green colour*.

### 174. Hydriodic Acid, HI.

Iodide of Potassium, KI, may be employed in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, yields *no precipitate*.

2. *Nitrate of Silver*, $AgO,NO_5$, throws down a *yellow precipitate* of the iodide of silver, AgI, which is insoluble in dilute nitric acid, $HO,NO_5$, is difficultly soluble in ammonia, $NH_4O$, but is readily dissolved by cyanide of potassium, KCy.

3. *Acetate of Lead*, $PbO,\bar{A}$, gives a *yellow precipitate* of the iodide of lead, PbI.

4. *Chloride of Mercury*, HgCl, produces a *scarlet precipitate* of the iodide of mercury, HgI, which is soluble in excess of either solution.

5. *Starch and Chlorine*, Cl, or *Nitric Acid*, $HO,NO_5$, form the *dark-blue precipitate* or *solution* of the iodide of starch.

6. *Binoxide of Manganese*, $MnO_2$, and *concentrated sulphuric acid*, $HO,SO_3$, added to the iodide in solution in a test-tube, and cautiously heated, *evolve the vapours of free iodine*, I, which may be recognised by the *fine purple colour* and the *irritating disagreeable odour*.

### 175. Hydrobromic Acid, HBr.

Bromide of Potassium, KBr, may be used in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, produces *no precipitate*.

2. *Nitrate of Silver*, $AgO,NO_5$, forms a *yellowish-white precipitate* of the bromide of silver, AgBr, which is not dissolved on the addition of dilute nitric acid, $HO,NO_5$,

but is difficultly soluble in ammonia, $NH_4O$, and readily soluble in cyanide of potassium, KCy.

3. *Starch and Chlorine*, Cl, or *Nitric Acid*, $HO,NO_5$, form with a compound of bromine only a *yellow colour*, owing to the formation of the yellow bromide of starch.

4. *Binoxide of Manganese*, $MnO_2$, and *concentrated sulphuric acid*, $HO,SO_3$, added to a bromide in a test-tube, and heated cautiously, cause the *evolution of bromine vapour*, Br, which is characterised by a *brownish-red colour* and a very decided *disagreeable suffocating odour.*

5. *Chlorine Gas*, Cl, allowed to impinge upon a solution of a bromide, *liberates the bromine*, Br, which communicates a *yellow* to a *brownish-red* colour to the liquid, and thereafter on adding ether to the solution, agitating briskly, and allowing the whole to settle, the ether dissolves and floats up the bromine, and yields a *brownish-red ethereal solution of bromine.*

### 176. Hydrosulphuric Acid, HS.

Sulphide of Ammonium, $NH_4S,HS$, may be employed in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, yields *no precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, gives a *black precipitate* of the sulphide of silver, AgS, which is insoluble in dilute nitric acid, $HO,NO_5$, and in ammonia, $NH_4O$.

3. *Acetate of Lead*, $PbO,\bar{A}$, produces a *black precipitate* of the sulphide of lead, PbS. This test is rendered more delicate if the acetate of lead be treated with caustic soda, NaO,HO, till the precipitate which forms at first is dissolved, and the solution thus obtained is used in the testing for the sulphide or for hydrosulphuric acid.

4. *Nitroprusside of Sodium*, with the addition of soda, forms with soluble sulphur compounds a fine *reddish-violet solution*, which is a delicate test for sulphur.

### 177. Hydroferrocyanic Acid, 2H,Cfy.

**Ferrocyanide of Potassium, 2K,Cfy, may be used in testing.**

1. *Nitrate of Baryta*, $BaO,NO_5$, forms *no precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, yields a *white precipitate* of the ferrocyanide of silver, 2Ag,Cfy, which does not dissolve in nitric acid, $HO,NO_5$, or in ammonia, $NH_4O$, but is readily soluble in cyanide of potassium, KCy.

3. *Perchloride of Iron*, $Fe_2,Cl_3$, gives a deep *Prussian-blue precipitate* of the ferrocyanide of iron, 4Fe,3Cfy, which is unaltered by dilute acids, but is decomposed into a *red-brown precipitate* by potash, KO,HO, or other alkalies.

4. *Sulphate of Copper*, $CuO,SO_3$, throws down a *bulky ruddy-brown precipitate* of the ferrocyanide of copper, 2Cu,Cfy, which is unaffected by dilute acids, but is decomposed by potash, KO,HO, and other alkalies.

5. *Acetate of Lead*, $PbO,\overline{A}$, produces a *yellow-white precipitate* of the ferrocyanide of lead, 2Pb,Cfy.

### 178. Hydroferridcyanic Acid, 3H,2Cfy.

**Ferridcyanide of Potassium, 3K,2Cfy, may be employed in testing.**

1. *Nitrate of Baryta*, $BaO,NO_5$, yields *no precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, produces an *orange precipitate* of the ferridcyanide of silver, 3Ag,2Cfy, which is insoluble in dilute nitric acid, $HO,NO_5$, but is soluble in ammonia, $NH_4O$, and in cyanide of potassium, KCy.

3. *Perchloride of Iron*, $Fe_2Cl_3$, gives merely a *brown colour.*

4. *Sulphate of Copper*, $CuO,SO_3$, throws down a *yellow-green precipitate* of the ferridcyanide of copper, 3Cu,2Cfy.

5. *Sulphate of Iron*, $FeO,SO_3$, produces a *deep Prussian-blue precipitate* of the protoferridcyanide of iron,

$3Fe,2Cfy$, which is unaltered by dilute acids, but is decomposed to a *brown precipitate* by means of potash, $KO,HO$, or other alkalies.

6. *Acetate of Lead*, $PbO,\bar{A}$, yields a *yellow-white precipitate* of the ferridcyanide of lead, $3Pb,2Cfy$.

179. *Concluding Remarks.*—The acids which belong to the second group are readily recognisable from each other. Hydrocyanic acid cannot be mistaken for any other substance in the production of the Prussian-blue test with the salts of iron, and the sulphur test leading to the development of the blood-red solution on the addition of perchloride of iron. Hydrochloric, hydriodic, and hydrobromic acids are accurately determined by the reactions with nitrate of silver, and by the oxide of manganese and sulphuric acid evolving the radicals present in each—viz., the chlorine, iodine, and bromine, with the characteristic colours and odours of these substances. Hydrosulphuric acid is at once indicated by the black precipitate which it gives either with a solution of silver or of lead. The two remaining acids—viz., hydroferrocyanic and hydroferridcyanic acids—are readily indicated by the tests with perchloride of iron and sulphate of iron.

## Inorganic Acids.—Third Group.

180. *Preliminary Remarks.*—The acids of the third group are only two in number, and they are distinguished from the two preceding groups of inorganic acids by giving no precipitates with either nitrate of baryta or with nitrate of silver. Two of the special characters are so characteristic of this group, that they may be regarded as supplementing the group tests, and deciding with

certainty as to the presence of either of the acids which constitute the third group. These special tests are the decolorising of the indigo solution, and the deflagration on charcoal, both of which tests are only given by nitric acid, or chloric acid, or their compounds.

### 181. Table of the Third Group of Inorganic Acids.

| | | |
|---|---|---|
| Characters of the Group. | Nitrate of Baryta, $BaO,NO_5$, | *No precipitate.* |
| | Nitrate of Silver, $AgO,NO_5$, | *No precipitate.* |

---

#### Special Characters.

| Inorganic Acids. | |
|---|---|
| Nitric Acid, $NO_5$,...... | Add sulphoindigotic acid and $HO,SO_3$, heat in tube, = *decoloration.*<br>Heat nitrate on charcoal before the blow-pipe, = *deflagration.*<br>Add copper and $HO,SO_3$, heat in tube, = *orange-red fumes of* $NO_4$.<br>Add $FeO,SO_3$ and $HO,SO_3$ to solution of nitrate, = *dark-brown colour.* |
| Chloric Acid, $ClO_5$,.... | Add sulphoindigotic acid and $HO,SO_3$, heat in tube, = *decoloration.*<br>Heat chlorate on charcoal before the blow-pipe, = *deflagration.*<br>Add copper and $HO,SO_3$, heat in tube, = *no orange-red fumes.*<br>Add $FeO,SO_3$ and $HO,SO_3$ to solution of chlorate, = *no dark-brown colour.*<br>When a chlorate, $KO,ClO_5$, is dried and ignited, it passes into a chloride, $KCl$, and its solution can then be tested for hydrochloric acid, $HCl$, by nitrate of silver, &c. |

### 182. Nitric Acid, $NO_5$.

Nitrate of Potash, $KO,NO_5$, may be employed in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, gives *no precipitate.*
2. *Nitrate of Silver*, $AgO,NO_5$, yields *no precipitate.*
3. *Sulphoindigotic Acid* added to the solution of the

nitrate till it is coloured distinctly blue, then a few drops of *concentrated sulphuric acid*, $HO,SO_3$, and the whole heated in a test-tube, when the *blue shade is decolorised.*

4. A fragment of the *solid nitrate*, when placed *on charcoal* and heated before the blow-pipe, causes the very rapid combustion of the charcoal, and consequent *deflagration.*

5. *Metallic Copper*, Cu, and some drops of *concentrated sulphuric acid*, $HO,SO_3$, added to the solution of a nitrate in a test-tube, and heated, gives rise to the disengagement of *orange-red fumes* of hyponitric acid gas, $NO_4$.

6. *Protosulphate of Iron*, $FeO,SO_3$, mingled with the nitrate solution and *concentrated sulphuric acid*, $HO,SO_3$, subsequently poured down the side of the vessel, give rise to a *dark-brown colour*, which will be observed at the junction of the two layers of liquid. A crystal of the protosulphate of iron will be similarly coloured.

### 183. Chloric Acid, $ClO_5$.

Chlorate of potash, $KO,ClO_5$, may be used in testing.

1. *Nitrate of Baryta*, $BaO,NO_5$, produces *no precipitate.*

2. *Nitrate of Silver*, $AgO,NO_5$, gives *no precipitate.*

3. *Sulphoindigotic Acid*, mingled with the solution of the chlorate, imparts a blue colour, which, on the addition of a few drops of *concentrated sulphuric acid*, $HO,SO_3$, and heating in a test-tube, undergoes *decoloration.*

4. A crystal of a *chlorate* placed on *charcoal*, and heated by the blow-pipe, gives rise to rapid combustion of the charcoal and *deflagration.*

5. *Metallic Copper*, Cu, and a few drops of *concentrated sulphuric acid*, $HO,SO_3$, mixed with the chlorate in a test-tube, and heated, *do not evolve orange-red fumes.*

6. *Protosulphate of Iron*, $FeO,SO_3$, and *concentrated*

*sulphuric acid*, $HO,SO_3$, added to a chlorate, *do not produce a dark-brown colour*.

7. A *chlorate*, such as chlorate of potash, $KO,ClO_5$, when ignited in a capsule or spoon, loses its oxygen, and becomes a chloride, such as chloride of potassium, $KCl$; and when the residue is dissolved in water, the solution gives an abundant *white precipitate* with nitrate of silver, and the other tests which are characteristic of chlorides or hydrochloric acid (par. 173).

184. *Concluding Remarks.*—The two acids of the third group of inorganic acids are most readily distinguished from each other by the test with copper and sulphuric acid, which evolves a red-brown gas if nitric acid is present, and no red-brown gas if chloric acid is the acid. The photosulphate of iron and sulphuric acid test is an excellent confirmatory character.

185. The three groups of inorganic acids can be conveniently arranged in one table in the course of systematic testing of *unknown* substances, and the student is referred to a subsequent part of the treatise (pars. 218, 220—226) for the order in which the various group tests and special characters should be applied, so as to be able to indicate, in the quickest and most certain manner what particular acid substance may be present in a solution or solid which may be handed to him. It will be profitable for the experimenter to receive at this part of the course of testing about twenty unnamed solutions, each containing one of the various acids, and probably some containing no acid, for the purpose of practically becoming conversant with the mode of applying the tests in a systematic manner.

186. And let me add one word of caution as to the hasty testing of unknown substances. In the testing of ordinary acid substances, or salts containing the acids, it

often happens that the medicinal and commercial substances contain slight impurities, and that the principal or primary acid of a substance may be mixed or contaminated with a minute quantity of another or secondary acid. Thus, phosphate of soda generally contains a little sulphate of soda, and hence, besides the larger proportion of phosphoric acid, a small quantity of sulphuric acid will be found; cyanide of potassium generally contains more or less carbonate of potash, accompanied by some oxalate of potash, and hence the carbonic and oxalic acids will indicate a precipitate with nitrate of baryta, which the principal acid—viz., the hydrocyanic acid—would not do; and the nitrate of potash is seldom free from chloride of potassium, and accordingly the solution of the salt will give an indication with nitrate of silver, owing to the hydrochloric acid being present as an impurity, whilst the nitric acid is the principal acid present in the solution. These illustrations will suffice to shew the experimenter the absolute need of applying as many confirmatory tests as possible to the unknown substance, so that he may not fail to detect the principal acid component in a saline mixture.

