Notes on analytical chemistry for students in medicine : extracted from the fifth edition of "Notes for students in chemistry" / by Albert J. Bernays.

NOTES ON ANALYTICAL CHEMISTRY

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FOR STUDENTS IN MEDICINE

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EXTRACTED FROM THE FIFTH EDITION OF 'NOTES FOR
STUDENTS IN CHEMISTRY'

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PREFACE.

In re-casting the sixth edition of my 'Notes for Students in Chemistry,' I found myself so cramped for space that I omitted the 'Notes on Analytical Chemistry,' and determined to publish them separately.

The present book is the third edition as a separate issue.

I have again to express my sincere thanks to my chief assistant, Mr. C. G. Stewart, and also to a former one, Mr. A. P. Hoskins, for the help afforded in passing the sheets through the press. At the suggestion of Messrs. Greg and Dear, I have expanded the preliminary portion, and I have to thank them for explaining to me the difficulties they experienced in the use of the book. Mr. Styles, a promising pupil, has also greatly aided me in correcting the press.

Albert J. Bernays.

Chemical Laboratory,
St. Thomas's Hospital Medical School.
February, 1889.

CONTENTS.

BERNAYS'S NOTES
ON
ANALYTICAL CHEMISTRY.

PRELIMINARY.

PURE DISTILLED WATER.

As distilled water is the great solvent of liquids, solids, and gases, substances may be contained in solution.

Distilled water is colorless, inodorous, and uninflammable. It has no effect upon the colors of blue litmus, red litmus, or turmeric papers: they are only wetted. A solution of Carbonate of Sodium to a small portion contained in a test tube, and of Nitrate of Silver to another portion, produces no change in the appearance of the water. Acidulated with Hydrochloric acid, no darkening takes place when Hydric sulphide is added to a further portion of the water. If quite pure, it is not rendered turbid by Lime-water, nor colored even faintly yellow by Nessler's test. Finally, a drop heated upon Platinum-foil should leave no residue, if the water is absolutely pure.

Water freezes at 0° C., and boils at 100° C. under a pressure of 760 millimetres. Water is said to boil when the tension of its vapor is equal to the superincumbent pressure. In becoming ice, one volume of water enlarges to 1·0908. It is almost incompressible. It is the standard of specific gravities of solids and liquids. Water has a maximum density at 4° C., and expands for all degrees above and below 4°. In the passage from ice, to liquid water of the same temperature, heat is absorbed and becomes latent; the latent heat of water is said to be 79 thermal units,—a thermal unit meaning the amount of heat required to raise a unit weight of water through 1° C. The latent heat of steam at 100° is 536 thermal units. Water has also the highest specific heat of bodies, and is taken as the standard of comparison of specific heats. By specific heat, we understand the quantity of heat necessary to raise one gramme weight of a body 1° C., as compared with that which is required to raise the same weight of water 1° C. Thus in the same time that one gramme of mercury is raised 30°, the gramme of water is raised 1° C.; the ratio between these two quantities would then be the specific heat of mercury. Each element has its own specific heat, and this is, generally, inversely as their atomic weights. But, if instead of comparing equal weights of the elements with an equal weight of water, we take the atomic weights of the elements, the elements have, for the most part, the same atomic heats. The atomic heats of most of the elements may be taken as 6·4, and they are obtained by multiplying the specific heat of each element by its atomic weight. Water is the great solvent. As a rule, the lower the temperature, the larger the amount of gases soluble in water. Equally, as a rule, the higher the temperature of water, the greater is its solvent power upon solids.

OF SUBSTANCES IN SOLUTION.

Now study the reactions with *Test-papers,* especially with *red litmus* and *blue litmus.*

A. Red litmus is turned blue: solution is alkaline.
B. Blue litmus is reddened: solution is acid.
C. Test-papers are unchanged: neutral.

A. THE SOLUTION IS ALKALINE: *red litmus is blued.*

If an alkaline solution contains free Ammonia, or Carbonate of Ammonium, the Ammonia will be recognised by the smell. If the alkaline solution contains a Sulphide, there will be the odor as of rotten eggs. If the alkaline solution contains a Cyanide, there will be a smell of prussic acid.

a. To a portion in a test-tube, say 20 drops, add a solution of *Carbonate of Sodium* Na_2CO_3: a careful observation of results is of first importance.

I. No precipitate in the alkaline solution, and no smell of Ammonia NH_3, even on boiling, would indicate either Potassium hydroxide KOH, Sodium hydroxide $NaOH$, or Salts of Potassium, or Sodium, with alkaline reaction. [Carbonate of Potassium K_2CO_3, Carbonate of Sodium Na_2CO_3, and Carbonate of Ammonium $(NH_4)_2CO_3$, are very soluble in water, and turn litmus paper blue.]

II. No precipitate with Sodium carbonate Na_2CO_3, but a smell of Ammonia NH_3, without, or with heating, would indicate a solution of Ammonium hydrate NH_4OH, or some Salt of Ammonium with alkaline reaction.

III. A white precipitate with Sodium carbonate Na_2CO_3, in the alkaline solution, points to the Hydroxides or Hydrates of Barium $Ba(OH)_2$, Strontium $Sr(OH)_2$, or Calcium $Ca(OH)_2$. [Barium carbonate $BaCO_3$, Strontium carbonate $SrCO_3$, and Calcium carbonate $CaCO_3$, are practically insoluble in pure water: they are precipitated from any of their soluble salts by solution of Carbonate of Sodium. Thus:

$$BaCl_2 + Na_2CO_3 = BaCO_3 + 2NaCl.$$
$$Sr2NO_3 + Na_2CO_3 = SrCO_3 + 2NaNO_3.$$
$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4.]$$

β. To a further portion of the alkaline solution, contained in a test-tube, add *Nitrate of Silver* $AgNO_3$.

The precipitate is *grey-brown:* divided into two portions, the one is soluble without effervescence in Nitric acid, and the other in Ammonia. The solution must contain Hydroxides of Potassium, Sodium, Ammonium, Barium, Strontium or Calcium, as these alone are soluble in water.

$$KOH + AgNO_3 = AgOH + KNO_3.$$
$$NaOH + AgNO_3 = AgOH + NaNO_3.$$
$$NH_4OH + AgNO_3 = AgOH + NH_4NO_3.$$
$$Ba(OH)_2 + 2AgNO_3 = 2AgOH + Ba2NO_3.$$
$$Sr(OH)_2 + 2AgNO_3 = 2AgOH + Sr2NO_3.$$
$$Ca(OH)_2 + 2AgNO_3 = 2AgOH + Ca2NO_3.$$

All the hydroxides are converted into soluble nitrates, and the Silver nitrate into insoluble grey-brown Silver hydroxide AgOH. If then, in an alkaline solution, Sodium carbonate has produced no ppt., the *Alkalies*, Potassium, Sodium and Ammonium hydrates may be present, and their presence is confirmed by the grey-brown ppt. when Silver nitrate has been added. [N.B.—With Ammonic hydrate, Silver nitrate will give no ppt. unless the solution of Ammonia is weak, or the solution of Silver nitrate is strong and in excess, because Silver hydroxide is so soluble in Ammonic hydrate.] Again, if Sodium carbonate has produced a white ppt. in an alkaline solution, the alkaline earths as Hydroxides, respectively, of Barium, Strontium, or Calcium may be present, confirmed by Silver nitrate occasioning a grey-brown ppt.

If the ppt. with Silver nitrate in an alkaline solution is *liver-brown,* readily soluble both in Ammonic hydrate and in Nitric acid, an Arsenate of Potassium, Sodium or Ammonium is present. Thus, with the common Sodium arsenate:

$$Na_2HAsO_4 + 3AgNO_3 = Ag_3AsO_4 + 2NaNO_3 + HNO_3.$$

If the ppt. is *bright yellow,* and soluble both in Ammonic hydrate and in Nitric acid, a Phosphate or an Arsenite, of Potassium, Sodium or Ammonium is present. *E.g.*

$$Na_2HPO_4 + 3AgNO_3 = Ag_3PO_4 + 2NaNO_3 + HNO_3.$$
$$K_3AsO_3 + 3AgNO_3 = Ag_3AsO_3 + 3KNO_3.$$

If the ppt. is *paler yellow,* a Bromide or an Iodide of Potassium, Sodium or Ammonium is present.

$$KBr + AgNO_3 = AgBr + KNO_3.$$
$$KI + AgNO_3 = AgI + KNO_3.$$

Neither Silver bromide AgBr, nor Silver iodide AgI, is soluble in Nitric acid, but Silver bromide is soluble in large excess of Ammonic hydrate, in which latter, Silver iodide, with loss of yellow color, is quite insoluble.

If the ppt. is *white*, soluble with effervescence in Nitric acid HNO_3, and equally readily in Ammonic hydrate, the solution must contain a Carbonate, either of Potassium, Sodium or Ammonium.

$$\begin{aligned} K_2CO_3 + 2AgNO_3 &= Ag_2CO_3 + 2KNO_3. \\ Na_2CO_3 + 2AgNO_3 &= Ag_2CO_3 + 2NaNO_3. \\ (NH_4)_2CO_3 + 2AgNO_3 &= Ag_2CO_3 + 2(NH_4)NO_3. \end{aligned}$$

If the ppt. is *white*, easily soluble at first, but permanent when an excess of Silver nitrate has been added, soluble in strong boiling Nitric acid, and in Ammonic hydrate, it is probably a Cyanide either of Potassium, *a*, Sodium, or Ammonium. The smell of Hydrocyanic acid (Prussic acid) is very pronounced in the alkaline solution.

$$a.\ KCN + AgNO_3 = AgCN + KNO_3.$$

If a *white* ppt., with Silver nitrate, soluble in Nitric acid and in Ammonic hydrate, a Borate, an Oxalate, a Tartrate, a Citrate, or an Acetate may be present.

$$\begin{aligned} NaBO_2 + AgNO_3 &= AgBO_2 + NaNO_3. \\ Na_2C_2O_4 + 2AgNO_3 &= Ag_2C_2O_4 + 2NaNO_3. \\ K_2C_4H_4O_6 + 2AgNO_3 &= Ag_2C_4H_4O_6 + 2KNO_3. \\ K_3C_6H_5O_7 + 3AgNO_3 &= Ag_3C_6H_5O_7 + 3KNO_3. \\ NaC_2H_3O_2 + AgNO_3 &= AgC_2H_3O_2 + NaNO_3. \end{aligned}$$

If a *white* ppt. with Silver nitrate, in an alkaline solution, changing by heat into more or less of a mirror of metallic silver, the white ppt. soluble both in Nitric acid and in Ammonic hydrate, a Sulphite of Potassium, Sodium, *a*, or Ammonium may be present.

$$\begin{aligned} a.\ Na_2SO_3 + 2AgNO_3 &= Ag_2SO_3 + 2NaNO_3. \\ Ag_2SO_3 + H_2O &= Ag_2 + H_2SO_4. \end{aligned}$$

If the ppt. is *white*, with Silver nitrate, in an alkaline solution, changing to yellow, orange-red and black, a Thiosulphate of Potassium, Sodium, *a*, or Ammonium may be present.

$$\begin{aligned} a.\ Na_2S_2O_3 + 2AgNO_3 &= Ag_2S_2O_3 + 2NaNO_3. \\ Ag_2S_2O_3 + H_2O &= Ag_2S + H_2SO_4. \end{aligned}$$

If the ppt. is *black*, with Silver nitrate, in an alkaline solution, it must be a Sulphide respectively of Potassium, *a*, Sodium, or Ammonium, *b*, of Barium, *c*, Strontium, or Calcium. The solution smells of Hydric Sulphide.

a. $K_2S + 2AgNO_3 = Ag_2S + 2KNO_3$.
b. $(NH_4)_2S + 2AgNO_3 = Ag_2S + 2NH_4NO_3$.
c. $BaS + 2AgNO_3 = Ag_2S + Ba2NO_3$.