## The Organic Acids.

187. *Preliminary Remarks.*—The acids of this series are very numerous, and a statement as to the properties of each would occupy much more space than it is possible to give. The majority of organic acids, however, are rare substances, and are not likely to be met with in the course of ordinary testing; and hence, in the present treatise, the examination of these acids will be confined

to eight members of the group which are of common occurrence. Four of these acids have already been considered along with the inorganic acids—viz., oxalic, hydrocyanic, hydroferrocyanic, and hydroferridcyanic acids—and the remaining four, we have now to proceed to examine.

## 188. Table of the Organic Acids.

Character of the Group. ………………… When the acids or their compounds are heated, *they are decomposed, and evolve fumes and char.*

**Special Characters.**

| Organic Acids; Neutral Solutions. | Chloride of Calcium, $CaCl$. | Sesquichloride of Iron, $Fe_2Cl_3$. | |
|---|---|---|---|
| Tartaric Acid, $\overline{T}$ $(2HO + C_8H_4O_{10})$, | *White pre.*, sol. in acids and alkalies,……. | *No pre*……… | Add $CaO,Aq$, to alkaline reaction in the cold, and a *white pre.* is given.<br>Add $KO,NO_5$, and stir well = *white crystalline pre.*<br>Heat the solid tartaric acid or tartrate = *carbonisation, with burned sugar odour.* |
| Citric Acid, $\overline{Ci}$ $(3HO + C_{12}H_5O_{11})$, | *White pre.*, sol. in acids and alkalies,……. | *No pre*……… | Add $CaO,Aq$, to alkaline reaction in the cold, and *no pre.* will be given.<br>Add $CaO,Aq$, to alkaline reaction, and boil, and a *white pre.* will be given.<br>Heat the solid citric acid or citrate = *carbonisation, with pungent acid fumes.* |
| Benzoic Acid, $BzO$ $(HO + C_{14}H_5O_2O)$, | *No pre*………… | *Yellow pre.*, sol. in $HCl$, | $PbO,\overline{A}$, added to neutral solution, gives *white pre.*<br>Heat the solid benzoic acid or benzoate = *volatilisation, with irritating fumes.* |
| Acetic Acid, $\overline{A}$ $(HO + C_4H_3O_3)$,… | *No pre*………… | *No pre.*, but a *red solution*, | When acetates are treated with $SO_3$, and heated in tube, they *evolve the acid vapours of acetic acid.*<br>When acetates are mingled with alcohol and $SO_3$, and heated in tube, they *evolve the fragrant vapours of acetic ether.* |

## 189. Tartaric Acid, $2HO,C_8H_4O_{10} = 2HO,\overline{T}$.

**Tartaric Acid, $2HO,\overline{T}$, may be used in testing.**

1. *Chloride of Calcium*, $CaCl$, added to the tartaric acid solution, which has been previously neutralised by soda, $NaO,HO$, gives a *white precipitate* of tartrate of lime, $2CaO,\overline{T}$, which is readily soluble in mineral acids.

2. *Sesquichloride of Iron*, $Fe_2Cl_3$, produces *no precipitate* with tartaric acid or its compounds.

3. *Lime-water*, $CaO,Aq$, added to the tartaric acid till the liquid shews an alkaline action on test-papers (changes red litmus to blue), produces in the cold a *white precipitate* of tartrate of lime, $2CaO,\overline{T}$, which is soluble in mineral acids.

4. *Nitrate of Potash* gives with tartaric acid, on stirring, a *white crystalline precipitate* of bitartrate of potash, $KO,HO,\overline{T}$, which is soluble in mineral acids and in alkalies.

5. *Acetate of Lead*, $PbO,\overline{A}$, forms a *white precipitate* of the tartrate of lead, $2PbO,\overline{T}$, which is readily soluble in nitric acid, $HO,NO_5$, and in ammonia, $NH_4O$.

6. *Heat.* When solid tartaric acid, or a tartrate, is heated in a capsule or spoon, it is *decomposed, begins to carbonise, and evolves abundantly a characteristic burned sugar odour.*

## 190. Citric Acid, $3HO,C_{12}H_5O_{11} = 3HO,\overline{Ci}$.

**Citric Acid, $3HO,\overline{Ci}$, may be employed in testing.**

1. *Chloride of Calcium*, $CaCl$, added to a solution of citric acid which has been neutralised with soda, $NaO,HO$, throws down a *white precipitate* of the citrate of lime, $3CaO,\overline{Ci}$, which is soluble in mineral acids.

2. *Sesquichloride of Iron*, $Fe_2Cl_3$, gives *no precipitate.*

3. *Lime-water*, $CaO,Aq$, added to citric acid to alkaline

reaction in the cold, yields *no precipitate;* but when the mixed solution is boiled, a *white precipitate* of citrate of lime, $3CaO,\overline{Ci}$, is given, which is soluble in mineral acids.

4. *Acetate of Lead*, $PbO,\overline{A}$, throws down a *white precipitate* of the citrate of lead, $3PbO,\overline{Ci}$, which is soluble in nitric acid, $HO,NO_5$, and in ammonia, $NH_4O$.

5. *Heat.* On the application of heat to citric acid and its compounds in a capsule or spoon, the acid is *decomposed, begins to char or carbonise, and evolves pungent acid fumes.*

### 191. Benzoic Acid, $HO + C_{14}H_5O_2O = BzO,HO$.

**Benzoic Acid, $HO,BzO$, may be employed in testing.**

1. *Chloride of Calcium*, $CaCl$, produces *no precipitate.*

2. *Sesquichloride of Iron*, $Fe_2Cl_3$, added to a solution of benzoic acid, which has been previously neutralised by soda, $NaO,HO$, gives a *yellow or buff coloured precipitate* of the benzoate of the sesquioxide of iron, $2Fe_2O_3,3BzO$, which is soluble in hydrochloric acid, $HCl$.

3. *Acetate of Lead*, $PbO,\overline{A}$, forms in solutions of benzoic acid which have been neutralised by potash, $KO,HO$, or soda, $NaO,HO$, a *white flocculent precipitate* of benzoate of lead, $PbO,BzO$.

4. *Heat.* When benzoic acid and its compounds are heated in a spoon or capsule, they *volatilise, and give off irritating fumes.*

### 192. Acetic Acid, $HO + C_4H_3O_3 = HO,\overline{A}$.

**Acetate of Potash, $KO,\overline{A}$, may be used in testing.**

1. *Chloride of Calcium*, $CaCl$, gives *no precipitate.*

2. *Sesquichloride of Iron*, $Fe_2Cl_3$, forms *no precipitate,* but yields a *red solution.*

3. *Acetate of Lead*, $PbO,\overline{A}$, produces *no precipitate.*

4. *Sulphuric Acid*, $HO,SO_3$, added to acetates, and the

mixture heated in a tube, causes the disengagement of the *acid vapours of acetic acid*, which may be recognised by the agreeable odour of vinegar.

5. *Alcohol* and *Sulphuric Acid*, $HO,SO_3$, added to acetic acid and its compounds, and heated in a tube, yield *acetic ether*, $C_4H_5O,\bar{A}$, the vapours of which, in escaping from the tube, may be recognised from their *agreeable and fragrant ethereal odour*, or bouquet of wine.

193. *Concluding Remarks.*—The four organic acids which have been examined in this group can readily be identified from each other. The test with chloride of calcium at once indicates tartaric or citric acid when a precipitate is given, and benzoic or acetic acid when no precipitate is obtained. The two former acids are easily separated by the addition of lime-water in the cold, which precipitates the tartaric acid, but does not throw down the citric acid until the mixture has been boiled. The benzoic acid is readily distinguished from acetic acid by the precipitate with sesquichloride of iron, and the acetic acid is most certainly identified by the production of acetic ether. In the case of the tartaric, citric, and benzoic acids, much assistance is derived from the action of heat in decomposing these acids and their compounds, and evolving characteristic fumes. The systematic testing of unknown organic acids is referred to in a subsequent part (pars. 219 and 228—231).

## Testing of Unknown Substances by Reagents.

194. The order in which the various tests have been applied to the different metallic oxides and acids in the foregoing part of this treatise, is the best which can be

followed when the student desires merely to examine *known* substances, or those which are *named* to him. But when the investigation is directed to the determination of the ingredients of a salt, or to the examination of a solution, the origin of which is *unknown*, and which may contain one or several of the metallic oxides and acids, then it is necessary that the tests should be applied to the unknown substance in a systematic manner.

195. The plan which is followed in the examination of substances of *unknown origin* is, *first*, to apply the group tests, and when evidence is obtained of the presence of a member of a particular group, then, *second*, to add the special tests which distinguish the members of the group from each other. The chemist, therefore, does not at haphazard apply the reagents which he works with, and thus occupy much time, and expend much labour in searching for each metallic oxide and acid individually, but he arranges the tests in such a way that he can easily learn the group to which the substance belongs, and thereafter it becomes a comparatively simple process to detect the individual substance.

196. The majority of the substances which the student will meet with in everyday-life are saline bodies which consist of a metallic oxide and an acid, such as nitrate of potash or saltpetre, $KO,NO_5$, which contains the metallic oxide potash, $KO$, in combination with the acid nitric acid, $NO_5$; and the general plan of work is to search for the metallic oxide in the first place, and thereafter to apply the tests for the acid.

197. During the course of testing the various groups of metallic oxides and acids, it has been repeatedly suggested that the experimenter should have placed in his hands *unnamed* substances, so that he might become acquainted with the mode of applying the tests systematically for the detection of unknown bodies, and the

following plan of work will be found serviceable in the examination of solutions of a simple nature.

198. The order of the application of the tests, for the metallic oxides is given in a condensed form in the tables A, B, and C, and a more full statement of the tests, and the results they indicate, is made in the succeeding paragraphs. Thereafter, the tests for the inorganic and organic acids are shortly given in the tables D and E, and more fully in the succeeding paragraphs.

199. The student must bear in mind that these tables are intended only for the examination of simple substances, or those which contain not more than one metallic oxide and one acid, and that where there is reason to believe that the substance under examination is of a complex nature, and may contain several metallic oxides and acids, the mode of testing given in larger works on the subject, such as Fresenius's *Qualitative Analysis*, must be resorted to. If the substance has been insoluble in water, and has been dissolved by means of an acid, special attention must be given to pars. 238—242 during the course of testing.

## Systematic Testing.

### TABLE A.—SIMPLE SUBSTANCES CONTAINING NOT MORE THAN ONE METALLIC OXIDE AND ONE ACID.

### 200.—Detection of the Metallic Oxide.

Add —HCl.

| *White Precipitate.* Add $NH_4O$ in excess to the Precipitate. | | | *No Precipitate.* Add HS to the Acidified Solution. | | | | | |
|---|---|---|---|---|---|---|---|---|
| *Precipitate is soluble.* | *Precipitate is insoluble.* —$SO_3$ gives a *white pre.*, sol. in excess of KO,HO.<br>KI yields a *yellow pre.* | *Precipitate becomes black.* SnCl produces a *gray pre.* Cu placed in solution becomes *silvered.* | *Yellow Precipitate.* Add $NH_4O$ in excess to the Precipitate. | | | *Orange Red Precipitate.* Zn and $SO_3$ give *black pre.* of metallic Sb, and $SbH_3$ is evolved as gas. | *Brown Precipitate.* HgCl produces a *gray pre.* $AuCl_3$ gives a *purple solution.* | *Black Pre.* See opposite page. |
| | | | *Precipitate is soluble.* Am., Sulp., Cop., *green pre.*<br>Am., Nit., Silv., *yellow pre.* | *Precipitate is insoluble.* Add KO,HO to new portion. | | | | |
| | | | | *White pre.*, insol. in excess. | *White pre.*, sol. in excess. | | | |
| AgO. | +PbO. | $Hg_2O$. | $AsO_3$.* | CdO. | $SnO_2$. | $SbO_3$. | SnO. | |

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* $AsO_5$ is distinguished from the $AsO_3$ by giving a *reddish-brown pre.* with ammonio-nitrate of silver.

### Table A continued.—Detection of the Metallic Oxide.

—HCl and HS give a *black precipitate.*

Add to separate portions of the original solution.

| (1.) | (2.) | (3.) | (4.) | (5.) SnCl gives a | | |
|---|---|---|---|---|---|---|
| —$SO_3$ produces a *white pre.,* soluble in excess of KO,HO.<br>KI yields a *yellow pre.* | KO,HO gives a *yellow pre.*<br>$NH_4O$ forms a *white pre.*<br>Cu placed in the solution becomes *silvered.* | $NH_4O$ yields an *azure-blue solution.*<br>2K,Cfy gives a *ruddy pre.*<br>Fe placed in the solution becomes *coated with metallic* Cu. | HO produces a *white pre.,* which is *insol.* in $\overline{T}$, and is changed to *black* by HS. | *Purple solution.*<br>FeO,$SO_3$ yields a *brown pre.,* which appears *blue* by transmitted light. | *Red solution.*<br>KO,$NO_5$ forms a *yellow pre.* | —HCl and HS give *no precipitate.*<br>Pass to table B. |
| —PbO. | HgO. | CuO. | $BiO_3$. | $AuO_3$. | $PtO_2$. | |

## Table B.—Detection of the Metallic Oxide.

201. Add $NH_4Cl$, $NH_4O$, and $NH_4S,HS$.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| *White Precipitate.* | | *Blue-Green Precipitate.* | *Skin-coloured Precipitate.* | *Black Precipitate.* Add—HCl to the Precipitate. | | | | *No pre.* |
| $KO,HO$ produces a *white pre., soluble in excess of* $KO,HO$.<br>To potash solution add | | $KO,HO$ gives a *blue-green pre.*<br>$KO,NO_5$ and $KO,CO_2$ evap., ignite = $CrO_3$, which with $PbO,\bar{A}$ gives a *yellow pre.* | $KO,HO$ yields a *skin col. pre.*<br>$NaO,HO,2CO_2$; blow-pipe test on Pt wire in outer flame forms a *green bead.* | *Precipitate is insoluble.* | | *Precipitate is soluble.* $KO,HO$ produces a | | Pass to table C. |
| $NH_4Cl$ *white pre.* | HS *white pre.* | | | KCy produces a *yellow-green pre.*, soluble in excess of KCy. | $Al_2O_3$; blow-pipe test on C gives a *sky-blue incrustation.* | *green pre.* 2K,Cfy gives a *light-blue pre.* | *red-brown pre.* 2K,Cfy yields a *dark-blue pre.* | |
| $Al_2O_3$. | ZnO. | $Cr_2O_3$. | MnO. | NiO. | CoO. | FeO. | $Fe_2O_3$. | |

### Table C.—Detection of the Metallic Oxide.

<table>
<tr><td colspan="8">202. Add $2NaO,HO,PO_5$ and $NH_4O$.</td></tr>
<tr><td colspan="4"><i>White Precipitate.</i><br>Add $CaO,SO_3$ to new portion of solution, and stir.</td><td colspan="4"><i>No Precipitate.</i><br>203. Evaporate a portion of the solution to dryness.</td></tr>
<tr><td colspan="2"><i>White Precipitate.</i><br>$NaO,S_2O_2$ yields on stirring</td><td colspan="2"><i>No Precipitate.</i><br>$NH_4O,\bar{O}$ produces</td><td colspan="3"><i>A residue is left.</i><br>Heat the residue more strongly.</td><td rowspan="3"><i>No residue</i>, and the liquid is <i>neutral</i> to test papers.</td></tr>
<tr><td rowspan="2"><i>White pre.</i><br>Alcohol test gives a <i>yellow - green flame.</i></td><td rowspan="2"><i>No pre.</i><br>Alcohol test yields a <i>carmine flame.</i></td><td rowspan="2"><i>White pre.</i><br>Alcohol test gives rise to <i>brick-red flame.</i></td><td rowspan="2"><i>No pre.</i><br>$CoO,NO_5$; blow-pipe test on C, <i>skin-coloured residue.</i></td><td colspan="2"><i>Not volatile.</i><br>Add $\bar{T}$ to the solution, and stir.</td><td rowspan="2"><i>Volatile.</i><br>$CaO,HO$ causes the escape of $NH_3$ as gas, which is recognised by <i>odour</i> and <i>action on test-papers.</i></td></tr>
<tr><td><i>White pre.</i><br>Alcohol test gives <i>violet flame.</i></td><td><i>No pre.</i><br>Alcohol test yields <i>strong yellow flame.</i></td></tr>
<tr><td>$BaO$.</td><td>$SrO$.</td><td>$CaO$.</td><td>$MgO$.</td><td>$KO$.</td><td>$NaO$.</td><td>$NH_4O$.*</td><td>$HO$.</td></tr>
</table>

* A solution of *free* $NH_4O$ leaves *no residue on evaporation*, but is recognised by the *odour* of hartshorn, and its *alkaline action on test papers.*

## Systematic Testing.

### SIMPLE SUBSTANCES CONTAINING NOT MORE THAN ONE METALLIC OXIDE AND ONE ACID.

### Detection of the Metallic Oxide.

204. Add dilute hydrochloric acid, —HCl, to a portion of the original solution.

*No precipitate is formed.* Pass to par. 205.

*A white precipitate is produced.*

Add ammonia, $NH_4O$, to the precipitate.

1. *The precipitate is dissolved;* indicative of OXIDE OF SILVER, AgO.

2. *The precipitate is not dissolved, and remains white.*

Sulphuric acid, $HO,SO_3$, gives a *white precipitate,* soluble in potash, KO,HO; and

Iodide of potassium, KI, yields a *yellow precipitate.*

The substance is a strong solution of OXIDE OF LEAD, PbO.

3. *The precipitate changes to black.*

Protochloride of tin, SnCl, produces a *gray precipitate,* and bright metallic copper, Cu, introduced into the solution acquires a *silvery coating.* The liquid contains the SUBOXIDE OF MERCURY, $Hg_2O$.

205. Add hydrosulphuric acid to the solution already acidified by hydrochloric acid.

*No precipitate is produced.* Pass to par. 210.

*A precipitate is formed.* Notice the colour.

206. *The precipitate is yellow.*

Add ammonia, $NH_4O$, in excess to the precipitate.

1. *The yellow precipitate is dissolved.*

Ammonio-sulphate of copper gives a *green precipitate.*

Ammonio-nitrate of silver yields a *yellow precipitate.*

These tests are indicative of ARSENIOUS ACID, $AsO_3$.

If the ammonio-nitrate of silver gives a *reddish-brown precipitate*, it indicates ARSENIC ACID, $AsO_5$.

2. *The yellow precipitate is not dissolved*, and potash, KO,HO, gives a *white precipitate*, insoluble in excess; indicative of OXIDE OF CADMIUM, CdO.

3. *The yellow precipitate is not dissolved*, and potash, KO,HO, produces a *white precipitate*, soluble in excess, = BINOXIDE OF TIN, $SnO_2$.

207. *The precipitate is orange red.*

The addition of metallic zinc, Zn, and a few drops of concentrated sulphuric acid, $HO,SO_3$, give rise to the formation of a *black powder* of metallic antimony, Sb, and the evolution of a gas, antimoniuretted hydrogen, $SbH_3$. The substance is TEROXIDE OF ANTIMONY, $SbO_3$.

208. *The precipitate is brown.*

Chloride of mercury, HgCl, gives a *gray precipitate.*

Chloride of gold, $AuCl_3$, yields a *purple solution.*

= PROTOXIDE OF TIN, SnO.

209. *The precipitate is black.*

Add to separate portions of the original solution—

1. Sulphuric acid, $HO,SO_3$, which gives a *white precipitate*, soluble in excess of potash, KO,HO, and iodide of potassium, KI, a *yellow precipitate;* indicative of the presence of a dilute solution of OXIDE OF LEAD, PbO.

2. Potash, KO,HO, produces a *yellow precipitate;* ammonia, $NH_4O$, a *white precipitate;* and bright metallic copper, Cu, is *silvered* when moistened with the liquid, = PEROXIDE OF MERCURY, HgO.

3. Ammonia, $NH_4O$, yields an *azure-blue solution;*

ferrocyanide of potassium, 2K,Cfy, a *ruddy-brown precipitate;* and bright iron, Fe, placed in the liquid is coated with *metallic copper,* = PROTOXIDE OF COPPER, CuO.

4. Water, HO, added in quantity forms a *white precipitate,* which is insoluble in tartaric acid, $HO,HO,\bar{T}$, and changes to a *black precipitate* on addition of hydrosulphuric acid, HS, = TEROXIDE OF BISMUTH, $BiO_3$.

5. Protochloride of tin, SnCl, produces a *purple solution;* and sulphate of iron yields a *finely-divided precipitate,* which appears *blue* by transmitted light, and *brown* by reflected light, = TEROXIDE OF GOLD, $AuO_3$.

6. Protochloride of tin, SnCl, forms a *red solution;* and nitrate of potash, $KO,NO_5$, gives, on stirring, a *yellow crystalline precipitate,* = BINOXIDE OF PLATINUM, $PtO_2$.

210. Hydrochloric acid, HCl, and hydrosulphuric acid, HS, have produced *no precipitate.*

Add chloride of ammonium, $NH_4Cl$, ammonia, $NH_4O$, and sulphide of ammonium, $NH_4S,HS$.

*No precipitate is formed.* Pass on to par. 215.

*A precipitate is produced.* Notice the colour.

211. *The precipitate is white.*

Add potash, KO,HO, to a portion of the original solution, which will give a *white precipitate,* soluble in excess of potash.

To different portions of the potash solution, add—

1. Chloride of ammonium, $NH_4Cl$, which yields a *white precipitate,* = ALUMINA, $Al_2O_3$.

2. Hydrosulphuric acid, HS, which gives a *white precipitate,* = OXIDE OF ZINC, ZnO.

212. *The precipitate is bluish-green.*

Potash, KO,HO, gives a *blue-green precipitate,* soluble in excess, and *reprecipitated* by chloride of ammonium, $NH_4Cl$.

Confirm by the addition to the original solution of nitrate of potash, $KO,NO_5$, and carbonate of potash, $KO,CO_2$; evaporate, ignite, dissolve the residue in water, and add acetate of lead, PbO,A, a *yellow precipitate*, = OXIDE OF CHROMIUM, $Cr_2O_3$.

213. *The precipitate is of a skin colour.*

Potash, KO,HO, yields a *skin-coloured precipitate;* and bicarbonate of soda, $NaO,HO,2CO_2$, moistened with the solution, and heated on a platinum wire in the outer flame of the blow-pipe, forms, on cooling, an *emerald-green bead*, = PROTOXIDE OF MANGANESE, MnO.

214. *The precipitate is black.*

Add hydrochloric acid, HCl, in excess to the precipitate.

1. *The black precipitate does not dissolve.*

(*a.*) Cyanide of potassium, KCy, produces a *yellow-green precipitate*, soluble in excess, = OXIDE OF NICKEL, NiO.

(*b.*) Alumina, $Al_2O_3$, or alum, moistened with the solution, and heated on charcoal in the outer flame of the blow-pipe, gives a *sky-blue residue*, = OXIDE OF COBALT, CoO.

2. *The black precipitate dissolves in the acid.*

(*a.*) Potash, KO,HO, yields a *green precipitate;* and ferrocyanide of potassium, 2K,Cfy, a *light-blue precipitate*, = PROTOXIDE OF IRON, FeO.

(*b.*) Potash, KO,HO, produces a *red-brown precipitate;* and ferrocyanide of potassium, 2K,Cfy, a *dark Prussian blue*, = PEROXIDE OF IRON, $Fe_2O_3$.

215. Chloride of ammonium, $NH_4Cl$, ammonia, $NH_4O$,

and sulphide of ammonium, $NH_4S,HS$, have yielded *no precipitate.*

Add phosphate of soda, $2NaO,HO,PO_5$, and ammonia, $NH_4O$, to a portion of the original solution.

*No precipitate is given.* Pass on to par. 217.

*A white precipitate is produced.*

216. Add sulphate of lime, $CaO,SO_3$, to a portion of the original solution, and stir well.

1. *A white precipitate is yielded.*

(*a.*) Hyposulphite of soda, $NaO,S_2O_2$, gives a *white precipitate*, and the alcohol flame is *yellow green*, = Baryta, BaO.

(*b.*) Hyposulphite of soda, $NaO,S_2O_2$, forms *no precipitate*, and the alcohol flame is of a *carmine colour*, = Strontia, SrO.

2. *No precipitate is produced.*

(*a.*) Oxalate of ammonia, $NH_4O,\bar{O}$, yields a *white precipitate;* and the alcohol flame is of a *brick-red tint*, = Lime, CaO.

(*b.*) Oxalate of ammonia, $NH_4O,\bar{O}$, gives *no precipitate*, and a portion of the solid or the residue, after evaporation, on being moistened with protonitrate of cobalt, $CoO,NO_5$, and heated on charcoal in the outer flame of the blow-pipe, become of a *skin colour*, = Magnesia, MgO.

217. Phosphate of soda, $2NaO,HO,PO_5$, and ammonia, $NH_4O$, have given *no precipitate.*

Evaporate a portion of the solution to dryness.

1. *A residue is obtained.*

Heat the residue more highly.

(*a.*) *The residue is volatile.*

Lime, $CaO,HO$, or potash, $KO,HO$, added to the solution, causes the evolution of the odour of hartshorn, and the vapours exhibit an alkaline action on test papers, then the substance is = Ammonia, $NH_4O$.

(*b.*) *The residue is not volatile.*

Tartaric acid, $HO,HO,\overline{T}$, added to the solution, and the whole stirred well, gives a *white precipitate;* and the alcohol flame is *violet,* = Potash, $KO$.

(*c.*) *The residue is not volatile.*

Tartaric acid, $HO,HO,\overline{T}$, gives *no precipitate;* and the alcohol flame is *yellow,* = Soda, $NaO$.

2. *No residue is left on evaporation.*

When free ammonia, $NH_4O$, is only present in a solution, the liquid will leave *no residue on evaporation,* but it will indicate a decided *alkaline action on test papers*—changing *red* litmus to *blue,* and *yellow* turmeric to *brown red*—and the *odour* of hartshorn will be evolved from the solution. The carbonate of ammonia, $2NH_4O,3CO_2$, acts similarly to free ammonia, $NH_4O$.

The liquid may now be tested with the blue litmus paper for the presence of a free acid, and if the *blue* colour is changed to *red,* this will indicate that a free acid is present, and the solution may be tested for the particular acid according to pars. 218—231.