The student will notice that the Hydroxides, the Arsenates, Arsenites, Phosphates, Bromides, Iodides, Cyanides, Carbonates, Borates, Oxalates, Tartrates, Citrates, Thiosulphates, Sulphites and Sulphides of Potassium, Sodium and Ammonium, are soluble in water. The *Chlorides* are also very soluble, but do not blue red litmus paper. Silver nitrate gives with the chlorides a white curd-like ppt., soluble in Ammonic hydrate and insoluble in Nitric acid.

$$NH_4Cl + AgNO_3 = AgCl + NH_4NO_3.$$

B. THE SOLUTION IS ACID : *blue litmus is reddened.*

To a portion in a test-tube, about 20 drops, add Sodium carbonate Na_2CO_3, dropwise, until alkaline to test-paper.

aa. If there is *effervescence,* without any precipitate, either a free acid is present, or an acid salt of Potassium, Sodium or Ammonium. Further, boil. If Ammonium is present, Carbonate of Ammonium $(NH_4)_2CO_3$, will be recognized by its odor, by its vapors which turn red litmus paper blue, and by the white fumes of Chloride of Ammonium NH_4Cl, when a glass rod dipped into Hydrochloric acid is approached.

Now heat a drop or so of the original solution on platinum-foil: no residue, but acid fumes, indicates either a free volatile acid, or an acid salt of Ammonium.

A glassy residue on platinum, with slight greenish flame, would indicate free Phosphoric acid, or an acid phosphate of Ammonium.

A crystalline residue on platinum indicates an acid salt of Potassium (violet color to flame), or Sodium (bright yellow color to flame).

ββ. No effervescence, but a *ppt.* at once; or effervescence with a *ppt.*: then the reddening of the litmus is due only to the nature of the salt, as many salts, neutral according to theory, have yet an acid reaction, and turn blue litmus paper red. Thus most salts of the ordinary metals redden litmus paper, as Ferrous sulphate $FeSO_4$, Cupric sulphate $CuSO_4$, Lead nitrate $Pb2NO_3$, Ferric chloride Fe_2Cl_6, Zinc sulphate $ZnSO_4$, &c. (These *salts* are *neutral* because the Hydrogen in the acid is displaced by its equivalent of other metal. Sulphuric acid H_2SO_4, has two atoms of displaceable Hydrogen: Zinc is a dyad, and displaces the two atoms of Hydrogen, but the resulting Zinc sulphate $ZnSO_4$, though a neutral salt, reddens blue litmus.) The ppt. consists generally of a Carbonate of some metal belonging to Groups I., II., III., IV. and V., all the Carbonates of which are insoluble in water: more rarely, by the loss of Carbonic acid with effervescence, of a basic Carbonate, or even of a Hydroxide. (A basic salt contains an Oxide or Hydroxide in combination with the neutral salt: thus, Basic Cupric carbonate $Cu(OH)_2, CuCO_3$.) The following are illustrations under each group:—

Groups.

I.—$2AgNO_3 + Na_2CO_3 = Ag_2CO_3 + 2NaNO_3$.

II.—$CdSO_4 + Na_2CO_3 = CdCO_3 + Na_2SO_4$.

III.—$Al_2Cl_6 + 3Na_2CO_3 + 3H_2O = Al_2(OH)_6 + 6NaCl + 3CO_2$.

IV.—$ZnSO_4 + Na_2CO_3 = ZnCO_3 + Na_2SO_4$.

V.—$BaCl_2 + Na_2CO_3 = BaCO_3 + 2NaCl$.

γγ. *No effervescence and no precipitate.*—Possibly a solution of Mercuric cyanide, or of feeble acids like Arsenious, Boracic, or Hydrocyanic acids.

δδ.—No effervescence, but a ppt. on standing or on heating: possibly Tartar emetic.

Confirm by further tests, ascertaining the page from the Index.

C. THE SOLUTION IS NEUTRAL TO TEST-PAPERS.

Now carefully add solution of Sodium carbonate to a small portion in a test-tube. If there is no ppt., even on boiling, we note the absence of all metallic salts belonging to Groups I. II. III. IV. and V. Ammonium in Group VI. will be recognized by the odor of the Carbonate: Salts of Potassium and Sodium by the residue upon platinum, and by the colors to flame. If, however, Sodium carbonate causes a ppt., a neutral salt of some metal belonging to Groups I. II. III. IV. and V. must be present. There are very few such possible, as they have generally an acid reaction.

For acid radicles, try the reactions given at pp. 3, 4.

As already stated at page 1, all the reactions with distilled water are negative, inasmuch as we only dilute the various tests.

The *colors communicated to flame* are very helpful, but, as a rule, it is better not to heat a liquid on platinum foil until we have ascertained something of the character of the unknown body by means of: 1. Test-papers; 2. Sodium carbonate; 3. Silver nitrate, especially if solution alkaline. If the substance is a solid, before the application of heat, ascertain: 1. Whether possessed of color or smell; 2. Whether a fragment is soluble in water; 3. Effect of solution on test-paper; 4. Addition of Sodium carbonate, and further, of Silver nitrate. When heated, remember that Salts of Potassium give a violet color to flame, and red, when seen cut off by blue glass. Sodium, a bright yellow. Lithium, a purple crimson.

Strontium, a crimson. Calcium, yellowish-red. Copper, green or blue. Lead, blue. Thallium, green. Barium, yellowish-green. Boracic acid, green. Antimony, bluish-green. Arsenic, lavender. Phosphorus, green, &c.

Precautions.

The student is further advised upon the following points:—

When a solution is heated in a test-tube, the latter should be kept in continuous slight agitation to prevent ejection of the contents, which should not exceed, for heating, one-third of the capacity of the tube.

Beware of adding concentrated acids to hot solutions, or to strong ammonia.

Always neutralise acid solutions with ammonia, before adding Sulphide of Ammonium, otherwise Sulphur would be precipitated and give rise to mistakes.

Tests should be employed almost dropwise at first, as otherwise many indications are lost. Whilst moderation is recommended in the use of tests, care should be taken to add a sufficiency, as otherwise serious mistakes must arise. Excess of a test must always be employed in order to separate members of particular groups.

If a liquid is strongly acid, dilute with distilled water, before adding most tests; by this method the presence of salts of Antimonous chloride, of Bismuth nitrate and chloride may be indicated by a ppt., or cloudiness, as they are only soluble in much free acid.

When filtration is required in Qualitative Analysis, do not allow the washings to pass into the filtrate; whenever it is possible, decant, or pour off the clear fluid from the ppt.

Do not mistake traces of impurity for the main substance present. The platinum-foil and wire should be kept scrupulously clean. Boil with Hydrochloric acid, and then test in flame till yellow Sodium flame has been driven off. The test-tubes should always be kept clean, and indeed general cleanliness observed; indeed, test-tubes should be washed before they are put aside and rinsed with distilled water. Keep the tests in a definite order on the shelves. Do not leave the stoppers out of bottles, or they will get mixed and cause serious errors.

As Hydric Sulphide H_2S, does not keep well, and as it must be of good quality, it should always be tested. About 25 drops, or roughly a cubic centimetre, of solution of Potassium di-chromate, acidulated with half the measure of Sulphuric acid, should give a green-blue solution, with deposit of Sulphur, on addition of a solution of Hydric Sulphide.

$$K_2Cr_2O_7 + 4H_2SO_4 + 3H_2S = K_2Cr_24SO_4 + 7H_2O + 3S.$$

Hydric sulphide H_2S, does not keep, because the Oxygen of air oxidizes the Hydrogen to Water H_2O, and precipitates the Sulphur: $2H_2S + O_2 = 2H_2O + S_2$.

STUDIES ON THE METALS, OXIDES, HYDROXIDES AND SULPHIDES; ALSO ON SALTS.

The Metals are insoluble in water. Some metals decompose Water, and dissolve as Hydroxides in water. Thus:—

$K_2 + 2H_2O = 2KHO + H_2$. $Na_2 + 2H_2O = 2NaHO + H_2$.

Most Oxides are insoluble in water. Combinations of Metallic Oxides with Water are called Hydroxides, or Hydrates: these are also, for the most part, insoluble in water. The only Hydroxides which are soluble in water are those of Potassium, Sodium, (Lithium), Barium, Strontium, Calcium and hypothetical Ammonium: their solutions strongly blue red litmus-paper.

KHO. $NaHO$. (LHO). $Ba(HO)_2$. $Sr(HO)_2$. $Ca(HO)_2$. NH_4HO.

When a solution of *Potassium hydroxide* KHO, is used as a test it is for the purpose of ascertaining whether salts are present, of metals other than those, the oxides and hydroxides of which are soluble in water. For instance, if Potassium hydroxide is added to a solution of Magnesium Sulphate $MgSO_4$, we obtain at once a permanent white precipitate of Magnesium hydroxide $Mg(OH)_2$, as it is nearly insoluble in water: in solution we find Potassium sulphate: $2KOH + MgSO_4 = Mg(OH)_2 + K_2SO_4$. In some cases, the hydroxide first precipitated by Potassium hydroxide is re-dissolved in excess, as with Lead hydroxide, Stannic and Stannous hydroxides, Antimonous hydroxide, Chromic and Aluminum hydroxides, and Zinc hydroxide: the greater number are insoluble in excess of the test.

A solution of *Ammonium hydroxide* is also employed as a test for the same reason, that it precipitates Metallic hydroxides from solutions of their Salts. Thus, with Magnesium sulphate we obtain a solution of Ammonium sulphate, and a precipitate of Magnesium hydroxide: $MgSO_4 + 2(NH_4OH) = (NH_4)_2SO_4 + Mg(OH)_2$. In some cases, the Hydroxide first precipitated is re-dissolved in excess, as with Silver hydroxide, Cadmium hydroxide, Cupric hydroxide, Zinc hydroxide, Nickel hydroxide, Cobalt hydroxide, and to a considerable extent Ferrous and Manganous hydroxides, and still less, Chromic hydroxide.