If the liquid under examination has yielded *no residue on evaporation,* is *neutral* to test papers, and evolves *no odour of alcohol or ether,* then the solution is merely Water, $HO$.

## Systematic Testing.

### TABLE D.—SIMPLE SUBSTANCES CONTAINING NOT MORE THAN ONE METALLIC OXIDE AND ONE ACID.

### 218. Detection of the Inorganic Acid.*

| If the solution is acid to test papers, add $NH_4O$ to neutral reaction, and filter from any precipitate which may form, then add $BaO,NO_5$. | | | | | |
|---|---|---|---|---|---|
| *White Precipitate.*<br>Add —HCl in excess to the Precipitate. | | | | | *No Precipitate.* |
| *Precipitate is insoluble.* | *Precipitate is soluble with effervescence.* | *Precipitate is soluble without effervescence.* Add to separate portions of the original solution, | | | See opposite page. |
| | | (1.)<br>$AgO,NO_5$ gives a *yellow pre.*<br>$MgO,SO_3$ and $NH_4O$ yield a *white pre.* | (2.)<br>HCl and turmeric paper, dry, produce *red tint.*<br>$SO_3$ and alcohol give *green flame.* | (3.)<br>CaCl produces a *white pre.* | |
| $SO_3$. | $CO_2$. | $PO_5$. | $BO_3$. | $\overline{O}$ | |

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* During the course of testing for the metallic oxides, indications of the presence of the following acids may have been obtained :

1. $AsO_3$ and $AsO_5$, which are *precipitated yellow* by the HS.
2. $CrO_3$, the solutions of which are either *yellow* or *red*, and which, on the addition of HS, are changed to a *green colour*, with the precipitation of S.
3. $CO_2$, which *effervesces* on the addition of HCl, and evolves *no odour*.
4. HS, which *effervesces* on the addition of HCl, and possesses the *odour of rotten eggs*.
5. HCy, which *escapes as gas* on the addition of HCl, and evolves a *peculiar odour*.

### Table D continued.—Detection of the Inorganic Acid.

$BaO,NO_5$ has given *no precipitate.*

Add $—NO_5$ and $AgO,NO_5$ to a fresh portion of the original solution.

| *White Precipitate.* Add to original solution, | | *Yellow Precipitate.* $MnO_2$ and $HO,SO_3$; heat in tube. | | *Black Precipitate.* | *No Precipitate.* Add sulphoindigotic acid and a few drops of $SO_3$; heat in tube. | | |
|---|---|---|---|---|---|---|---|
| (1.) $FeO,SO_3$, $Fe_2,Cl_3$, $KO,HO$ and HCl to acid reaction. | (2.) $MnO_2$ and $HO,SO_3$; heat in tube; evolve Cl as gas with *green colour* and *strong odour.* | Evolve I, as vapour with *violet colour* and *strong odour.* Starch and Cl, *blue pre.* | Evolve Br, as vapour with *brown-red colour* and *strong odour.* Starch and Cl, *no blue pre.* | $PbO,\overline{A}$ gives *black pre.* Odour of the solution resembles that of *rotten eggs.* | *Decoloration of the liquid.* Add to original solution Cu and $SO_3$; heat in tube. | | *No decoloration.* The solution contains no acid belonging to the foregoing table. If the liquid is neutral to test papers, and leaves no residue on evaporation, then no acid is present. If the solution is acid to test papers, then examine for organic acids according to table E, par. 219. |
| | | | | | *Ruddy fumes* of $NO_4$. $FeO,SO_3$ and $SO_3$ give *dark-brown colour.* | *No ruddy fumes.* Chlorate, heated in a capsule, becomes a *chloride.* | |
| HCy. | HCl. | HI. | HBr. | HS. | $NO_5$. | $ClO_5$. | |

HF, $SiO_3$, 2H,Cfy, and 3H,2Cfy, are not included in the above table, but may be tested for according to pars. 167, 168, 177, and 178.

## Systematic Testing.

### TABLE E.—SIMPLE SUBSTANCES CONTAINING NOT MORE THAN ONE METALLIC OXIDE AND ONE ACID.

### 219.—Detection of the Organic Acid.*

If the solution is acid to test papers, add NaO,HO to neutral reaction, and subsequently CaCl.

| *White Precipitate.* | | *No Precipitate.* | |
|---|---|---|---|
| Add CaO,Aq to original solution to alkaline reaction. | | To neutral solution add $Fe_2Cl_3$. | |
| *White pre. in the cold.* | *No pre. in the cold.* | *Yellow pre.* | *Red solution.* |
| $KO,NO_5$, and stir well, gives *white pre.*<br>Dry, and ignite; evolves *fumes with burned sugar odour.* | Boil mixed liquid in tube; *white pre.*<br>Dry, and ignite; evolves *pungent acid fumes.* | Dry, and ignite; evolves *irritating aromatic fumes.* | Alcohol and $SO_3$; heat in tube; evolve *acetic ether* with *fragrant ethereal odour.* |
| $\bar{T}$ | $\bar{C}$i. | BzO. | $\bar{A}$. |

* These tests are applicable for the detection of the organic acids when they are free, or are in combination with the alkalies or alkaline earths.

When the metallic oxide belongs to the fourth group of metals, the base must be separated by HS, and where the metallic oxide is of the third group, it can be separated by $NH_4S,HS$, and filtration. In the latter case, the liquid is subsequently acidulated with HCl. In either instance, the solution is heated, and filtered a second time.

The organic acids as a class are charred on the application of heat; and where there is reason to believe that a saline matter contains an organic acid, the application of heat to the salt in a small capsule will generally suffice to indicate by the charring that an organic substance, probably an acid, is present, and the nature of the fumes evolved will in many cases lead to the detection of the particular organic acid.

## Systematic Testing.

### SIMPLE SUBSTANCES CONTAINING NOT MORE THAN ONE METALLIC OXIDE AND ONE ACID.

### Detection of the Inorganic Acid.

220. Whilst testing for the metallic oxides, indications may be obtained of the presence of several of the acids, thus:

1. Hydrochloric Acid, HCl, when added to the solution, may give rise to the *disengagement of bubbles of gas*, which will denote the presence of one of three acids.

(*a.*) The gas possesses *no odour*, = CARBONIC ACID, $CO_2$.

(*b.*) The gas evolves *an odour of rotten eggs*, = HYDROSULPHURIC ACID, HS.

(*c.*) The gas exhibits *a peculiar odour*, resembling that of bitter almonds, = HYDROCYANIC ACID, HCy.

2. Hydrosulphuric Acid, HS, when applied in testing for the metallic oxide, may afford evidence of the presence of certain acids, thus:

(*a.*) *A yellow precipitate* which is soluble in ammonia, $NH_4O$, may indicate ARSENIOUS ACID, $AsO_3$, or ARSENIC ACID, $AsO_5$.

(*b.*) If the original solution was either *red* or *yellow* and the hydrosulphuric acid, HS, changes the colour to *green*, with the precipitation of finely-divided sulphur, S, = CHROMIC ACID, $CrO_3$, which may be confirmed by the addition of acetate of lead, $PbO,\bar{A}$, to the original solution, and the production of a *yellow precipitate*.

221. If the original solution is acid to test papers, neutralise with dilute ammonia, —$NH_4O$, filter from any precipitate which may form, and add nitrate of baryta, $BaO,NO_5$.

*No precipitate is formed.* Pass on to par. 222.

*A white precipitate is produced*; add dilute hydrochloric acid, —HCl, to the precipitate.

1. *The precipitate does not dissolve,* = SULPHURIC ACID, $SO_3$.

2. *The precipitate dissolves with effervescence,* and the escaping gas has no odour, = CARBONIC ACID, $CO_2$.

3. *The precipitate dissolves without effervescence.*

(*a.*) Nitrate of Silver, $AgO,NO_5$, gives a *yellow precipitate,* and sulphate of magnesia, $MgO,SO_3$, and ammonia, $NH_4O$, give a *white precipitate,* = PHOSPHORIC ACID, $PO_5$.

(*b.*) Add to the solution some hydrochloric acid, HCl, dip a piece of turmeric paper in the acid mixture, and dry. A *bright-red colour* indicates BORACIC ACID, $BO_3$. Confirm by the addition of sulphuric acid, $HO,SO_3$, and alcohol, and the latter will burn with a *green flame.*

(*c.*) Chloride of Calcium, CaCl, gives a *white precipitate,* which is insoluble in acetic acid, $\bar{A}$, = OXALIC ACID, $\bar{O}$.

222. Add to the original solution a few drops of dilute nitric acid, $HO,NO_5$, and nitrate of silver, $AgO,NO_5$.

*No precipitate is given.* Pass on to 226.

*A precipitate is produced.* Notice the colour.

223. *The precipitate is white,* and is soluble in ammonia, $NH_4O$.

1. Add a few drops of protosulphate of iron, $FeO,SO_3$, and of perchloride of iron, $Fe_2Cl_3$, then potash, $KO,HO$, and lastly, hydrochloric acid, HCl, to acid reaction. The production of *Prussian blue* indicates HYDROCYANIC ACID, HCy.

2. Add binoxide of manganese, $MnO_2$, and sulphuric acid, $HO,SO_3$, and heat in test-tube. *Chlorine,* Cl, *is*

*evolved with slight green colour and suffocating odour,* = Hydrochloric Acid, HCl.

224. *The precipitate is yellow, or yellowish white.*

Add binoxide of manganese, $MnO_2$, and sulphuric acid, $HO,SO_3$, and heat in test-tube.

1. *Iodine*, I, *is evolved with a violet colour and suffocating odour,* and the original solution gives, with starch and chlorine, a *blue precipitate,* = Hydriodic Acid, HI.

2. *Bromine*, Br, *is given off with a brown-red colour and a suffocating odour;* and starch and chlorine give *no blue colour,* = Hydrobromic Acid, HBr.

225. The *precipitate is black.*

Add acetate of lead, $PbO,\bar{A}$, to the original solution, and a *black precipitate* will confirm the presence of Hydrosulphuric Acid, HS. The original solution will have the *odour of rotten eggs.*

226. Add to the original solution sufficient sulpho-indigotic acid to colour the liquid of a blue tint, and a few drops of sulphuric acid, $HO,SO_3$, and heat in a tube.

*The blue colour remains.* Pass on to 227.

*The blue colour disappears,* or *decoloration occurs.*

Add to the original solution, a piece of metallic copper, Cu, and sulphuric acid, $HO,SO_3$, and heat in a test-tube.

1. *Ruddy fumes are evolved.*

Sulphate of iron, $FeO,SO_3$, and sulphuric acid, $HO,SO_3$, give a *dark-brown colour,* = Nitric Acid, $NO_5$.

2. *No ruddy fumes are given off.*

Evaporate a portion of the original solution to dryness, ignite or heat strongly; and any chlorate, such as chlorate of potash, $KO,ClO_5$, which is present will be decomposed into a chloride, such as chloride of potassium, $KCl$; and on dissolving the residue in water, and adding nitrate of silver, a *white precipitate* will indicate that the original solution contained CHLORIC ACID, $ClO_5$. Confirm by deflagrating some of the residue on or with charcoal.

227. The solution contains no acid belonging to the foregoing groups. Test the liquid by means of litmus and turmeric papers, and if it is neutral, and leaves no residue on evaporation to dryness, then no acid is present. If the test papers exhibit an acid action, or the liquid leaves a residue on evaporation, and none of the foregoing acids have been detected, one of the following organic acids may be present.

## Systematic Testing.

### SIMPLE SUBSTANCES CONTAINING NOT MORE THAN ONE METALLIC OXIDE AND ONE ACID.

**228. Detection of the Organic Acids.**

The organic acids are readily tested when they are free or in combination with the alkalies or the alkaline earths, but if they are combined with any of the metallic oxides of the third or fourth group, it becomes necessary to separate the metallic oxide from the organic acid before the tests can be applied for the detection of the latter. The metallic oxides of the fourth group are separated by hydrosulphuric acid, $HS$, and subsequent filtration, when a liquid is obtained, which on boiling, to expel the excess of hydrosulphuric acid, is in a condition to test for the organic acid. When the metallic oxide belongs to the third group, sulphide of ammonium, $NH_4S,HS$, is employed for the precipitation; and after filtration, the liquid is acidified with hydrochloric acid, HCl, heated, filtered again if necessary, and the solution, when cold, is ready for testing.

229. If the solution is acid to test papers, neutralise by the addition of caustic soda, $NaO,HO$, and then add chloride of calcium, CaCl.

*No precipitate is obtained.* Pass on to par. 230.

*A white precipitate is formed.*

Add lime-water, $CaO,Aq$, to alkaline reaction.

(*a.*) A *white precipitate is given in the cold.*

Nitrate of potash, $KO,NO_5$, yields on stirring a *white precipitate*, and when the liquid is dried up, and the residue ignited, it evolves fumes with a *burned sugar odour*, = TARTARIC ACID, $\overline{T}$.

(*b.*) *No white precipitate is given in the cold.*

On boiling the mixed liquid, a *white precipitate* is produced. When the solution is evaporated, and the residue ignited, it gives rise to *pungent acid fumes*, = CITRIC ACID, $\overline{Ci}$.

230. To a neutral solution, add perchloride of iron, $Fe_2Cl_3$.

1. *A yellow or buff-coloured precipitate is given.* On evaporation, and ignition of the residue, it gives rise to *irritating aromatic fumes*, = BENZOIC ACID, BzO.

2. *A red solution is obtained.* Alcohol and sulphuric acid, $HO,SO_3$, added to the original solution, and heat applied in a test-tube, give rise to the evolution of the *fragrant odour of acetic ether.* Indicative of ACETIC ACID, $\overline{A}$.

231. The testing for the organic acids is much facilitated

by the preliminary step of heating a portion of the solid, or the residue left on the evaporation of the solution, in a capsule, and when, as a general rule, charring occurs, and fumes are evolved. Wherever, therefore, it is considered likely that an organic acid may be present, the operator should at once heat strongly or ignite a portion of the material under examination, and any charring which may be observed will indicate the presence of an organic substance, and most probably that of an organic acid. At the same time it must be borne in mind that the absence of any charring does not certainly prove the freedom of the material from an organic substance.

## Systematic Testing of Solid Substances.

232. When the material under examination is a solid body, it is necessary before the application of the foregoing tests that the substance be obtained in a state of solution. For this purpose the material is generally treated first with water, and failing its solution in that liquid, it is then acted upon by acids. A few substances will not dissolve in either water or acids, and these require special treatment. The general plan of procedure is the following:

### The Substance is neither a Metal nor an Alloy.

233. Add about twenty grains of the material in a state of fine division to ten times its weight of water, in a test-tube, flask, or basin, and heat to boiling.

*The substance dissolves in the water.* Proceed to test the solution for metallic oxides and acids, commencing at pars. 200 and 204.

234. *The substance does not dissolve completely in the water.* Allow the insoluble matter to settle, and decant off a small portion of the liquid, or filter if necessary. Evaporate a few drops of the liquid to dryness, and if a residue is obtained, then the water must have dissolved out some ingredient, and proceed to test the liquid by pars. 200 and 204.

235. The *residue insoluble in water* is treated with dilute hydrochloric acid, —HCl, in a test-tube, and heat applied. If the substance still remains insoluble, add some concentrated hydrochloric acid, HCl, and heat again. Should the acid act upon the substance, then certain points may be observed at this stage of the process which may facilitate the recognition of the compound, and of the acid contained therein. Thus,

1. *Effervescence* evolving gas with *no odour* indicates CARBONIC ACID, $CO_2$.
2. *Effervescence* giving rise to gas with *odour of rotten eggs* = HYDROSULPHURIC ACID, HS.
3. *Evolution of prussic acid odour* = HYDROCYANIC ACID, HCy.
4. *Disengagement of chlorine* indicates a CHROMATE, PEROXIDE, &c.

236. *The substance entirely dissolves in the hydrochloric acid solution,* or the sediment on settling leaves a solution which yields a residue on the evaporation of a few drops, which proves that a certain part of the substance has been dissolved. Proceed to test the liquid as at par. 205.

237. *The residue insoluble in hydrochloric acid* is boiled with concentrated nitric acid, $HO,NO_5$, and water, HO; and if that fails to effect complete solution, or to

yield a liquid which leaves a residue on evaporation, then treat the substance with aqua regia, a mixture of two parts of concentrated hydrochloric acid, $HCl$, and one part of concentrated nitric acid, $HO,NO_5$, and boil in test-tube.

*Solution takes place;* dilute with water, and test as at par. 205.

*An insoluble residue is left;* examine the substance according to par. 297.

238. When the substance under examination is insoluble in water, but is soluble in acids, there are several special points to be observed on the application of the tests at pars. 210 and 211. The acid has the power of dissolving the phosphates, borates, and oxalates of the alkaline earths, or second group of metals; and these are precipitated on the addition of the chloride of ammonium, $NH_4Cl$, ammonia, $NH_4O$, and sulphide of ammonium, $NH_4S,HS$, at par. 210, and they are thus liable to be mistaken for alumina or zinc. Should, therefore, a white precipitate be obtained at par. 210, the following process is to be followed.

239. Add to a portion of the original acid solution, tartaric acid, $HO,HO,\bar{T}$, and ammonia, $NH_4O$, in excess.

1. *No precipitate is produced;* absence of the phosphates, borates, and oxalates of the alkaline earths. Test for alumina and oxide of zinc as at par. 211.

2. *A white precipitate is formed;* presence of a phosphate, borate, or oxalate of an alkaline earth.

240. Add to a fresh portion of the original acid solution, ammonia, $NH_4O$, to alkaline reaction, acetic acid, $\bar{A}$, to acid reaction, some acetate of potash, $KO,\bar{A}$, and a few drops of perchloride of iron, $Fe_2Cl_3$; a *white*

*precipitate* indicates *phosphoric acid*, $PO_5$, as a PHOSPHATE. Thereafter, add more perchloride of iron, $Fe_2Cl_3$, till the solution is coloured red; boil, filter, add ammonia, $NH_4O$, in excess to remove the iron; filter again, and test the liquid for the alkaline earth, as at par. 215.

241. Take the original acid solution, dip turmeric paper therein, and dry; a *bright-red colour* will denote *boracic acid*, $BO_3$, as a BORATE. To determine the alkaline earth in combination therewith, add a solution of bicarbonate of soda, $NaO,HO,2CO_2$; boil, filter, wash with water, dissolve the residue in hydrochloric acid, HCl, and test for the alkaline earth as at par. 215.

242. Add to a portion of the original substance some binoxide of manganese, $MnO_2$, moisten with water, and drop in concentrated sulphuric acid, $HO,SO_3$. *Evolution of carbonic acid* with effervescence denotes *oxalic acid*, $\bar{O}$, as an OXALATE. The alkaline earth in combination therewith may be detected by igniting a portion of the original substance in a capsule, digesting the residue in dilute hydrochloric acid, HCl, and testing the liquid as at par. 215.

### The Substance is a Metal or an Alloy.

243. Add dilute nitric acid, $HO,NO_5$, to a fragment of the metal in a test-tube, and heat. Failing the solution of the metal, add concentrated nitric acid, $HO,NO_5$, and heat.

*The metal or alloy dissolves in the acid.* Test as at par. 204.

244. *The metal or alloy is changed into a white* or *yellow-white pulverulent residue;* indicative of TIN, Sn, or ANTIMONY, Sb. Digest a fragment of the metallic

substance in hydrochloric acid, HCl, and test the liquid as at par. 205. Treat another portion of the metal with aqua regia (two parts of hydrochloric acid, HCl, and one part of nitric acid, $HO,NO_5$), and test as at par. 204.

245. *The metal or alloy retains its metallic appearance when digested with nitric acid*, = GOLD, Au, or PLATINUM, Pt. Add aqua regia, a mixture of two parts of hydrochloric acid, HCl, and one part of nitric acid, $HO,NO_5$, boil, and test the solution as at par. 204.

246. During the process of examining compounds which may contain a metallic oxide and an acid, the operator will be much facilitated in his observations and special modes of research by the consideration of the probable states of combination of the different substances. The metallic oxides are generally found united only with a few of the acids, forming well-known salts; and the operator having tested for and discovered the particular metallic oxide present, may fairly consider what acid or acids that oxide may most likely be in combination with. Thus if oxide of zinc has been detected in solution, it should be recollected that this metallic oxide is generally met with in combination with sulphuric acid, $SO_3$, as the sulphate of zinc, or *Glauber's salts*, $ZnO,SO_3$; though it may also be found as the chloride of zinc, ZnCl, the latter being the ingredient in *Burnett's disinfecting fluid.* Again, if oxide of silver, AgO, has been discovered in a solution, then it is most likely in combination with nitric acid, $NO_5$, as the nitrate of silver, $AgO,NO_5$, is the most common compound of silver. In every instance, however, satisfactory evidence of the presence of a particular acid must be obtained by the employment of the tests given in the tables.

247. Much assistance is likewise derived from the recollection of the solubility of the various compounds in water and in acids; as in testing a water solution of a saline substance, and having found the metallic oxide, it is needless to test specially for those acids which form with that oxide, compounds which are insoluble in water. Thus, when a substance has dissolved readily in water, and has yielded evidence of the presence of protoxide of iron, $FeO$, the student may specially search for sulphuric acid, $SO_3$, or hydrochloric acid, $HCl$, as the protoxide of iron forms compounds with these acids which are soluble in water—namely, the sulphate of iron or *green vitriol*, $FeO,SO_3$, and the chloride of iron, $FeCl$; but it is needless to test for carbonic acid, $CO_2$, or phosphoric acid, $PO_5$, both of which combine with oxide of iron to form compounds which are insoluble in water. The following table may be advantageously consulted during the course of testing, and the student is recommended to use it frequently, and thus become familiarised with the mode of working it.

## 248. Table of the Solubility of the Metallic Oxides, Acids, Water and in

| | | Potash, KO. | Soda, NaO. | Ammonia, $NH_4O$. | Baryta, BaO. | Strontia, SrO. | Lime, CaO. | Magnesia, MgO. | Alumina, $Al_2O_3$. | Oxide of Chromium, $Cr_2O_3$. | Oxide of Zinc, ZnO. | Oxide of Manganese, MnO. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | W | W | W | W | W | W | A | A | A | A | A |
| Sulphuric Acid,........$SO_3$ | W | W | W | W | O | O | W | W | W | W | W | W |
| Phosphoric Acid,.......$PO_5$ | W | W | W | W | | | A | A | | | | |
| Boracic Acid,...........$BO_3$ | W | | W | | | | A | | | | | |
| Oxalic Acid,............$\overline{O}$ | W | W | W | W | | | A | | | | | |
| Carbonic Acid,.........$CO_2$ | W | W | W | W | A | A | A | A | | | A | A |
| Hydrocyanic Acid,....HCy | W | W | | | | | | | | | | |
| Hydrochloric Acid,...HCl | W | W | W | W | W | W | W | W | | W | W | W |
| Hydriodic Acid,........HI | W | W | | W | | | | | | | | |
| Hydrobromic Acid,...HBr | W | W | | | | | | | | | | |
| Hydrosulphuric Acid, HS | W | W | W | W | W | | W | | | | A | A |
| Nitric Acid,.............$NO_5$ | W | W | W | W | W | W | | | | | | |
| Chloric Acid,...........$ClO_5$ | W | W | | | | | | | | | | |
| Tartaric Acid,..........$\overline{T}$ | W | W | W | W | | | A | | | | | |
| Citric Acid,.............$\overline{Ci}$ | W | W | | | | | | | | | | |
| Benzoic Acid,...........BzO | W | W | | W | | | | | | | | |
| Acetic Acid,.............$\overline{A}$ | W | W | W | W | | | W | | W | | W | |

1. The vacant spaces in the above table refer to compounds which are
2. Compounds which are sparingly soluble in water, and are otherwise
3. Substances which are insoluble in water, and only partially or sparingly
4. Compounds which are sparingly soluble in water and in acids, and in by the triple sign Ⓦ.

**and Salts in Water (W), in Acid (A), and Insoluble in Acids (O).**

| Oxide of Nickel, $NiO$. | Oxide of Cobalt, $CoO$. | Protoxide of Iron, $FeO$. | Sesquioxide of Iron, $Fe_2O_3$. | Oxide of Silver, $AgO$. | Oxide of Lead, $PbO$. | Suboxide of Mercury, $Hg_2O$. | Peroxide of Mercury, $HgO$. | Oxide of Copper, $CuO$. | Teroxide of Bismuth, $BiO_3$. | Oxide of Cadmium, $CdO$. | Teroxide of Gold, $AuO_3$. | Binoxide of Platinum, $PtO_2$. | Teroxide of Antimony, $SbO_3$. | Protoxide of Tin, $SnO$. | Binoxide of Tin, $SnO_2$. | Arsenious Acid, $AsO_3$. | Arsenic Acid, $AsO_5$. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | A |  | A | A | A | A | A | A | A |  |  |  | A |  | Ⓐ | W | W |
| W |  | W | W | Ⓦ | Ⓐ | W | W | W |  |  |  |  |  |  |  |  |  |
|  |  | A | A | A | A |  |  | A |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | A |  |  | A |  |  | A |  |  |  |  |  |  |  |  |  |
|  |  |  |  | A |  |  | A |  |  |  |  |  |  |  |  |  |  |
|  | W | W | W | O | Ⓦ | Ⓐ | W | W |  |  | W | W | W | W | W | W |  |
|  |  | W |  | O | W |  | A |  |  | W |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  | W |  |  |  |  |  |  |
| A | A | A |  | A | A |  | A | A |  | A |  |  | A |  |  | A | A |
|  | W |  | W | W | W | W | W | W | W |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | W |  |  |  |  |  |  |  |  |  |  | W |  |  |  |  |
|  |  | W |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  | W | W |  | W |  |  | W |  |  |  |  |  |  |  |  |  |

comparatively rare or unknown in commerce and in medicine.
soluble in acids, are marked with a double sign, thus, W.
soluble in acid, are indicated by the double sign Ⓐ.
considerable part appear undissolved by either liquid, are represented

249. The mode of applying the foregoing table may be best observed by taking an example. Thus, the operator has dissolved a saline substance in water, and has detected the presence of magnesia, $MgO$. He is desirous of learning what acid is likely to be in combination therewith, and on glancing down the column underneath magnesia, the first filled-up square he meets is in a line with sulphuric acid, $SO_3$, and the W signifies that the sulphate of magnesia, $MgO,SO_3$, is soluble in water. On passing still further down the column, he encounters another filled-up square with W in a line with hydrochloric acid, $HCl$, denoting that the chloride of magnesium, $MgCl$, is also soluble in water. The operator is thus informed that the acids most likely in combination with the magnesia, $MgO$, are sulphuric acid, $SO_3$, or hydrochloric acid, $HCl$, and he devotes special attention to the examination for these acids.