If **Hydrochloric acid** has any action upon a *Metal*, it exchanges its Hydrogen for the other Metal, and Hydrogen is generated as a Gas; in such a case we obtain a Chloride in solution, *e.g.*, Zinc and Iron, Magnesium, Aluminum and Tin, are thus immediately acted upon by Hydrochloric acid, and solutions, respectively, of Zinc, Ferrous, Magnesium, Aluminum, and Stannous chlorides are obtained.

$$
\begin{aligned}
Zn &+ 2HCl = ZnCl_2 + H_2.\\
Fe &+ 2HCl = FeCl_2 + H_2.\\
Mg &+ 2HCl = MgCl_2 + H_2.\\
Al_2 &+ 6HCl = Al_2Cl_6 + 3H_2.\\
Sn &+ 2HCl = SnCl_2 + H_2.
\end{aligned}
$$

Upon Cadmium, Cobalt and Nickel, there is a similar but slower reaction. Lead, Copper, Quicksilver, Antimony, Bismuth, Silver, Gold and Platinum, are practically not acted upon by Hydrochloric acid.

With *Hydroxides*, Hydrochloric acid forms *Chlorides* and *Water*. Thus, with Potassium hydroxide, Silver hydroxide, Calcium hydroxide, Bismuth hydroxide, and Stannic hydroxide, Hydrochloric acid yields, respectively, Potassium, Silver, Calcium, Bismuth and Stannic chlorides.

$$
\begin{aligned}
KOH &+ HCl = KCl + H_2O.\\
AgOH &+ HCl = AgCl + H_2O.\\
Ca(OH)_2 &+ 2HCl = CaCl_2 + 2H_2O.\\
Bi(OH)_3 &+ 3HCl = BiCl_3 + 3H_2O.\\
Sn(OH)_4 &+ 4HCl = SnCl_4 + 4H_2O.
\end{aligned}
$$

Mercurous and Silver chlorides are insoluble in water: Lead chloride is with difficulty soluble: therefore Hydrochloric acid is used as the first Group test, by means of which Mercurous and Silver are completely precipitated from solutions of their nitrates or any other soluble salts. Lead is only partially precipitated as chloride. The other Chlorides are soluble in water.

Dilute sulphuric acid, when it acts upon the metals, such as Zinc, Iron and Magnesium, exchanges in a similar manner its Hydrogen for Zinc, Iron and Magnesium, and we obtain a Sulphate, respectively, of Zinc, Iron or Magnesium, with evolution of Hydrogen, thus:—

$$
\begin{aligned}
Zn &+ H_2SO_4, 2H_2O = ZnSO_4 + H_2 + 2H_2O.\\
Fe &+ H_2SO_4, 2H_2O = FeSO_4 + H_2 + 2H_2O.\\
Mg &+ H_2SO_4, 2H_2O = MgSO_4 + H_2 + 2H_2O.
\end{aligned}
$$

With the exception of Barium sulphate, Strontium sulphate, and Lead sulphate, all Sulphates are soluble in water, so that we may find any metallic sulphate in solution except these three.

Sulphuric acid, as Oil of vitriol, has usually a different action, when heated with many metals: we obtain a Sulphate of the metal, but a portion of the acid is decomposed, so that Sulphur dioxide SO_2, and Water, are formed at the same time. *E.g.*, Copper and Mercury, when heated with the concentrated acid give Cupric and Mercuric sulphate, together with Sulphur dioxide and Water:

$$
\begin{aligned}
Cu &+ 2H_2SO_4 = CuSO_4 + SO_2 + 2H_2O.\\
Hg &+ 2H_2SO_4 = HgSO_4 + SO_2 + 2H_2O.
\end{aligned}
$$

Nitric acid HNO_3, is the greatest solvent of the metals, and for the most part changes them into Nitrates, with partial decomposition of the acid. The concentrated acid has no action upon Gold and Platinum, Iron and Aluminum. Tin and Antimony are changed into white acid Oxides insoluble in water. Hydrogen is not evolved when a Nitrate is formed, but it may be Nitric oxide, Nitrous acid, Ammonic hydrate or Nitrous oxide, together with Water. *E.g.*

$$\begin{aligned}
3Cu + 8HNO_3 &= 3(Cu2NO_3) + 2NO + 4H_2O. \\
3Hg + 8HNO_3 &= 3(Hg2NO_3) + 2NO + 4H_2O. \\
2Ag + 3HNO_3 &= 2AgNO_3 + HNO_2 + H_2O. \\
4Zn + 9HNO_3 &= 4(Zn2NO_3) + H_3N + 3H_2O. \\
4Zn + 10HNO_3 &= 4(Zn2NO_3) + N_2O + 5H_2O.
\end{aligned}$$

Aqua regia, or a mixture of Nitric and Hydrochloric acids, changes the metals into *Chlorides.* The two acids act upon one another so as to liberate Chlorine which forms a Chloride, together with Nitrosyl chloride NOCl, and Water, H_2O. Thus :—

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

Gold dissolves as Auric chloride $AuCl_3$; Platinum as Platinic chloride $PtCl_4$; Tin as Stannic chloride $SnCl_4$; Antimony as Antimonous chloride $SbCl_3$; Iron as Ferric chloride Fe_2Cl_6, and so on.

If any acids, such as Hydrochloric, Sulphuric, or Nitric acid, are present in a liquid in a free state, Litmus is reddened, and solution of *Sodium carbonate* Na_2CO_3 neutralizes the free acids, with effervescence from the escape of Carbon dioxide, and with formation of soluble Chloride, Sulphate, or Nitrate of Sodium. *E.g.*

$$\begin{aligned}
2HCl + Na_2CO_3 &= 2NaCl + H_2O + CO_2. \\
H_2SO_4 + Na_2CO_3 &= Na_2SO_4 + H_2O + CO_2. \\
2HNO_3 + Na_2CO_3 &= 2NaNO_3 + H_2O + CO_2.
\end{aligned}$$

Sodium carbonate Na_2CO_3 is said to *neutralize* these acids, as it exchanges Sodium Na, for every atom of Hydrogen it displaces from them.

We use Sodium carbonate as a Preliminary test, because it occasions Precipitates in most solutions of Metallic salts, as all Carbonates are insoluble in water, except those of Potassium, Sodium and Ammonium.

Sodium carbonate $Na_2CO_3, 10H_2O$ is the neutral Sodium salt of Carbonic acid. It is easily soluble in water, and strongly alkaline: it therefore blues red litmus paper. We may divide all soluble metallic salts, or their soluble Hydroxides into two divisions.

DIVISION A. comprises Groups I., II., III., IV. and V., or all Metals, the Carbonates of which are insoluble in water.

DIVISION B. comprises Group VI , or all such Metals, the Carbonates of which are soluble in water. This group comprises salts of Potassium, Sodium and Ammonium (with rarer alkaline Metals), as the Carbonates of these Metals are alone soluble in water, and therefore cannot be precipitated by Sodium carbonate.

DIVISION OF THE METALS INTO GROUPS COMPRISED UNDER A. AND B.

DIVISION A.—THE CARBONATES OF THIS DIVISION ARE PRACTICALLY INSOLUBLE IN WATER.

The precipitates are for the most part white, but with a Mercurous salt, black; with a Mercuric, red-brown; with a Cupric, blue; with Ferric, gelatinous red-brown; with Ferrous, dirty green; with Cobalt, pink; with Nickel, apple-green; with Chromic, bluish-green. If any free acid is present, there is effervescence, with, at first, re-solution of the precipitate.

It should be remembered that most of the Nitrates, Sulphates, and Chlorides of the Metals in this Division are soluble in water. The Carbonates, Sulphites, Phosphates, Arsenates, Arsenites, Borates, Oxalates, and Silicates of these Metals are not soluble in water: therefore, if Sodium carbonate has given a ppt., none of these salts can be present.

DIVISION A. *Group I.*—Hydrochloric acid* HCl, precipitates Lead, (Thallium), Silver and Mercurous, from solutions of their soluble salts, respectively, as Chloride of Lead, (Thallium), Silver and Mercurous chloride.

$$2HCl + Pb2NO_3 = 2HNO_3 + PbCl_2\text{, white.}$$
$$(2HCl + Tl_2SO_4 = H_2SO_4 + 2TlCl\text{, white.})$$
$$HCl + AgNO_3 = HNO_3 + AgCl\text{, white.}$$
$$2HCl + Hg_22NO_3 = 2HNO_3 + Hg_2Cl_2\text{, tawny.}$$

No precipitate: absence of Lead, (Thallium), Silver and Mercurous: pass on to Group II.

Hydrochloric acid is a solution of HCl in water. All chlorides are soluble in water, except those of Silver and Mercurous. Chloride of Lead is with difficulty soluble, but it is quite possible

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* Concentrated solution of Hydrochloric acid will precipitate Antimonous oxy-chloride, soluble in excess, from solutions of Tartar emetic; Cream of Tartar, from neutral tartrate of Potassium; Arsenious acid from soluble Arsenites, and the respective acids from alkaline Borates, Silicates, Titanates, Antimonates, Stannates, Molybdates, and Tungstates; Aluminum hydroxide and Zinc hydroxide from solutions in Potassium hydroxide and Sodium hydroxide; Sulphur from the higher Sulphides of Alkalies and Alkaline earths; Sulphur from Thiosulphates, Uric acid, Hippuric acid, Benzoic acid, Salicylic and Gallic acid, from Urates, Hippurates, Benzoates, Salicylates, and Gallates of the Alkalies; &c., &c.

to have a solution of Chloride of Lead, and it is therefore necessary to look for Lead in Group II. if Hydrochloric acid has occasioned no precipitate. Several metallic Chlorides which are decomposed by water, as Antimonous chloride and Bismuth chloride, are soluble in HCl, and can only be met with, as such, in solution of HCl.

Division A. *Group II.*—The Metals of this Group are not precipitated by Hydric chloride.