250. Again as another example. A substance is being experimented upon, and it is found insoluble in water, but soluble in acid, with effervescence or the escape of gas, which has no odour. From this he infers the presence of carbonic acid, $CO_2$, and thereafter, on testing for the metallic oxide, he may discover it to be oxide of lead, $PbO$. On glancing at the table, he receives an assurance of the correctness of his analysis, by observing that, passing down the lead column till it meets the carbonic acid line, he will there find the letter A, signifying that the carbonate of lead $PbO,CO_2$, is insoluble in water but soluble in acid.

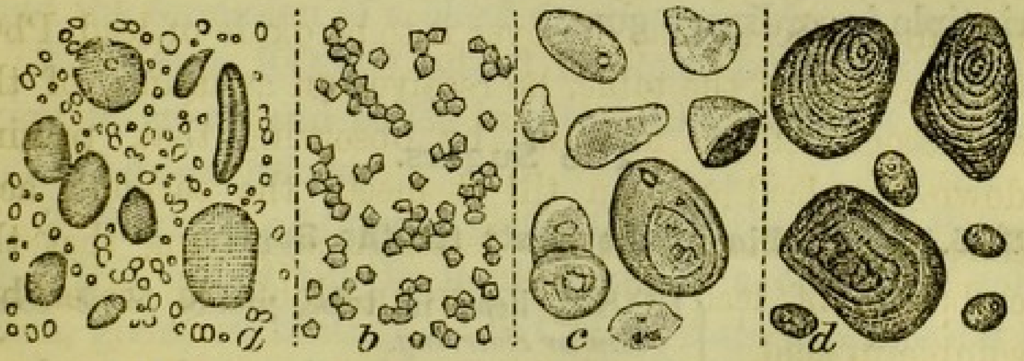
## Amylaceous and Saccharine Group of Substances.

251. This group of substances contains starch, gum, cane-sugar, grape-sugar, and milk-sugar. The starch is a well-known ingredient of most vegetable tissues, and the gum is generally met with in the form of gum-arabic. The cane-sugar is the saccharine substance which is present in the juices of the stems of plants; whilst the grape-sugar is the sweet substance present in the fruits of plants and in honey. Milk-sugar is found in milk.

### Starch, $C_{12}H_{10}O_{10}$.

**Ordinary Starch may be used in testing.**

252. There are many varieties of this substance as obtained from different plants, such as wheat-starch, potato-starch, rice, sago, tapioca, arrowroot, &c.; and the granules of each kind present a different appearance when examined under the microscope, as may be observed in the following diagram :



*a*, Wheat. *b*, Rice. *c*, Sago. *d*, Potato.

253. The chemical characters of starch are, that it softens in cold water, and when treated with hot water it forms a semi-transparent liquid, which jellies more or

less completely on cooling. In the cold the following tests may be applied to the solution.

1. *Tincture of Iodine* (solution of Iodine in Alcohol), which yields a *dark colour.*

2. *Iodide of Potassium*, KI, and *Nitric Acid*, $HO,NO_5$, which give a *dark-blue colour.*

3. *Iodide of Potassium*, KI, and *Chlorine*, Cl (evolved by acting upon bleaching-powder by sulphuric acid, $HO,SO_3$), also a *dark-blue colour.*

On heating any of the above mixtures, the blue colour disappears, but may occasionally be brought back on the subsequent cooling of the liquid.

### 254. Gum, $C_{12}H_{11}O_{11}$.

Ordinary Gum may be employed in testing.

Gum-arabic is soluble in cold water, and yields a solution which is commonly called mucilage, and is used in everyday life for causing substances to adhere together. The solution of gum is tasteless and insipid, and gives the following indication.

*Alcohol*, which throws down a *white fibrous-looking precipitate* of arabin, $C_{12}H_{11}O_{11}$, which is the essential principle in ordinary gum.

## The Sugars.

### 255. Table of the Tests for the Sugars.

| | |
|---|---|
| Sucrose, or Cane-Sugar, $C_{12}H_9O_9 + 2HO$,...... | $HO,SO_3$, heat in tube, yields *black solution or charring.* |
| | KO,HO, heat in tube, gives no *brown colour.* |
| | $CuO,SO_3$, and KO,HO, to blue solution, and heat in tube, produce a *red pre.* of $Cu_2O$. |
| | KO,HO, and $BiO_3,3NO_5$, heat in tube, form *no black pre.* |
| | Yeast = *glucose*, and at 70° to 80° F., = *alcohol* and $CO_2$. |

| | |
|---|---|
| Glucose, or Grape-Sugar, $C_{12}H_{12}O_{12}+2HO$,... | $HO,SO_3$, heat in tube, gives *no charring.*<br>$KO,HO$, heat in tube, yields a *dark-brown solution.*<br>$CuO,SO_3$, and $KO,HO$, to blue solution, and heat in tube, form a *red pre.* of $Cu_2O$.<br>$KO,HO$, and $BiO_3,3NO_5$, heat in tube, gives *black pre.*<br>Yeast, at 70° to 80° F., = *alcohol* and $CO_2$. |
| Lactose, or Milk-Sugar, $C_{24}H_{19}O_{19}+5HO$,... | The crystals of milk-sugar are very *hard* and *gritty.*<br>$HO,SO_3$, heat in tube, produces a *black solution or charring.*<br>$KO,HO$, heat in tube, gives a *dark-brown colour.*<br>$CuO,SO_3$, and $KO,HO$, to blue solution, and heat in tube, produces a *red pre.* of $Cu_2O$.<br>$KO,HO$, and $BiO_3,3NO_5$, heat in tube, gives *black pre.*<br>Casein ferments milk-sugar into *alcohol* and $CO_2$. |

### 256. Cane-Sugar, $C_{12}H_9O_9+2HO$.

A solution of ordinary Loaf-sugar may be used in testing.

1. *Concentrated Sulphuric Acid*, $HO,SO_3$, added to the solution of sugar in a test-tube, the mixed liquids thoroughly mingled, and heat applied, gives rise to *charring* and the formation of a *black solution.*

2. *Potash*, $KO,HO$, added in equal bulk to the solution of sugar, and boiled in a test-tube, does *not* produce a *dark-brown colour.*

3. *Sulphate of Copper*, $CuO,SO_3$, and thereafter *Potash*, $KO,HO$, added till the liquid becomes a clear blue solution, gives, on heating, *no red precipitate* of suboxide of copper, $Cu_2O$.

4. *Potash*, $KO,HO$, and a few drops of *ternitrate of bismuth*, $BiO_3,3NO_5$, produce, on boiling, *no black precipitate. Soda*, $NaO,HO$, or *Carbonate of Potash*, $KO,CO_2$, may be employed in place of potash.

5. *Yeast*, added to the solution of cane-sugar, converts it into grape-sugar, and thereafter, at 70° to 80° F., true fermentation occurs, and the sugar is resolved into *alcohol*, $C_4H_5O,HO$, and *carbonic acid*, $CO_2$.

### 257. Grape-Sugar, $C_{12}H_{12}O_{12} + 2HO$.

A solution of Honey or Grapes may be employed in testing.

1. *Concentrated Sulphuric Acid*, $HO,SO_3$, on heating in tube with grape-sugar, gives *no charring*.

2. *Potash*, $KO,HO$, gives, on boiling in a test-tube, a more or less *dark-brown colour*, according to the quantity of grape-sugar in the solution.

3. *Sulphate of Copper*, $CuO,SO_3$, and *Potash*, $KO,HO$, added to blue solution, yield, on heating, a *red precipitate* of suboxide of copper, $Cu_2O$.

4. *Potash*, $KO,HO$, and some drops of *Ternitrate of Bismuth*, $BiO_3,3NO_5$, give rise, on boiling, to a *black precipitate*. Soda, $NaO,HO$, or *carbonate of potash*, $KO,CO_2$, may be used in place of the potash.

5. *Yeast* develops with the solution of grape-sugar, at 70° to 80° F., the process of fermentation which results in the resolution of the grape-sugar into *alcohol*, $C_4H_5O,HO$, and *carbonic acid*, $CO_2$.

### 258. Milk-Sugar, $C_{24}H_{19}O_{19} + 5HO$.

A solution of ordinary Milk-Sugar may be used in testing.

1. *Concentrated Sulphuric Acid*, $HO,SO_3$, produces, when heated with milk-sugar in a test-tube, a *black solution or charring*.

2. *Potash*, $KO,HO$, boiled with milk-sugar in a test-tube, gives rise to a *dark-brown colour*.

3. *Sulphate of Copper*, $CuO,SO_3$, and thereafter *potash*, $KO,HO$, till the solution is blue, produce, on heating, a *red precipitate* of $Cu_2O$.

4. *Potash*, $KO,HO$, and *Ternitrate of Bismuth*, $BiO_3,3NO_5$ produce, on heating, a *black precipitate*.

5. *Casein*, or *Cheese*, added to milk-sugar, causes fermentation and the decomposition of the sugar into *alcohol*, $C_4H_5O,HO$, and *carbonic acid*, $CO_2$.

6. The crystals of milk-sugar may be distinguished from cane-sugar and grape-sugar, by being *hard* and *gritty*, and being very *slowly dissolved by water*.

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## The Albuminous Group of Substances.

259. Animal fluids are liable to contain three substances of complex constitution. Albumen, which is present in the blood and other liquids and juices ; Fibrin, which is an important constituent of the blood ; and Casein, which is found in milk. These substances form a group by themselves, and the following table gives the principal tests for each.

### 260. Table of the Tests for the Proteic or Albuminoid Group.

| | |
|---|---|
| Albumen.. | Heat in tube, 140° to 212° F., *coagulation*, *insol.* in $-NO_5$.<br>$NO_5$ ($HCl$, $SO_3$, $HO,PO_5$, or tannic acid) in the cold, produce *coagulation*.<br>$\bar{A}$ in the cold, gives *no coagulation*.<br>$HgCl$ ($PbO,\bar{A}$, $CuO,SO_3$, or $AgO,NO_5$) in the cold, form a *precipitation*.<br>Alcohol (or Creosote) in the cold, produce *coagulation*.<br>$+HCl$, heat in tube, gives *violet solution*.<br>$+NO_5$, heat tube, *yellow sol.*<br>$+SO_3$, heat tube, *brown-red sol.*<br>$KO,HO$, heat tube, gives *solution*, with which $PbO,\bar{A}$ yields a *brown* to *black pre.* |
| Fibrin.......... | *Spontaneous coagulation.* |

### Table of the Tests for the Proteic or Albuminoid Group.—Continued.

| | |
|---|---|
| Casein…… | Heat in tube, *no coagulation.* |
| | $NO_5$ (HCl or $SO_3$) cold, *coagulation.* |
| | $\bar{A}$ in the cold, *coagulation, soluble* in excess of $\bar{A}$. |
| | HgCl ($PbO,\bar{A}$, $CuO,SO_3$, or $AgO,NO_5$) cold, *precipitation.* |
| | Rennet causes *coagulation.* |
| | + HCl, + $NO_5$, and + $SO_3$, heat in tube, *same as with albumen.* |
| | KO,HO, heat in tube, *solution;* add $PbO,\bar{A}$, *brown to black pre.* |

## 261. Albumen.

The White of Egg, diluted with water, may be used in testing.

1. *Heat* the albuminous solution in a test-tube to a temperature ranging between 140° to 212° F. and *coagulation* occurs, which is not dissolved on the subsequent addition of *dilute nitric acid*, $HO,NO_5$.

2. Add *dilute Nitric Acid*, $HO,NO_5$, in the cold, and *coagulation* takes place. The same is produced on the addition of *Hydrochloric Acid*, HCl; *Sulphuric Acid*, $HO,SO_3$; *Monobasic Phosphoric Acid*, $HO,PO_5$; or *Tannic Acid.*

3. *Acetic Acid*, $HO,\bar{A}$, produces *no coagulation.*

4. *Chloride of Mercury*, HgCl, in the cold, causes *precipitation. Acetate of Lead*, $PbO,\bar{A}$; *Sulphate of Copper*, $CuO,SO_3$; and *Nitrate of Silver*, $AgO,NO_5$, produce a *similar result.*

5. *Alcohol*, $C_4H_5O,HO$ (or *Creosote*), in the cold, causes *coagulation.*

6. *Concentrated Hydrochloric Acid*, +HCl, when boiled with the albumen in a test-tube, gives a *violet solution.*

7. *Concentrated Nitric Acid*, $HO,NO_5$, yields, on heating, a *yellow solution.*

8. *Concentrated Sulphuric Acid*, $HO,SO_3$, produces, on heating, a *brown-red solution.*

9. *Potash*, $KO,HO$, when boiled with albumen, causes decomposition, and forms the *Sulphuret of Potassium*, $KS$, which, on the addition of *Acetate of Lead*, $PbO,\overline{A}$, gives a *dark-brown* or *black precipitate* of the sulphuret of lead, $PbS$.