To the **Hydrochloric acid** solution, add solution of **Hydric Sulphide** in water. Hydric sulphide H_2S is a gas of the well-known odor of rotten eggs. In solutions of Metallic salts, it exchanges its Hydrogen for some other metal, and precipitates the Metal in the form of a Sulphide insoluble in water. The Metals of Groups III. and IV. are not precipitated in presence of Hydrochloric acid; therefore Group-test II. is expressed by **Hydrochloric acid + Hydric Sulphide.**

a. Solutions of Salts of Antimony, Stannic and Stannous, (of Gold and Platinum), are precipitated as Sulphides, insoluble in water. These Sulphides are, however, soluble, after neutralization with Ammonic hydrate, in Ammonium Sulphide.

$$2\mathrm{SbCl_3} + \mathrm{HCl} + 3\mathrm{H_2S} = 6\mathrm{HCl} + \mathrm{HCl} + \mathrm{Sb_2S_3}, \text{ orange-red.}$$

$$\mathrm{SnCl_4} + \mathrm{HCl} + 2\mathrm{H_2S} = 4\mathrm{HCl} + \mathrm{HCl} + \mathrm{SnS_2}, \text{ yellow.}$$

$$\mathrm{SnCl_2} + \mathrm{HCl} + \mathrm{H_2S} = 2\mathrm{HCl} + \mathrm{HCl} + \mathrm{SnS}, \text{ dark brown.}$$

b. Solutions of Salts of Lead, Mercuric, Bismuth, Copper and Cadmium are precipitated as insoluble Sulphides, and the Sulphides (after neutralization with Ammonium hydrate) are not soluble in Ammonium Sulphide.

$$\mathrm{PbCl_2} + \mathrm{HCl} + \mathrm{H_2S} = 2\mathrm{HCl} + \mathrm{HCl} + \mathrm{PbS}, \text{ slate-colored.}$$

$$\mathrm{HgCl_2} + \mathrm{HCl} + \mathrm{H_2S} = 2\mathrm{HCl} + \mathrm{HCl} + \mathrm{HgS}, \text{ black.}$$

$$2(\mathrm{Bi3NO_3}) + \mathrm{HCl} + 3\mathrm{H_2S} = 6\mathrm{HNO_3} + \mathrm{HCl} + \mathrm{Bi_2S_3}. \text{ brown-black.}$$

$$\mathrm{CuSO_4} + \mathrm{HCl} + \mathrm{H_2S} = \mathrm{H_2SO_4} + \mathrm{HCl} + \mathrm{CuS}, \text{ black-brown.}$$

$$\mathrm{CdSO_4} + \mathrm{HCl} + \mathrm{H_2S} = \mathrm{H_2SO_4} + \mathrm{HCl} + \mathrm{CdS}, \text{ bright yellow.}$$

Group II.—No precipitate: absence of soluble salts of Antimonous, Stannic, Stannous (Lead), Mercuric, Bismuth, Cupric and Cadmium. Pass on to Group III.

N.B.—No arsenite nor arsenate of any Metal of this and the former group is soluble in water. If Carbonate of Sodium has occasioned a ppt., Salts of these Acids cannot be present.

Division A. *Group III.*—The Metals of this Group are not precipitated by Hydric chloride HCl, nor by Hydric sulphide H_2S, in presence of Hydric chloride.

To a fresh portion of the original solution Ammonic chloride is added, and then Ammonic hydrate: the presence of excess of Ammonic chloride prevents the precipitation of the Metals of the next Group. Solutions of Ferric, Aluminum and Chromic salts are decomposed and precipitated respectively, as Ferric hydroxide, Aluminum hydroxide, and Chromic hydroxide.

$$\begin{aligned}
Fe_2Cl_6 &+ 6NH_4OH = 6NH_4Cl &&+ Fe_2O_6H_6.\\
Al_2Cl_6 &+ 6NH_4OH = 6NH_4Cl &&+ Al_2O_6H_6.\\
Cr_23SO_4 &+ 6NH_4OH = 3[(NH_4)_2SO_4] &&+ Cr_2O_6H_6.
\end{aligned}$$

Group III.—No precipitate: absence of Ferric, Aluminum and Chromic salts, soluble in water. Pass on to Group IV.

DIVISION A. *Group IV.*—The metals of this Group are not precipitated by Hydric chloride HCl: nor by Hydric sulphide H_2S, in presence of Hydric chloride HCl: nor by Ammonic hydrate NH_4OH, in presence of Ammonic chloride NH_4Cl.

To a fresh portion of the Original Solution, Ammonium chloride is added, and then Ammonium sulphide. The latter test is similar in its reaction to Hydric sulphide in Group-test II., and, if used by itself would first precipitate all the metals of Groups I., II., III., and IV. It should never be added to an acid solution, as the Acid decomposes the Ammonium sulphide: for this reason, we neutralize an acid solution with Ammonium hydrate, before addition of Ammonium sulphide. Solutions of Salts of Ferrous, Cobalt and Nickel, Zinc and Manganous belong to this Group IV., and are precipitated as *Sulphides,* insoluble both in water and in the tests.

$$\begin{aligned}
FeSO_4 &+ (NH_4)_2S = (NH_4)_2SO_4 &&+ FeS, \text{ black.}\\
CoCl_2 &+ (NH_4)_2S = 2NH_4Cl &&+ CoS, \text{ black.}\\
NiCl_2 &+ (NH_4)_2S = 2NH_4Cl &&+ NiS, \text{ black.}\\
MnSO_4 &+ (NH_4)_2S = (NH_4)_2SO_4 &&+ MnS, \text{ flesh-coloured.}\\
ZnSO_4 &+ (NH_4)_2S = (NH_4)_2SO_4 &&+ ZnS, \text{ white.}
\end{aligned}$$

Group IV.—No precipitate: absence of soluble salts of Ferrous, Cobalt and Nickel, of Manganous and of Zinc.

DIVISION A. *Group V.*—The Metals of this Group are not precipitated by Hydric chloride HCl: nor by Hydric sulphide H_2S, in presence of Hydric chloride HCl: nor by Ammonic hydrate NH_4OH, in presence of Ammonic chloride NH_4Cl: nor by Ammonic sulphide $(NH_4)_2S$, in presence of Ammonic chloride NH_4Cl.

To a fresh portion Ammonic chloride is added, and then, dropwise, Ammonic carbonate.

a. A white precipitate of, respectively, Barium carbonate, Strontium carbonate, and Calcium carbonate, from any soluble salt of Barium, Strontium and Calcium.

$$\begin{aligned}
BaCl_2 &+ (NH_4)_2CO_3 = 2NH_4Cl + BaCO_3, \text{ white.}\\
SrCl_2 &+ (NH_4)_2CO_3 = 2NH_4Cl + SrCO_3, \text{ white.}\\
CaCl_2 &+ (NH_4)_2CO_3 = 2NH_4Cl + CaCO_3, \text{ white.}
\end{aligned}$$

Group V.—a. No precipitate: absence of soluble salts of Barium, Strontium and Calcium.

b. No precipitate, but only by Sodic carbonate Na_2CO_3, the Divisional-test A: Magnesium is present in form of some soluble salt. Confirmed by the use of Ammonic chloride, Ammonic hydrate and then Sodic phosphate: when a white crystalline ppt. of Ammonic Magnesium phosphate $(NH_4)Mg\ PO_4,\ 6H_2O$.

Group V.—b. No precipitate: absence of Magnesium in form of Salt.

Division B. *Group VI.*—Sodium carbonate gives no precipitate: absence of Salts of Metals belonging to Groups I., II., III., IV. and V. This Group comprises only soluble Salts, or Hydroxides, of the Metals Potassium, Sodium, (Lithium) and Ammonium.

Boil a portion of the original solution with Sodium carbonate, if Ammonium is present in form of an odorless salt, Ammonium carbonate will be evolved in colorless vapor, which blues red litmus, and fumes with a glass rod dipped into Hydrochloric acid.

$$2NH_4Cl + Na_2CO_3 = 2NaCl + (NH_4)_2CO_3.$$

Salts of Ammonium volatilize, with, or without decomposition, when heated on Platinum-foil: they may leave a residue if the Ammonium salts contained a fixed acid. They also afford a yellow ppt. with Platinic chloride.

Salts of Sodium give a yellow color to flame and leave a residue. (Salts of Lithium give a purple color to flame.)

Salts of Potassium give a violet color to flame, and are precipitated by Platinic chloride.

Group VI.—No reaction, and no residues: absence of Salts, and of Hydroxides, of Potassium, Sodium, Lithium and Ammonium.

Recapitulation.

Division A.	**Carbonate of Sodium** Na_2CO_3, with or without effervescence and usually without the application of heat, gives a ppt. in solutions of Metallic salts. If no ppt. pass on to Division B.
Group I.	**HCl**, a ppt. Pb. Ag. Hg_2. No ppt., pass on to Group II.
Group II.	**HCl + H_2S**, a ppt. Pb in dilute solutions. Sb. Sn. Au. Pt. Hg. Cd. Bi. Cu. No ppt., pass on to Group III.
Group III.	**$NH_4Cl + NH_4OH$**, a ppt. Fe_2. Al_2. Cr_2. No ppt., pass on to Group IV.
Group IV.	**$NH_4Cl + (NH_4)_2S$**, a ppt. Fe. Co. Ni. Mn. Zn. No ppt., pass on to Group V.
Group V.	**$NH_4Cl + (NH_4)_2CO_3$**, a white ppt. Ba. Sr. Ca. No ppt. Magnesium.

Division B. **Carbonate of Sodium** Na_2CO_3, no precipitate. *a.* On boiling with Na_2CO_3, there is an odor of Ammonia, Litmus is blued, and fumes are formed with Hydrochloric acid: (NH_4). *b.* No reaction. Yellow color to flame. Na. Purple color to flame. Li. Violet color to flame. K. *c.* No reaction: absence of all metals in the form of salts.

REACTIONS OF THE METALS AND STUDIES OF THEIR OXIDES, HYDROXIDES AND SALTS.

Division A.—Solutions of such metallic salts, soluble in water as are precipitated by a solution of Sodium carbonate Na_2CO_3, either as Carbonates or as Hydroxides, or as Hydroxides combined with Carbonates (Basic salts).

Group I.—Metals precipitated by Hydrochloric acid HCl, as Chlorides. Lead, Silver, (Thallium) and Mercurous belong to this Group. Solutions of their soluble Salts are precipitated as Lead, Silver, (Thallium) and Mercurous chlorides. The Sulphides of these metals are in shades of black, and are insoluble in Ammonium sulphide $(NH_4)_2S$, after neutralizing the acid liquid with Ammonic hydrate NH_4OH.

1. Lead, Plumbum, Pb = 207.

Chief soluble salts of Lead: Acetate $Pb2C_2H_3O_2,3H_2O$ Nitrate $Pb2NO_3$. Chloride $PbCl_2$. Solutions faintly acid. Goulard's Extract is Liquor Plumbi sub-acetatis $2PbO,Pb2C_2H_3O_2$. Slightly soluble, alkaline, blues litmus. Lead is a bluish, lustrous, malleable metal. Dyad. Sp. gr. 11·37. Sp. heat 0·0314. Melts at 334°. Blow-pipe bead on charcoal flattens under the pestle, and marks paper like black-lead. Melts, and gives a yellow incrustation of Oxide, when heated on charcoal in outer blow-pipe flame. Dilute Hydrochloric and Sulphuric acids, no reaction. Nitric acid HNO_3, dissolves Lead as Lead nitrate $Pb2NO_3$. $3Pb + 8HNO_3 = 3(Pb2NO_3) + 4H_2O + 2NO$. Boiling H_2SO_4 produces insoluble Lead sulphate $PbSO_4$, with Sulphur dioxide SO_2 and Water H_2O.