### 262. Fibrin.

Fresh-drawn Blood may be employed in testing.

The most characteristic property of fibrin is the power of *spontaneous coagulability* which it possesses, and which is well seen when *fresh-drawn blood* is allowed to stand at rest, and the fibrin *spontaneously begins to clot* or form a *coagulum.* When the fresh-drawn blood is agitated with a bundle of twigs, the fibrin attaches itself thereto, and it may be thereafter washed in water to free it from blood, and in ether to separate fatty matters.

### 263. Casein.

Ordinary fresh Milk may be used in testing.

1. *Heat* does *not coagulate* the casein.

2. *Nitric Acid*, $HO,NO_5$, in the cold, causes *coagulation. Hydrochloric Acid*, $HCl$, and *Sulphuric Acid*, $HO,SO_3$, act similarly.

3. *Acetic Acid*, $HO,\overline{A}$, forms a *coagulum*, which is soluble in great excess of the acid.

4. *Chloride of Mercury*, $HgCl$, in the cold, *precipitates the casein ;* solutions of *Lead*, *Copper*, and *Silver* likewise do so.

5. *Rennet* (the infusion of the stomach of the calf) causes *coagulation.*

6. *Concentrated Hydrochloric*, *Nitric*, and *Sulphuric Acids*, heated with casein, give the *same results as with albumen.*

7. *Potash*, $KO,HO$, decomposes casein when boiled therewith, yielding *Sulphuret of Potassium*, $KS$, which *blackens* on addition of *Acetate of Lead*, $PbO,\bar{A}$.

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## Vegeto-Alkaloids or Alkalis.

264. These substances are organic bases which are found in a few plants, and which possess powerful medicinal and poisonous properties. The class is a numerous one, but there are only three members of the group which call for special notice. These are Strychnia or Strychnine, Morphia or Morphine, and Quinia or Quinine.

265. Strychnine occurs principally in the seeds of the *Strychnos nux vomica*, which, when pulverised, yield *powdered nux vomica*. This powder is well known, and may be recognised by the following tests.

1. *Concentrated Sulphuric Acid*, $HO,SO_3$, gives a *thick black mass* resembling treacle in consistence and appearance.

2. *Concentrated Nitric Acid*, $HO,NO_5$, yields a *bright-red resinous mass* with a figgy aspect. The red colour is due to the presence of the alkaloid brucine.

3. *Water* partially dissolves the nux-vomica powder, and yields a liquid with an intensely *bitter taste*, which can be safely observed when the tip of the finger is moistened with the solution and placed on the tongue.

266. *Morphine* is the active ingredient of opium, and consequently of laudanum, which is a mixed water and alcoholic solution of opium. The numerous substances which are present in the opium, besides the morphine, hinder the production of the tests for morphine either in a water solution of the opium or in ordinary laudanum;

but decided evidence can be obtained in either solution of the meconic acid which is in combination with the morphine in the opium.

267. *Meconic Acid*, $3HO + C_{14}HO_{11}$, is tested for by the addition of perchloride of iron, $Fe_2Cl_3$, to the water solution of the opium, or of the laudanum diluted with water, which gives a *blood-red solution* which is not bleached on the subsequent addition of *chloride of mercury*, HgCl. The well-known peculiar odour of opium and laudanum is also of importance in the testing operations.

268. *Quinine* is the principal active ingredient in peruvian or cinchona bark, where it is associated with the alkaloid *cinchonine*.

**269. Table of the Tests for the Alkaloids.**

| | |
|---|---|
| Strychnine, $C_{42}H_{22}N_2O_4$, or $\overset{+}{Sr}$,... | KO,HO gives a *white pre.*, *insol.* in excess.<br>$NaO,HO,2CO_2$, in an acid solution, yields *no pre.*<br>$K,CyS_2$ produces a *white pre.*<br>HgCl forms a *white pre.*<br>$AuCl_3$ produces a *lemon-yellow pre.*<br>Cl,Aq and $NH_4O$ yield a *colourless solution.*<br>$+NO_5$, in the cold, gives a *colourless solution*, and when heated a *yellow solution.*<br>$+SO_3$ and $KO,2CrO_3$ form a *violet colour*, fading into a *yellow solution.*<br>$+SO_3$ and $MnO_2$ (or $PbO_2$ with trace of $NO_5$), *violet* passing to *yellow.* |
| Morphine, $C_{34}H_{19}NO_6$, or $\overset{+}{Mo}$,... | KO,HO produces a *white pre.*, *sol.* in excess.<br>$NaO,HO,2CO_2$ forms in neutral solutions a *white pre.*, *insol.* in excess.<br>$Fe_2Cl_3$ gives in neutral solutions a *blue solution.*<br>$IO_5$ evolves iodine, recognised by its *odour*, the *brown colour* of the liquid, and on the addition of starch, a *blue colour.*<br>$+NO_5$, in the cold, yields a *red solution*, which becomes *yellow* on standing or on heating. |

### Table of the Tests for the Alkaloids—Continued.

| | |
|---|---|
| Quinine, $C_{40}H_{24}N_2O_4$, or $\overset{+}{Q}$,.... | $KO,HO$ yields a *white pre.*, *insol.* in excess.<br>$NaO,HO,2CO_2$ produces a *white pre.*, *sol.* in great excess.<br>$+NO_5$ gives in the cold a *colourless solution*, and when heated a *yellow solution.*<br>$Cl,Aq$, and thereafter $-NH_4O$, give rise to an *emerald-green solution.*<br>When solution of quinine is treated with much water, and poured from one vessel to another, *fluorescence* is observed. |

### 270. Strychnine, $C_{42}H_{22}N_2O_4$, or $\overset{+}{Sr}$.

A solution is obtained by heating a few crystals with an equal quantity of *oxalic acid*, $\overline{O}$, in water in a test-tube, when a solution of the oxalate of strychnine, $\overset{+}{Sr},\overline{O}$, is formed, and may be used in testing.

1. *Potash*, $KO,HO$, added to the solution of strychnine, gives a *white precipitate* of strychnine, $\overset{+}{Sr}$, which is *insoluble* in excess of the potash.

2. *Bicarbonate of Soda*, $NaO,HO,2CO_2$, gives in an acid solution *no precipitate.*

3. *Sulphocyanide of Potassium*, $K,CyS_2$, produces, on stirring, a *white precipitate.*

4. *Chloride of Mercury*, $HgCl$, yields, on stirring in the cold, a *white precipitate.*

5. *Perchloride of Gold*, $AuCl_3$, gives, on stirring, a *lemon-yellow precipitate.*

6. *Chlorine Water*, $Cl,Aq$, and subsequently *Ammonia*, $NH_4O$, yield *no green solution.*

7. *Concentrated Nitric Acid*, $HO,NO_5$, gives no colour in the cold (provided brucine be absent), and only a *yellow solution* when heated.

8. *Concentrated Sulphuric Acid*, $HO,SO_3$, added in small quantity to the strychnine on a white porcelain plate, and thereafter a glass rod dipped in *bichromate of*

*potash*, $KO,2CrO_3$, drawn across the plate, give rise to the production of a magnificent *violet colour*, which quickly fades into *red* and *yellow*. This is the most delicate and most characteristic test for strychnine. A small *crystal* of the *bichromate of potash* may be used instead of the solution.

9. *Concentrated Sulphuric Acid*, $HO,SO_3$, and *Binoxide of Manganese*, $MnO_2$, also produce the *violet colour*, fading into *red* and *yellow*. *Binoxide of Lead*, $PbO_2$, containing a trace of nitric acid, $HO,NO_5$, may be employed in place of the binoxide of manganese.

### 271. Morphine, $C_{34}H_{19}NO_6$, or $\overset{+}{Mo}$.

A solution of Muriate of Morphia, $\overset{+}{Mo},HCl$, may be employed in testing.

1. *Potash*, $KO,HO$, gives a *white precipitate* of hydrated morphia, $\overset{+}{Mo},2HO$, which is *soluble* in excess of potash.

2. *Bicarbonate of Soda*, $NaO,HO,2CO_2$, yields in neutral solutions a *white precipitate* of hydrated morphia, $\overset{+}{Mo},2HO$, which is *insoluble* in excess.

3. *Perchloride of Iron*, $Fe_2Cl_3$, forms in neutral solutions a *blue colour*, more or less deep, according to the strength of the solution of morphia.

4. *Iodic Acid*, $IO_5$, which is colourless, when added to the morphia solution, gives rise to the liberation of *free iodine*, I, and this colours the liquid of a *brown tint*, and evolves the odour of iodine. The subsequent addition of *starch* paste forms a more or less *deep-blue colour*.

5. *Concentrated Nitric Acid*, $HO,NO_5$, forms, in the cold, a *red solution*, which fades to *yellow* when allowed to stand for some time, or when heated in a tube.

### 272. Quinine, $C_{40}H_{24}N_2O_4$, or $\overset{+}{Q}$.

Ordinary medicinal Quinine, which is the Bisulphate of Quinine, $2\overset{+}{Q},SO_3$, is sparingly soluble in water, but the addition of a few drops of *Concentrated Sulphuric Acid*, $HO,SO_3$, forms the Sulphate of Quinine, $\overset{+}{Q},SO_3$, which is readily soluble in water, and may be used in testing.

1. *Potash*, $KO,HO$, yields a *white precipitate* of hydrated quinine, $\overset{+}{Q},6HO$, which is *insoluble* in excess.

2. *Bicarbonate of Soda*, $NaO,HO,2CO_2$, produces a *white precipitate*, which is *soluble* in great excess.

3. *Concentrated Nitric Acid*, $HO,NO_5$, forms, in the cold, a *colourless solution*, and on heating, it becomes of a *yellow tint*.

4. *Chlorine Water*, $Cl,Aq$, added to the solution of quinine, and thereafter an excess of dilute ammonia, $NH_4O$, produces a fine *emerald-green solution*. This is the most characteristic test for quinine.

5. *Water*, $HO$, added in large quantity to the solution of quinine, forms a liquid which exhibits a fine fluorescent appearance. The fluorescence is best seen on the surface of the liquid, and when the solution is poured from one vessel to another.

## Neutral Substance; Not an Alkaloid.

### 273. Salicine, $C_{26}H_{18}O_{14}$.

Salicine is a bitter neutral substance, which is found in white crystalline needles and scales with a silky lustre.

1. *Concentrated Sulphuric Acid*, $HO,SO_3$, added to the solid salicine, produces a *blood-red resinous* substance, which gradually dissolves in the acid. This test is characteristic of salicine.

2. *Dilute Sulphuric Acid*, $HO,SO_3$, mingled with a water solution of salicine, and boiled for some time in a

test-tube, gives rise suddenly to *turbidity*, and the formation of a *white crystalline precipitate* of saliretin. *Dilute Hydrochloric Acid*, HCl, will form the same precipitate.

## Systematic Qualitative Analysis.

### Preliminary Examination.

274. During the course of the examination of unknown substances as referred to in this treatise (pars. 204 to 250), special reference was made to the mode of applying the tests in a systematic manner for the detection of simple compound substances, or those containing *not more than one metallic oxide and one acid.* The operator may now proceed to acquire a knowledge of the processes which may be followed in the preliminary examination of unknown substances, and which may consist of one or more ingredients.

275. The previous parts of the course of Practical Chemistry will have made the operator familiar with the names and symbols of all the reagents, and of the metallic oxides and acids which generally constitute the many chemical substances which he is likely to meet with; and considering it probable that the student is now conversant with the symbols of the substances, these will be principally used in the following paragraphs. The tabular statement of the modes of operating being more readily observed will be adhered to, and the more full description of the processes will be left to be filled in by the teacher or by the intelligent student.

276. The investigation which is now to be entered

upon is of a more varied character than what has already been given, and hence more steps must be followed in the various processes. The consequence is, that the quantity of the material under examination is apt to run done before the testing has been satisfactorily concluded. It is therefore necessary to lay down the rule, that the greatest care be taken at every stage to economise the substance under analysis, and to use as little as possible in each test. The general plan of work is to subject the material under examination to the action of heat in a narrow piece of glass tube, and observe any change which may occur in the general appearance of the substance, and the nature of any vapours or gases which may be evolved. Occasionally the material is more or less volatilised on the application of heat, and condenses once again in the colder part of the tube, and the colour and nature of this sublimation must be specially observed. The next operation is to heat a portion of the substance under examination before the blow-pipe, either on charcoal or on a platinum wire, and occasionally by the aid of a flux, when certain incrustations may be formed on the charcoal, and colours be communicated to the beads on the platinum wire, which will indicate the presence of the various metallic oxides and other bodies.

277. The course of examination specially considers certain *preliminary operations* which serve to indicate the general character of the material in process of analysis, whether that be a saline substance or a metal, and in some instances to give reliable tests for the identification of the constituents; but in all cases the operator should further proceed to the solution of the substance (pars. 233—237 and 243—245); and to the application of the tests included in the Systematic Course at pars. 204—230. When the substance is insoluble in

water and in acids, the operator will pay special attention to the remarks made at par. 297, where the properties of the comparatively few substances which resist the action of the ordinary solvents—viz., water and acids—are particularly referred to. In the majority of instances, the pupil will find that the saline substance under examination is readily dissolved by water or by acids; but when these fail to give a solution, then recourse must be had to the mode of testing given at par. 297. Where the operator has reason to believe that the substance under examination is of a complex nature, and contains more than one metallic and acid, or more than one metal, he must consult one of the larger treatises on Practical Chemistry, such as Fresenius's *Qualitative Analysis*.

## Preliminary Examination

*It is neither a Metal*

278. The student will observe the general appearance,
substance; then reduce the crystals or larger pieces to a
testing as follows :

279. Introduce some of the powder into a piece of hard
a quarter of an inch in diameter, and heat gently over a

| 280. The substance *does not undergo any change.* | 281. The material *changes colour*, but does *not fuse readily.* | 282. The substance *fuses*, and *no water is evolved.* | 283. Water vapour *is readily evolved.* |
|---|---|---|---|
| This indicates the absence of<br>1. *Matters which alter in colour when heated.*<br>2. *Substances which fuse.*<br>3. *Bodies with water of crystallisation.*<br>4. *Volatile matters.*<br>5. *Organic bodies.* | 1. *Yellow* when hot, and *white* on cooling, = ZnO.<br>2. *Yellow - brown*, hot; and *yellow*, cold, = $SnO_2$.<br>3. *Reddish - brown*, hot; and *yellow*, cold; whilst it fuses at red heat, = PbO.<br>4. *Orange* or *reddish brown*, hot; and *yellow*, cold; and fuses at white heat, = $BiO_3$.<br>5. *Red*, cold; to *black*, hot; then *reddish - brown*, cold, = $Fe_2O_3$.<br>6. *Yellow*, cold; to *orange*, hot; and fuses at white heat, = $KO,CrO_3$. | Heat more strongly, and insert fragment of charcoal. *Deflagration* indicates either *nitrates* or *chlorates.* | Presence of—<br>1. Substances with *water of crystallisation.*<br>2. *Hydrates* or bodies containing water in combination.<br>3. Substances containing *water as moisture.*<br>Use test papers, and see if vapour is *alkaline* or *acid.* |

## of a Solid Substance.

*nor an Alloy.*

specific gravity, shape, hardness, colour, odour, &c., of the fine powder in a mortar. This powder may be used in

glass tube, closed at one end, about three inches long, and Bunsen lamp or spirit-lamp.

284. Gases and vapours other than steam are given off.

1. The gas *relights* a splinter of wood with a red tip = *oxygen*, indicative of the presence of CHLORATES, NITRATES, PEROXIDES, &c.
2. The gas has the odour of *burning sulphur*, = SULPHATES and SULPHITES.
3. The gas is of a *brown-red colour*, $NO_3$, = NITRATES.
4. The gas extinguishes a match, and renders $CaO,Aq$ *turbid*, = CARBONATES.
5. The gas burns with a *pale-blue flame*, $CO$, = OXALATES.
6. The gas burns with a *rose tint*, and has peculiar odour, $Cy$, = CYANIDES.
7. The gas has the *odour of rotten eggs*, and blackens paper with $PbO,\bar{A}$, = $HS$, and indicates SULPHIDES.
8. The gas has the *odour of hartshorn*, $NH_3$, and indicates *salts of* AMMONIA or ORGANIC SUBSTANCES *containing nitrogen.*

285. The substance rises in vapour, and condenses as a solid in the cold part of the tube, = *sublimation.*

1. *Reddish-brown drops*, hot; and *yellow solid*, cold, = SULPHUR, $S$.
2. *White deposit*, and $CaO,HO$, *evolves* $NH_3$, = AMMONIACAL SALTS.
3. *Metallic globules*, = MERCURY, $Hg$.
4. Deposit is *black*, and *red* when rubbed, = $HgS$.
5. *Fuses, sublimes, white*, = $HgCl$.
6. *No fusion, sublimes; yellow*, hot; *white*, cold, = $Hg_2Cl$.
7. Substance is *red*, and sublimes *yellow*, = $HgI$.
8. Sublimate is *metallic mirror*, = $As$.
9. *Small dazzling crystals*, = $AsO_3$.
10. *Reddish yellow*, hot; and *yellow*, cold, = $AsS_3$ or $AsS_5$.
11. Fuses to *yellow liquid*, and then *sublimes*, = $SbO_3$.
12. Readily liquefies, and sublimes with *irritating fumes*, = $BzO$.

286. The substance *chars* in the tube, indicative of the presence of *organic substances.* After full charring, if the residue *effervesces* on the addition of —$HCl$, whilst the original substance did *not effervesce*, = ORGANIC ACIDS.

## Preliminary Examination of

### *It is neither a Metal*

The operator, having specially noticed the results of the

proceed to observe any further indications which may be

287. A piece of charcoal is taken, and a shallow cavity being formed in it, a small portion of the substance under examination is placed on the charcoal, and exposed to the inner blow-pipe flame for a short time.

288. The substance *becomes fused, and is taken up by the charcoal,* or merely leaves a bead in the cavity, but does not give rise to the incrustation of the sides of the cavity.

These results are indicative of *alkaline salts.*

289. *A white residue is left on the charcoal.*

May indicate $SiO_3$, $BaO$, $SrO$, $CaO$, $MgO$, $Al_2O_3$, or $ZnO$. The latter is *yellow* when hot. If the residue appears *luminous* when the blow-pipe flame is directed upon it, this is specially indicative of $SrO$, $CaO$, $MgO$, or $ZnO$. Moisten the residue with $CoO,NO_5$, and heat again in blow-pipe flame.

Residue becomes *blue,* = $Al_2O_3$.

Residue becomes *green,* = $ZnO$.

Residue becomes *red tint,* = $MgO$.

Residue, *blue tinge,* may be $SiO_3$.

290. The material (1.) yields *an incrustation on the charcoal,* (2.) is reduced to the *metallic state,* or (3.) leaves a *residue of another colour,* which is *infusible.* Add to a new portion of the powder some dry $NaO,HO,2CO_2$, place on charcoal, and heat strongly in the inner flame of the blow-pipe.

(*a.*) *A metallic globule,* but *no incrustation* of the charcoal, = Cu or Au.

(*b.*) *Metallic globules* and *incrustation* on charcoal.

The incrustation is—

1. *White,* and *garlic odour,* = As.
2. *White,* and globules *brittle,* = Sb.
3. *Yellow,* hot; and *white,* cold, = Zn.
4. *Faint yellow,* hot; and *white,* cold. Globules bright and soft, = Sn.
5. *Orange yellow,* hot; and *yellow,* cold. Globules *soft* and *easily* cut, = Pb.
6. *Reddish yellow,* hot; and *yellow,* cold. Globules brittle, = Bi.
7. *Red brown,* and *easily volatilised,* = Cd.
8. *Dark red,* and globules *bright and soft,* = Ag.

a Solid Substance—Continued.

*nor an Alloy.*

heating of the substance in the narrow glass tube, will now yielded by heating the material before the blow-pipe.

291. Mix a small portion of the substance with $NaO,NH_4O,HO,PO_5$, and heat on a platinum wire in the outer flame of the blow-pipe.

292. *A clear bead* (whilst hot) *is readily formed.*

(*a.*) *The bead is coloured.*

1. *Blue*, with a *violet tinge*, = COBALT.
2. *Green*, hot; *blue*, cold; and in inner flame of blow-pipe, *red*, = COPPER.
3. *Green*, hot or cold, = CHROMIUM.
4. *Brown red*, hot; *yellow*, cold; and in inner flame, *red*, hot, and *yellow*, cold, = IRON.
5. *Yellow brown*, hot; *yellow*, cold; and in inner flame, *colourless*, hot, and *blackish gray*, cold, = BISMUTH.
6. *Yellow to opal*, hot; *dull yellow*, cold; and in inner flame, *grayish white*, = SILVER.
7. *Amethyst red*, hot or cold; and in inner flame, *colourless*, = MANGANESE.

(*b.*) *The hot bead is colourless.*

1. On cooling, the bead remains *clear*, = ANTIMONY, ALUMINA, ZINC, CADMIUM, LEAD, LIME, or MAGNESIA. When the metal is in large quantity, ZINC, CADMIUM, LIME, and MAGNESIA give *enamel-white beads;* and LEAD yields an *enamel-yellow bead.*
2. On cooling, the bead becomes *enamel white*, with minute portion of substance, = BARYTA or STRONTIA.

293. *A clear bead is slowly formed.*

1. The bead is *colourless*, hot or cold; add $Fe_2O_3$, and reheat; gives reactions of iron bead, par. 292 (4), = SILICIC ACID.
2. The bead is *colourless*, hot or cold, and is *not altered by* $Fe_2O_3$, = TIN.

294. The substance does *not dissolve* in the $NaO,NH_4O,HO,PO_5$, but is observed in the *metallic state floating in the bead*, = GOLD or PLATINUM.

## Preliminary Examination of Substances—Continued.

295. *It is either a Metal or an Alloy.*

(*a*.) Heat a portion of the metal or alloy with *diluted acetic acid*. *Hydrogen evolved as gas* indicates the presence of a metal of the ALKALIES, ALKALINE EARTHS, or MANGANESE.

(*b*.) Heat the metal or alloy on charcoal in the inner flame of the blow-pipe.

Compare incrustations with pars. 289—290. Further,

1. *Garlic odour* = ARSENIC.
2. *Fluidity* = MERCURY.
3. *Green flame* = COPPER.
4. *Fuses without incrustation* = GOLD.
5. Do *not fuse* in blow-pipe flame, may be either PLATINUM, IRON, MANGANESE, NICKEL, or COBALT.

(*c*.) Place metal or alloy in glass tube closed at one end, and heat.

1. *Sublimate of metal* in cold part of tube, indicative of MERCURY, CADMIUM, or ARSENIC. The mercury is in small globules.
2. *No sublimate;* absence of MERCURY.

296. The substance is a fluid.

(*a*.) Evaporate a portion to dryness in porcelain capsule. Proceed with residue as a solid substance (par. 278).

(*b*.) Place *litmus* and *turmeric papers* in the solution under examination.

1. The *liquid is acid*, indicative of a FREE ACID, or an ACID SALT.
2. The liquid is *alkaline*, and denotes the presence of a free ALKALI or ALKALINE EARTH, or ALKALINE SULPHIDE or CARBONATE.

(*c*.) Notice the odour of the fluid, and heat gently to see if liquid is WATER, ALCOHOL, or ETHER. If *alcohol* or *ether*, evaporate to dryness, and treat any residue as a solid substance.

(*d*.) If water be the solvent, and the liquid be acid, add more water, and a *milky or white appearance*, denotes either ANTIMONY or BISMUTH.

## Solution of Substances.

297. *The substance is neither a Metal nor an Alloy.*

Treat the substance with water and acids as directed at pars. 233—237.

The substance is *insoluble in water and in acids.*

(*a.*) *Yellow*, and burns with *odour of* $SO_2$, = SULPHUR.

(*b.*) *Black*, burns on platinum vessel, and deflagrates with $KO,NO_5$, = CHARCOAL.

(*c.*) Add $NH_4S,HS$ to a small quantity of the substance under examination.

| The substance becomes *black.* | The substance remains *white.* |
|---|---|
| 1. If fused when *heated in glass tube*, may indicate PbCl, PbBr, AgCl, AgBr, or AgI. Mix with 4 parts of white flux, and fuse in porcelain capsule before the blow-pipe. When cold, add water, boil, filter, and test the liquid for HCl, HBr, or HI (pars. 222—224). The residue is either the metal Ag or Pb. Digest in $NO_5$, and test the solution (pars. 204—209).<br>2. Cy was evolved from glass tube, and metallic Ag remains, = AgCy.<br>3. The substance did not change when heated in glass tube, = $PbO,SO_3$. Add solution of $NaO,CO_2$, and boil, filter. | 1. Mix a portion with fine sand and $HO,SO_3$; heat in platinum capsule. *Irritating fumes are evolved*, which are *acid* to test papers, and *corrode glass;* indicative of HF from CaF.<br>Treat the residue with HCl, boil, filter; add $NH_4O$; filter again if necessary, and test for lime.<br>2. *No fumes are evolved.* Mix with 4 times its weight of white flux, and fuse on platinum before blow-pipe. When cold, add water, boil, filter. |

| Filtrate. | Contents of filter. |
|---|---|
| Test for $SO_3$ (par. 221). | Dissolve in $NO_5$, and test for LEAD (pars. 204, 205, and 210). |

| Filtrate. | Contents of filter. |
|---|---|
| Add HCl and BaCl for SULPHURIC ACID.<br>If no $SO_3$, then evaporate, and retreat with water, and insoluble flakes denote SILICA or SILICATES. | If $SO_3$ has been detected, the metallic oxide is on the filter.<br>Add —HCl; filter again, and test the liquid for BaO, SrO, or CaO. |

298. The substance *is a metal or an alloy.*

Proceed as at pars. 243—245.

# INDEX.

THE END.

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