Galena, or Lead sulphide PbS, is the chief ore of lead. When roasted in the reverberatory furnace, the sulphide is oxydized in part to Lead oxide PbO, and into Lead sulphate $PbSO_4$. Thus: $2PbS + 3O_2 = 2PbO + 2SO_2$. $PbS + 2O_2 = PbSO_4$. When unchanged Sulphide is heated with Oxide and Sulphate of Lead, we obtain the metal Lead and Sulphur dioxide $PbS + 2PbO = 3Pb + SO_2$. $PbS + PbSO_4 = 2Pb + 2SO_2$. Galena resembles metallic Lead in lustre, but is brittle and not malleable. Hot HCl dissolves PbS as $PbCl_2$, with evolution of H_2S. Nitric acid forms a nitrate, with separation of Sulphur and Lead sulphate: nitrous fumes are evolved.

Lead oxide, PbO, is yellow, or salmon-colored, fusible; alkaline when moistened, slightly soluble; it is dissolved by Nitric acid, as Lead nitrate:

$PbO + 2HNO_3 = Pb2NO_3 + H_2O$. On charcoal, it is easily reduced to the metallic state, with yellow incrustation of Oxide. Hydroxide of Lead $Pb(OH)_2$, white, almost insoluble in water, soluble in Potassium hydroxide, KOH. Lead hydro-carbonate $Pb(OH)_2,PbCO_3$, is White Lead, insoluble in water, and therefore precipitated from solutions of Lead salts by Sodium carbonate; it dissolves with effervescence in Nitric acid, as Nitrate.

Tests for Lead in soluble salts.

I. Hydric chloride HCl, the group-test, gives a white precipitate of Lead chloride $PbCl_2$, soluble on addition of water and boiling; insoluble in Ammonic hydrate NH_4OH.

Hydric chloride with Hydric sulphide $HCl + H_2S$, slate-colored Sulphide PbS, insoluble in NH_4OH, and in Ammonic sulphide $(NH_4)_2S$. The ppt. may be red at first, as Lead chloro-sulphide $2PbCl_2,3PbS$, and it is changed, by excess of H_2S, into Lead sulphide PbS.

Potassium hydroxide KOH, white ppt. of Hydroxide $Pb(OH)_2$, soluble in KOH in excess.

Ammonic hydroxide NH_4OH, white hydroxide, either immediately or on heating: insoluble.

Sulphuric acid, H_2SO_4, white, insoluble $PbSO_4$, soluble in Ammonium acetate.

Potassium iodide KI, yellow ppt. of Lead iodide PbI_2, soluble in much boiling water, and deposited as golden scales on cooling.

Potassium dichromate $K_2Cr_2O_7$, yellow ppt. of Lead chromate $PbCrO_4$, soluble in excess of KOH.

Heated on charcoal with Na_2CO_3, bluish, lustrous beads of malleable metal, with incrustation of yellow Oxide.

2. Thallium, Tl = 204.

Tin-white metal: tarnishes in air. Under water, in presence of air, dissolves slowly as Thallous hydrate. Sp. gr. 11·9. Sp. heat 0·0336. Monad and triad. Melts at 294° C. Precipitates lead from its salts. Carbonate, Tl_2CO_3, requires 20 parts of water for solution: in ordinary solutions, Tl_2 is precipitated by Na_2CO_3. Thallous oxide, Tl_2O, is black: deliquesces as hydroxide, crystallizing in colorless, or pale yellow prisms.

In soluble Thallous salts:—

I. HCl, a curd-like precipitate, little soluble in water, and less in HCl.

H_2S precipitates partially as Sulphide, in absence of mineral acids.

NH_4HS as brown-black Sulphide, insoluble.

Flame colored emerald-green.

3. Silver, Argentum, Ag = 108.

Lustrous, white metal. Monad. Sp. gr. 10·57. Sp. heat 0·056. Melts at 1040° C. Blow-pipe bead lustrous, malleable; no incrustation. Absorbs oxygen when melted, and gives it out again; "spits" on cooling. Tarnished by H_2S. Not oxydized by air: a noble metal. Not acted upon by HCl except at a red-heat. Not touched by dilute Sulphuric acid, Boiled with H_2SO_4: $Ag_2+2H_2SO_4=Ag_2SO_4+SO_2+2H_2O$. Nitric acid the great solvent: $2Ag_2+6HNO_3=4AgNO_3+3H_2O+N_2O_3$. Silver hydroxide, AgOH, is grey-brown, soluble in NH_4OH, and also in HNO_3.

The Nitrate, $AgNO_3$, and the Sulphate, Ag_2SO_4, the chief soluble salts: the latter requires 200 parts of water for solution. Silver nitrate is neutral to test-paper and melts at 200° C.: "lunar caustic."

Silver carbonate, Ag_2CO_3, is nearly white, insoluble in water, and therefore precipitated by the divisional test A, as Ag_2CO_3.

Silver glance, Ag_2S, Argentite, is the chief Ore. Roasted with NaCl, into Na_2SO_4 and AgCl: the AgCl into Ag by metallic iron; the Ag amalgamated, and the Hg removed by heat.

Tests for *Silver* in soluble Salts: generally the nitrate.

I. Hydrochloric acid, HCl, white, curd-like precipitate insoluble on boiling with water (soluble in much HCl or in chlorides on boiling, and re-precipitated on addition of water), soluble in NH_4OH, and changing to violet in strong light.

Hydric sulphide, H_2S, brown-black Silver sulphide Ag_2S, soluble in boiling Nitric acid.

Potassium hydroxide, KOH, grey-brown Hydroxide, AgOH, soluble both in NH_4OH and in HNO_3; insoluble in KOH.

Ammonium hydroxide, NH_4OH, behaves like KOH, but the precipitate so soluble in excess, that if solution acid, no precipitate.

Potassium dichromate, $K_2Cr_2O_7$, crimson chromate Ag_2CrO_4, soluble in HNO_3.

Potassium iodide, KI, pale-yellow iodide AgI, insoluble both in NH_4OH, and in HNO_3.

Cu, Fe, Hg, and Zn precipitate grey Silver, lustrous under pressure.

On charcoal, in either flame, white, lustrous, malleable beads, without incrustation.

4. MERCURY, HYDRARGYRUM, Hg = 200; AS MERCUROUS, Hg_2.

Lustrous, silvery liquid. Dyad. Sp. gr. 13·56. Sp. heat 0·032. Boils at 358° C. Melts at −39·5° C. Not acted upon by HCl, nor by dilute Sulphuric acid. Chlorine attacks it immediately. Dilute nitric acid gives Mercurous nitrate: $3Hg_2+8HNO_3=3(Hg_22NO_3)+4H_2O+2NO$. Boiled with Sulphuric acid, into Mercuric sulphate: $Hg+2H_2SO_4=HgSO_4+SO_2+2H_2O$.

Two Oxides, both of which are insoluble in water. Only Mercurous oxide, Hg_2O, comes into Group I. It is black, and changed by light into Mercury and Mercuric oxide. Mercurous carbonate is yellow, insoluble; by pouring mercurous nitrate into an excess of Sodium Hydro-carbonate, $NaHCO_3$. Division-test A, Sodium carbonate, gives a precipitate in soluble Mercurous salts, first yellowish-white, then, through yellow, to dingy grey-green.

Chief soluble Salt, Mercurous nitrate, Hg_22NO_3, very acid. (Calomel, Hg_2Cl_2, is white, and quite insoluble in water. By boiling with HCl into $HgCl_2$ + Hg. Volatilised by heat, blackened by $(NH_4)_2S$, and by $2NH_3$ converted into black $NH_2Hg_2Cl+NH_4Cl$. Prepared by subliming Hg with $HgCl_2$.)

Tests for *Mercurous*, in soluble Salts.

I. HCl, white, insoluble Mercurous chloride, Hg_2Cl_2, turned into black mercurous chloro-amide by NH_4OH. Thus: $2NH_3 + Hg_2Cl_2 = NH_2Hg_2Cl + NH_4Cl$. ($Hg_2Cl_2$ dissolves in Aqua regia as $2HgCl_2$, and in nitric acid as Mercuric chloride and Nitrate.)

H_2S, black Mercurous sulphide, Hg_2S, insoluble in HNO_3 (but soluble in Aqua regia as Mercuric chloride).

KOH, black Hg_2O, insoluble in excess.

NH_4OH, black Hg_2O, insoluble in excess.

$K_2Cr_2O_7$, brick-dust colored Mercurous chromate, Hg_2CrO_4.

KI, finch-green precipitate of Mercurous iodide, Hg_2I_2.

$SnCl_2$, a white precipitate of Calomel, Hg_2Cl_2, changing to grey metallic Mercury, on addition of excess of Stannous chloride. $Hg_2Cl_2 + SnCl_2 = SnCl_4 + Hg_2$.

Cu, Zn, and Fe precipitate metallic Mercury.

Mercurous salts, heated with dry Na_2CO_3 in a narrow tube, yield globules of Hg.

Heated on Platinum, Hg_22NO_3, first white, then yellow, red, black, HgO, and volatilised as $2Hg + O_2$.

N.B.—In solutions of Tartar emetic, the group test HCl *precipitates white Antimonous oxy-chloride,* $SbOCl$, *soluble in excess as* $SbCl_3 + H_2O$, *and discovered in Group II. by* H_2S, *with which it gives an orange-colored sulphide,* Sb_2S_3. *In concentrated solutions of alkaline Arsenites in which Sodium carbonate gives no precipitate,* HCl *gives a copious white precipitate of Arsenious oxide,* As_2O_3, *soluble in excess, and discovered in Group II. by* H_2S.

Group II.—**Hydrochloric acid** produces no precipitate, but on addition of **Hydrogen sulphide,** H_2S, to the **Hydrochloric acid** solution, the following metals are precipitated as sulphides:

Arsenious .	As_2S_3,	bright yellow sulphide.
Antimonous	Sb_2S_3,	orange-red sulphide.
Stannic . .	SnS_2,	pale yellow sulphide.
Stannous .	SnS,	brown sulphide.
Platinic .	PtS_2.	black sulphide.
Aurous .	Au_2S_2,	black sulphide.
Lead . .	PbS,	slate-colored sulphide.
Cupric . .	CuS,	black sulphide.
Mercuric .	HgS,	black sulphide.
Bismuth .	Bi_2S_3,	brown-black sulphide.
Cadmium .	CdS,	yellow sulphide.

As_2S_3, Sb_2S_3, SnS_2, SnS as SnS_2, (Au_2S_2 and PtS_2) are soluble, after neutralisation with Ammonia, in Ammonic sulphide $(NH_4)_2S_2$.

PbS, CuS, HgS, Bi_2S_3, CdS, are not soluble in Ammonic sulphide.

a. Sulphides soluble in Ammonic sulphide after neutralising the free acid with Ammonic hydrate.

Arsenicum as Arsenious oxide, As_2O_3, forms an acid with water, Arsenious acid, H_3AsO_3, and salts called *Arsenites*. Those of Potassium, Sodium, and Ammonium alone soluble in water, and strongly alkaline. If therefore

Sodium carbonate has been added, and there is a precipitate, Arsenious oxide need not be looked for. But if Na_2CO_3 has given no precipitate, and $AgNO_3$ a yellow precipitate soluble in NH_4OH and in HNO_3, then HCl + H_2S gives a yellow precipitate of As_2S_3, soluble in NH_4OH, in $(NH_4)_2CO_3$, and in $(NH_4)_2S$. See p. 46.

The only *Arsenates* soluble in water are the Arsenates of Potassium, Sodium, and Ammonium. HCl liberates Arsenic acid, H_3AsO_4, very soluble in water, and H_2S gives no visible result. Leave about 25 drops in the test-tube, boil down to a drop, and add more H_2S; a yellow precipitate of Arsenious sulphide, As_2S_3, with Sulphur, soluble in NH_4OH, will indicate an Arsenate. See p. 46.

5. ANTIMONY, STIBIUM, $Sb_4 = 480$, $Sb = 120$.

A bluish-white, lustrous, crystalline, brittle metal. Triad and Pentad. Sp. gr. 6·7. Sp. heat 0·051. Fuses at 430° C. Immediately attacked by Cl_2; burns to Antimonous chloride, $SbCl_3$. Dilute Sulphuric acid has no action. Boiled with H_2SO_4 to white sulphate: $Sb_4 + 12H_2SO_4 = 2(Sb_2 3SO_4) + 6SO_2 + 12H_2O$. Dilute HCl has no reaction. With Nitric acid into a white powder called Metantimonic acid: $Sb_4 + 8HNO_3 = 4HSbO_3 + 4NO + 2N_2O_3 + 2H_2O$. Heated in air, Antimony burns into white Antimonous oxide, Sb_2O_3; yellow-tinted when heated, with white incrustation.

Antimonous sulphide, Sb_2S_3, or Stibnite, is the ore; metallic-looking. Heated with metallic iron, yields antimony; $2Sb_2S_3 + 6Fe = 6FeS + Sb_4$. Boiled with HCl, is the source both of Antimonous chloride, $SbCl_3$, and of Hydrogen sulphide, H_2S. $Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S$.

Antimonous chloride, $SbCl_3$, is only soluble in presence of much free HCl: decomposed by water into insoluble white Oxy-chloride, SbOCl, soluble in Tartaric acid, $H_2C_4H_4O_6$.

$$SbCl_3 + H_2O = SbOCl + 2HCl.$$

Chief soluble salts: Antimonous chloride, $SbCl_3$, in HCl, strongly acid. Tartar emetic, $2(KSbOC_4H_4O_6),H_2O$, faintly acid, and precipitated by, I., HCl as SbOCl, soluble in excess, and discovered in Group II.

Tests for *Antimonous*, as Chloride, $SbCl_3$.

II. HCl + H_2S, orange-red Sb_2S_3, insoluble in Ammonia and in Carbonate of ammonium; soluble in Ammonium sulphide, after neutralising with Ammonic hydrate. Sb_2S_3, soluble in strong HCl to Antimonous chloride; a source of H_2S. Thus: $Sb_2S_3 + 6HCl = 2SbCl_3 + 3H_2S$.

KOH, white Sb_2O_3, soluble in excess.

NH_4OH, white, insoluble in excess.

Water precipitates white Oxy-chloride, SbOCl, soluble in Tartaric acid.

Zn, in presence of HCl, precipitates Sb on platinum as a black powder, insoluble in cold HCl.

Cu, in HCl solution, when heated, is covered with a violet-grey deposit of Antimony: Reinsch's test. The deposit, heated with KOH, exposing the metal freely to the air, is gradually oxydized and dissolved; dilute, pass H_2S through liquid, filter off Cupric sulphide and add HCl, when orange-red Sb_2S_3 appears. Antimonous sulphide is insoluble in $(NH_4)_2CO_3$.

Zn, with dilute sulphuric acid, in presence of an Antimonous salt, gives off Stibine, SbH_3, as a colorless gas: Marsh's test. In a H_2 apparatus, provided with a drying tube and a jet, the gas may be kindled, and burns with bluish-green flame to white Antimonous oxide, Sb_2O_3, and water, H_2O. On porcelain, close to the inner flame, a black deposit of Antimony, soluble in Ammonic sulphide, and separating as orange-red Sb_2S_3 on evaporating. A piece of filter paper, moistened with Silver nitrate, is blackened with $SbAg_3$ when suspended in escaping SbH_3.

Heated on Charcoal with $NaHCO_3$, in the inner blow-pipe flame, lustrous beads of Antimony, with white incrustation of Sb_2O_3. Beads brittle.

6. TIN, STANNUM, Sn = 118.

White lustrous metal, malleable. Dyad and Tetrad. Sp. gr. 7·25. Sp. heat 0·056. Melts at 228° C. Readily dissolved by HCl as Stannous chloride, $SnCl_2$. $Sn + 2HCl = SnCl_2 + H_2$. Dilute sulphuric acid has no action upon tin; but, when boiled with sulphuric acid, into Stannous sulphate, $SnSO_4$. $Sn + 2H_2SO_4 = SnSO_4 + SO_2 + 2H_2O$. Concentrated Nitric acid has no action; but, when somewhat diluted, Tin is changed into a white powder—Metastannic acid, $H_{10}Sn_5O_{15}$, with evolution of Nitrous fumes. Chlorine attacks Tin, and forms Stannic chloride. Tin-foil burns into Stannic oxide, SnO_2.

Tin has two chief basic oxides: Stannous, SnO, and Stannic oxide, SnO_2.

The Ore of Tin, "Tinstone" is Stannic oxide, SnO_2. The metal is obtained by reduction of SnO_2, with Carbon at a low red-heat.

STANNOUS OXIDE, SnO.

The chief Stannous Salt is the Chloride $SnCl_2.2H_2O$. It is very acid, as dissolved in HCl; decomposed by water into Oxy-chloride of tin, $SnO,SnCl_2$. Stannous oxide, SnO, is black: Hydroxide, SnH_2O_2, white, soluble in KOH, as Stannate of Potassium.

Tests for Tin as *Stannous.*

II. $HCl + H_2S$, dark brown Stannous sulphide, SnS,H_2O, readily soluble, after neutralising with NH_4OH, in yellow Ammonic sulphide, as Stannic sulphide, and re-precipitated as yellow Stannic sulphide by HCl.

KOH, white SnH_2O_2, soluble in excess.

NH_4OH, white Hydroxide, insoluble.

Na_2CO_3, precipitates white Hydroxide, SnH_2O_2, with evolution of CO_2. On boiling, black SnO.

$HgCl_2$ is reduced to Hg_2Cl_2, and further, by heat, into 2Hg. So that stannous chloride is a test for Mercuric, p. 23.

Zn precipitates metallic Tin, readily soluble in dilute HCl.

On Charcoal, with $NaHCO_3$, in reducing flame, small beads of metallic Tin, with white incrustation of Stannic oxide.

STANNIC OXIDE, SnO_2.

Is white; insoluble in water. Its chief salt is Stannic chloride $SnCl_4$, very acid.

Tests for *Stannic*.

II. HCl + H_2S, yellow precipitate of hydrated sulphide, SnS_2, $2H_2O$, soluble in KOH, and also in $(NH_4)_2S$ after neutralising with Ammonic hydrate.

KOH, white hydroxide, soluble in excess as Stannate.

NH_4OH, white Hydroxide, insoluble.

Zn precipitates metallic Tin.

On Charcoal, with $NaHCO_3$, in reducing flame, beads of metallic Tin, and a white incrustation of SnO_2.

7. GOLD, AURUM, Au = 196.

Yellow lustrous metal, very malleable and ductile. Monad and Triad. Sp. gr. 19·5. Sp. heat 0·032. Melts at 1240°. Native. Insoluble in HCl, in HNO_3, and H_2SO_4. Chlorine attacks it immediately, and dissolves it as Auric chloride, $AuCl_3$, with yellow or orange color. Aqua regia dissolves it by its free Chlorine.

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

Auric oxide, Au_2O_3, the chief Oxide, is of a brown color. Its Hydrate, $Au_2H_6O_6$, is a powder of reddish-yellow color. By heat into Gold and Oxygen.

Tests for Gold as Auric chloride, $AuCl_3$. Solution, yellow, or orange, strongly acid.

II. HCl + H_2S, black di-aurous disulphide, Au_2S, Au_2S_3, soluble in ammonium sulphide. H_2S precipitates gold from hot solutions.

KOH precipitates yellow-brown Aurate, $KAuO_2,3H_2O$, soluble in excess.

NH_4OH, olive-brown Fulminating Gold, $Au_2O_3,4NH_3$.

$SnCl_2$, containing a little $SnCl_4$, gives purple of Cassius, $SnAu_2,Sn_2O_6,4H_2O$.

$FeSO_4$, a precipitate of brown-colored gold.

$$6FeSO_4 + 2AuCl_3 = Fe_2Cl_6 + 2(Fe_23SO_4) + 2Au.$$

Oxalic acid reduces Gold salts to metallic state. $3H_2C_2O_4 + 2AuCl_3 = 6HCl + 6CO_2 + Au_2$.

Upon Charcoal, all Gold compounds reduced to lustrous Gold without incrustation.

8. PLATINUM, Pt = 194·5.

Dull white metal, malleable and ductile. Dyad and Tetrad. Always native. Sp. gr. 21·5. Sp. heat 0·031. Melts at about 2000°. Like Gold, it does not tarnish in flame, and is easily attacked by Chlorine. Platinic chloride, $PtCl_4$, is reddish-brown or reddish-yellow, and is the chief Salt. By heating Platinic chloride, $PtCl_4$, Platinous chloride $PtCl_2$ and Cl_2 result: then Platinum and Chlorine. Platinic oxide, PtO_2, is black; its hydrate, when dry, brown.

Tests for *Platinic* in Platinic chloride. Solution strongly acid and colored reddish-yellow.

II. HCl + H_2S, especially by heat, brown PtS_2,H_2O, soluble in much Ammonic sulphide.

KHO generally precipitates potassium Platinic chloride, $2KCl,PtCl_4$, with yellow color, as Platinic chloride is really $2HCl,PtCl_4$. Excess of KHO gives the yellow Hydrate when boiled.

NH_4HO, gives yellow precipitate of $2NH_4Cl,PtCl_4$, because the Ammonia finds the necessary HCl to make it Ammonic chloride.

Oxalic acid does not reduce Platinic salts.

On Charcoal, heated in the blow-pipe flame, Platinum remains as an infusible grey powder, flattened under pestle, in mortar, to dull white metal.

b. Sulphides insoluble in Ammonic sulphide, after neutralising free acid with Ammonic hydrate.

LEAD, PLUMBUM, Pb = 207.

Chief salts: acetate, nitrate, chloride, See p. 16. In a dilute solution of a Lead-salt, although Na_2CO_3 will have given a white precipitate, HCl will occasion none: Lead oxide must be sought for again in Group II., subdivision *b*, by the same tests as already given at p. 16.

9. COPPER, CUPRUM, Cu = 63·3.

A lustrous metal of red color, malleable, ductile, and tenacious. Dyad. Sp. gr. 8·95. Sp. heat 0·093. Melts at 1300°. Oxydizes readily at a red-heat, forming both red Cuprous oxide and black Cupric oxide. Sometimes native. Insoluble in dilute Sulphuric and Hydrochloric acids: slowly soluble in HCl in presence of air: $Cu + 2HCl = CuCl_2 + H_2$. With hot Sulphuric acid: $Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2$. With dilute Nitric acid: $3Cu + 8HNO_3 = 3(Cu2NO_3) + 4H_2O + 2NO$. A good method of making Nitric oxide. Chlorine attacks it immediately; to Cupric chloride, $CuCl_2$.

Cupric oxide, CuO, is the chief Oxide. Readily prepared by heating Cupric nitrate, $Cu2NO_3$, to redness. It is black and quite insoluble in water. With 2HCl, into green $CuCl_2$ and H_2O. With Nitric acid, into blue $Cu2NO_3$, and H_2O. With H_2SO_4, into $CuSO_4$ and H_2O. Anhydrous Cupric sulphate is white; blue vitriol, $CuSO_4,5H_2O$, blue crystals. Cuprous oxide, Cu_2O, is Ruby Copper Ore: salts colorless. The chief ore of copper is Copper pyrites, $FeCuS_2$. By roasting, the Iron oxydized, and slagged off as Silicate by further heating with Silica, SiO_2. Sulphur dioxide is given off, and on further calcining the Cuprous sulphide, Cu_2S, it becomes in part $2CuO + SO_2$. When 2CuO is heated with remaining Cu_2S, we obtain $4Cu + SO_2$.

Tests for *Cupric* in soluble salts. The commonest are the sulphate, nitrate, chloride, and acetate. All are colored blue or green, and have an acid reaction. The color of the solution would suggest either a Cupric or a Nickel salt.

Na_2CO_3, blue precipitate of basic carbonate, soluble with deep-blue color in NH_4OH. Malachite is $CuH_2O_2,CuCO_3$: it is green. Azurite is $2CuH_2O_2,CuCO_3$, and is blue.

II. $HCl + H_2S$ brown-black ppt. of Cupric sulphide CuS, slightly coloring the solution. Insoluble in Ammonic sulphide. HCl alone, changes blue solution to green.

KOH, blue precipitate of CuH_2O_2, insoluble in excess: when heated, in part into black CuO. If glucose first added, CuH_2O_2 is dissolved by KOH with deep blue color, and precipitated on heating as yellow or red Cuprous oxide Cu_2O.

NH_4OH, first a greenish-blue precipitate of basic salt, soluble in excess to bright blue ammoniated salt.

Ammonium carbonate in excess re-dissolves Cupric hydrocarbonate with deep-blue color: may be employed for separating Copper from Bismuth.

Potassium ferrocyanide, $K_4FeC_6N_6$, a red-brown ppt. of Cupric ferrocyanide, $Cu_2FeC_6N_6$.

Fe deposits metallic Copper, especially recognisable, by its color, if solution acid. Zn and Pb also precipitate Cu.

On Charcoal, with Na_2CO_3 in inner flame, red beads of Copper.

Borax bead, moistened with original solution, and heated in outer flame, is green when hot; otherwise blue. In inner flame colorless, or red from metallic Copper.

Flame colored green or blue.

10. MERCURIC, Hg = 200.

Mercury and Mercurous oxide and salts have been already described at p. 17. Mercuric oxide is yellow or red, and insoluble in water. Black when heated, and volatilised as Hg and Oxygen. Heated with 2HCl into H_2O and Mercuric chloride, $HgCl_2$. Its chief salt is Mercuric chloride $HgCl_2$, known better as Corrosive sublimate. It is prepared by subliming a mixture of Mercuric sulphate with Sodium chloride. $HgSO_4 + 2NaCl = Na_2SO_4 + HgCl_2$. Completely volatile. Soluble in 16 parts of cold water. Sodium carbonate gives a heavy red-brown precipitate of $2HgO,HgCO_3$ in solutions of Mercuric chloride, but no precipitate in solutions of Mercuric cyanide: HCl immediately separates hydrocyanic acid from the cyanide.

Tests for *Mercuric* in solutions of Mercuric chloride.

II. $HCl + H_2S$, when the latter is slowly added, detects mercuric at once by white precipitate of Chloro-sulphide $HgCl_2,2HgS$, then yellow, orange, black sulphide HgS, insoluble in strong nitric acid.

KOH, yellow Mercuric oxide, HgO.

NH_4OH, white Mercuric chloro-amide: $2NH_3 + HgCl_2 = NH_4Cl + NH_2Hg_2Cl$.

KI, scarlet ppt. of HgI_2, soluble, without color, in excess.

$SnCl_2$, first Mercurous chloride, Hg_2Cl_2, and then Hg: in solution Stannic chloride. Mercuric chloride a test for Stannous salt.

Cu separates Hg as silvery mirror, the Mercury volatilising by heat.

Heated in the solid state with Na_2CO_3 in glass tube, Mercury volatilises.

11. BISMUTH, Bi = 208.

A lustrous, reddish-white metal: very brittle. Triad and Pentad. Chiefly native. Sp. gr. 9·8. Sp. heat 0·031. Melts at 270°. Chlorine attacks Bismuth, and forms Bismuth chloride, $BiCl_3$, soluble in free HCl: decomposed by water into white Oxy-chloride, BiOCl, greatly increased as a precipitate by Tartaric acid. Nitric acid dissolves Bismuth as Nitrate, $Bi3NO_3$, soluble in nitric acid: it crystallizes as $Bi3NO_3,5H_2O$. Bismuth nitrate, $Bi3NO_3$ is decomposed and precipitated white, on addition of water, as basic nitrate, $BiNO_4,H_2O$. Dilute sulphuric acid has no action, but hot H_2SO_4 yields Water, Sulphur dioxide, and Bismuth sulphate Bi_23SO_4. Aqua regia dissolves it as Bismuth chloride, $BiCl_3$.

Sodium carbonate, with effervescence, a white precipitate of basic carbonate of Bismuth.

Chief salts, Nitrate and Chloride: easily decomposed by water, and the precipitates increased by Tartaric acid. Very acid to test-paper.

Tests for Bismuth in soluble salts.

II. $HCl + H_2S$, dark-brown ppt. of Bismuth sulphide Bi_2S_3, insoluble in Ammonic sulphide; soluble in HNO_3.

KOH, white Hydroxide, insoluble in excess; on boiling, yellow.

NH_4OH, white ppt. of Hydroxide: insoluble in excess.

$K_2Cr_2O_7$, deep-yellow ppt. of Chromate Bi_23CrO_4, insoluble in KOH (distinction from Lead), soluble in Nitric acid.

On Charcoal, in reducing flame with Na_2CO_3, beads of reddish-white metal: brittle. But slight incrustation of yellow color.

12. Cadmium, Cd = 112.

Tin-white, lustrous metal. Dyad. Sp. gr. 8·6. Sp. heat 0·056. Fuses at 320°. Boils at 860°. Dilute sulphuric and hydrochloric acids slowly dissolve cadmium as $CdSO_4$ and $CdCl_2$, with evolution of H_2. Dilute nitric acid dissolves it rapidly, forming $Cd2NO_3$, H_2O, and NO. Chlorine immediately dissolves it as chloride, and so also does aqua regia.

Sulphide, CdS, and carbonate, $CdCO_3$, known as ores. Chief ones, in association with zinc: cadmium most volatile. (See Zinc, p. 28.) Cadmium oxide, CdO, is brown; hydroxide, $Cd(OH)_2$, white; both insoluble in water, but dissolved as $CdCl_2$, $CdSO_4$, or $Cd2NO_3$, by the respective acids with separation of water.

Chief salts: $Cd2NO_3$; $CdCl_2,2H_2O$; $CdSO_4,4H_2O$; CdI_2; $CdBr_2$.

Sodium carbonate precipitates white Cadmium carbonate.

Tests in soluble Cadmium salts. Solutions colorless.

II. $HCl + H_2S$, light-yellow precipitate of CdS, insoluble in Ammonic sulphide, soluble in HNO_3 and in hot dilute H_2SO_4.

KOH, white ppt. of Hydroxide, insoluble.

NH_4OH, white ppt. of Hydroxide CdH_2O_2, so soluble in excess that ammonium salts prevent precipitation.

$(NH_4)_2CO_3$, ppt. of white Carbonate, insoluble.

$K_4FeC_6N_6$, white ppt. of Cadmic ferrocyanide $Cd_2FeC_6N_6$.

Ferricyanide of potassium yellow-brown precipitate, $Cd_3Fe_2C_{12}N_{12}$.

On Charcoal, in reducing flame, with Na_2CO_3, beads of Cadmium with brown incrustation of Oxide.

13. Palladium, Pd = 106.

Lustrous metal, silver-white. Unchangeable in air. Sp. gr. 11·4. Melts at 1500°. Precipitated from Palladous chloride by Potassium iodide and reduced from the latter by heat. Dissolved by hot nitric acid, and by sulphuric acid: slowly by Hydrochloric acid.

Palladous oxide PdO is black: prepared by heating $Pd2NO_3$. Solutions of salts, brown or reddish-brown.

Tests for palladous in soluble salts: chloride, nitrate, or sulphate.

II. $HCl + H_2S$ precipitates black palladous sulphide, insoluble in ammonium sulphide, but soluble in boiling HCl.

KOH, brown basic salt, soluble when boiled.

NH_4OH, flesh-colored precipitate, soluble in excess.

KI, black palladous iodide.

$FeSO_4$, precipitates palladium as a black powder.

Heated on charcoal, the salts yield spongy palladium.

14. IRON AS FERRIC.

Ferric salts are yellow, yellow-red, or red-brown. Acid reaction.

Sodium carbonate, with effervescence, a bulky red precipitate.

HCl deepens the yellow or yellow-red color.

II. $HCl + H_2S$ reduces ferric salts to ferrous, Group IV. Only sulphur, of white or yellow color, is deposited. Thus:—

$$Fe_2Cl_6 + HCl + H_2S = 2FeCl_2 + S + 2HCl + HCl.$$

If, then, a whitish or yellowish ppt., in a solution originally colored reddish-yellow or yellow, add NH_4OH to one portion: this, with the H_2S present, forms Ammonic sulphide, and throws down black Hydrated Ferrous sulphide. To another portion of the $HCl + H_2S$ reaction, add Potassium ferricyanide; Turnbull's blue is precipitated. A FERRIC salt was present. See Group III.

N.B.—$HCl + H_2S$ reduces solutions of chromic acid of rich red-yellow color to the condition of green salts of CHROMIC OXIDE. *See Chromic acid, p. 48. Chromates of the alkaline metals soluble in water. The acid Chromates, of red-yellow color, are converted, with effervescence, into neutral yellow Chromates, by Sodic Carbonate.*

Group III.—To the Tests $HCl + H_2S$ float a few drops of Ammonic hydrate: if no ppt., pass on to Group V.

If a ppt., the only metal in Group III., which would be as black Ferrous sulphide, is Ferric; Aluminum would be white; Chromic would be dirty green.

The metals of this Group III. are precipitated as **Hydroxides** in neutral solutions to which first **Ammonic chloride,** and then **Ammonia** has been added. Comprises:

Ferric as hydroxide . .	$Fe_2H_6O_6$.
Aluminum as hydroxide	$Al_2H_6O_6$.
Chromic as hydroxide .	$Cr_2H_6O_6$.
(Manganic as hydroxide	$Mn_2H_6O_6$.)

14. IRON, FERRUM, Fe = 56.

White metal, malleable, ductile, tenacious. Dyad, Tetrad and Hexad. Sp. gr. 7·84. Sp. heat 0·114. Rusts in damp air. Rendered Passive by concentrated Nitric acid, and not acted upon. Very dilute Nitric acid dissolves Iron as Ferrous nitrate, but when allowed to heat, Ferric nitrate, Fe_26NO_3, together with Water, Ammonia, and Nitrous fumes, is formed. HCl dissolves iron as Ferrous chloride: $Fe + 2HCl = FeCl_2 + H_2$. Dilute sulphuric acid yields $FeSO_4 + H_2$. Chlorine attacks Iron, and produces Ferric chloride, Fe_2Cl_6. With $I_2 = FeI_2$.

Ferric oxide, Fe_2O_3, is red-brown: an ore of Iron as red Hæmatite, reduced to metallic state by carbon at a white heat.

Ferric hydrate, $Fe_2H_6O_6$; also native as brown Hæmatite, $2Fe_2O_3,3H_2O$.

Solutions of Ferric salts yellow, yellow-red, or red-brown: acid reaction.

Tests for Ferric salts, soluble in water. Chief salts: Ferric chloride, $Fe_2Cl_66H_2O$; and Ferric sulphate, $Fe_23SO_4 9H_2O$.

I. HCl brightens the yellow color.

II. HCl and H_2S precipitates Sulphur, white or yellow, and reduces Ferric to Ferrous salts: $Fe_2Cl_6 + HCl + H_2S = 2FeCl_2 + S + 2HCl + HCl$.

III. $NH_4Cl + NH_4OH$, precipitates flocculent red-brown Ferric hydroxide, $Fe_2H_6O_6$, insoluble in excess.

KOH, similar reaction.

K_4FeCy_6, precipitates Prussian blue.

K_3FeCy_6, a brown coloration, but no precipitate.

Potassium sulphocyanide, KNCS, gives blood-red solution, unaffected by HCl.

On Charcoal, with Na_2CO_3, in reducing flame, a dull-black Powder attracted by the magnet.

Fused with Borax, on Platinum wire, in reducing flame, the bead green; in outer flame, yellowish-red.

15. ALUMINUM, Al = 27.

Lustrous white metal, malleable and ductile. Pseudo-triad. Sp. gr. 2·7. Sp. heat 0·214. Melts at 700°. Unchanged in air. Readily dissolved by dilute HCl, and H_2SO_4, as Al_2Cl_6, and Al_23SO_4, with evolution of H_2. Nitric acid does not attack it. Chlorine combines with it, when heated, to Aluminum chloride, Al_2Cl_6. The metal is made from the anhydrous Chloride, by the action of Sodium, and heat. $Al_2O_3 + 3C + 3Cl_2 = Al_2Cl_6 + 3CO$. $Al_2Cl_6 + 3Na_2 = Al_2 + 6NaCl$.

Aluminum oxide Al_2O_3, is white, and the only Oxide. Salts colorless, and of acid reaction. Aluminic hydroxide, $Al_2H_6O_6$, is white and gelatinous: becomes Oxide when heated.

Na_2CO_3, precipitates the Hydroxide, from salts.

NH_4HS, precipitates the white Hydroxide, and not the sulphide.

Tests for Aluminum in soluble salts. Salts colorless and acid. Chief salts: Potassic-alum, $K_2Al_24SO_4,24H_2O$. Ammonic-alum $(NH_4)_2Al_24SO_4,24H_2O$. Aluminum sulphate, $Al_23SO_4,18H_2O$. Aluminum chloride, $Al_2Cl_6,12H_2O$.

III. $NH_4Cl + NH_4OH$, a white, gelatinous precipitate of $Al_2H_6O_6$, insoluble in excess.

KOH, white, gelatinous Hydroxide, soluble in excess as Potassic aluminate, $K_2O,Al_2O_3,3H_2O$.

$(NH_4)_2CO_3$, white precipitate of Hydroxide, insoluble in excess.

Na_2HPO_4, white Aluminic phosphate, not soluble in Acetic acid.

Heated on Charcoal strongly, moistened with Cobalt nitrate, and re-heated, yields Thénard's blue.

16. CHROMIUM, Cr = 52.

Nearly white. Dyad to Hexad. Almost infusible. Sp. gr. 7. Sp. heat 0·1. Nitric acid, no reaction. HCl dissolves it with evolution of H_2 as Chromous chloride, $CrCl_2$. Also dissolved by heat in H_2SO_4 : H_2 evolved.

Chief Basic oxide is Chromic oxide, Cr_2O_3, bright green: the coloring matter of the Emerald. Its salts are green, or reddish-violet. Its Hydrate $Cr_2H_6O_6$, also green. Chromic chloride $Cr_2Cl_6,12H_2O$, is green, and very soluble. The chief salt of Chromic oxide is Chrome-alum, $K_2Cr_24SO_4$, $24H_2O$, in ruby-red octahedra: its solution is reddish-violet, with acid reaction.

Tests for Chromic salts. Na_2CO_3, bluish grey-green basic carbonate.

III. NH_4Cl+NH_4OH, a dirty green gelatinous precipitate of hydroxide, $Cr_2H_6O_6$, soluble on boiling with excess of ammonia, with peach-blossom color.

KOH, blue-green hydroxide, soluble in excess to emerald-green. On boiling, re-precipitated completely.

Fused with Na_2CO_3 and KNO_3, on platinum, yellow chromate is obtained. Borax-bead is colored green: so also is microcosmic salt.

17. MANGANESIUM, Mn = 55.

Manganic oxide, Mn_2O_3, is blackish-brown. Found as the mineral Braunite. Salts deep red, and decomposed by heat into Manganous salts (p. 29). In the rare manganese alum, $K_2Mn_24SO_4,24H_2O$.

18. GLUCINUM OR BERYLLIUM, Be = 9·4.

Silver-white metal, malleable and ductile. Dyad. Sp. gr. 2·1. Sp. heat 0·4079. Like Aluminum it dissolves in Potassium hydroxide. Melts at about 1000°. Dissolves in HCl to beryllium chloride, and H_2. Its oxide, BeO, resembles MgO; its hydrate is white and gelatinous. Sodium carbonate precipitates $BeCO_3$, white, soluble in great excess. Salts, acid. $BeSO_4,7H_2O$; $BeCl_2,4H_2O$.

III. $NH_4Cl + NH_4OH$, white, gelatinous hydroxide, BeH_2O_2.

KOH, white hydroxide, soluble in excess.

$(NH_4)_2CO_3$, white carbonate, easily soluble in excess. ($Al_2H_6O_6$, insoluble.) Diluted and boiled, reprecipitated.

$(NH_4)_2S$, white hydroxide.

Group IV.—Metals of this Group are precipitated by **Ammonic** sulphide, $(NH_4)_2S$, in presence of Ammonium chloride, as sulphides.

Zinc	as ZnS, white sulphide.
Manganous	MnS, flesh-tinted sulphide.
Ferrous	FeS, black sulphide.
Cobalt.	CoS, black sulphide.
Nickel.	NiS, black sulphide.
Uranous	*US, black sulphide.*
Uranic	*U_2S_3, yellowish-brown sulphide.*

19. Zinc, Zn = 65·3.

Bluish-white, lustrous metal. Dyad. Brittle at common temperatures. Malleable and ductile between 100° and 150°. Sp. gr. 7. Melts at 433°. Sp. heat 0·095. When pure, but little acted upon by dilute sulphuric and Hydrochloric acids. With the ordinary dilute acids, the metal gives the respective Chloride and Sulphate, with evolution of H_2. In cold Nitric acid: $4Zn + 10HNO_3 = 4(Zn2NO_3) + NH_4NO_3 + 3H_2O$.

With hot Nitric acid, besides an Ammonic salt, a Nitrate, Nitric, and Nitrous oxides, Nitrogen and water. Potassium Hydroxide dissolves zinc; $2KOH + Zn = ZnO,K_2O + H_2$.

Zinc oxide ZnO is white, and canary-yellow whilst hot. Its Hydroxide ZnH_2O_2 is white, and very soluble in KOH and NH_4OH. Zinc carbonate is found native as Calamine, $ZnCO_3$; by heat, into Oxide, and reduced to metal by carbon. Zinc distils at 1040°, so that when Cadmium and Zinc together, Cd distils first. Zinc sulphide, ZnS, is the common Ore. When roasted, it oxydizes, and SO_2 is evolved; the Oxide is reduced by Carbon.

Salts of zinc have acid reaction. Common salts are $ZnSO_4,7H_2O$; $ZnCl_2,H_2O$. Colorless. Sodium carbonate precipitates white basic carbonate of zinc.

Tests for Zinc in soluble salts:—

IV. $NH_4Cl + (NH_4)_2S$, white, flocculent Zinc sulphide, ZnS, insoluble in KOH.

KOH, white ppt. of Zinc hydroxide, ZnH_2O_2, soluble in excess.

NH_4OH, white ZnH_2O_2; soluble in excess. If free acid, or Ammonic salts present, no ppt.

$(NH_4)_2CO_3$, white, gelatinous, basic Carbonate, soluble in excess.

K_4FeCy_6, white, gelatinous, ppt. of Zinc ferrocyanide, Zn_2FeCy_6.

K_3FeCy_6, brownish-yellow ppt. of Zinc ferricyanide, Zn_32FeCy_6.

With Na_2CO_3 upon Charcoal, in reducing flame, an incrustation of white Oxide, canary-yellow whilst hot.

Heated strongly on Charcoal, note the passing yellow color of the Oxide: moisten with Cobalt nitrate and re-heat, when Rinman's green is obtained.

20. Manganesium, Mn = 55.

Greyish metal with reddish tinge. So oxydizable that it must be kept under benzene. Decomposes water. Dyad. Sp. gr. 8. Sp. heat 0·122. Dissolved by all three dilute acids. Melts at white heat. The metal is obtainable from its Oxides, at a white heat, by Carbon.

Chief Ore, found native, is Pyrolusite or the Peroxide MnO_2. Dark grey. In cold HCl dissolves as Manganic chloride, $MnCl_4$, with red color; on warming, into Manganous chloride, $MnCl_2$, and Chlorine, Cl_2. $MnO_2 + 4HCl = MnCl_2 + Cl_2 + 2H_2O$. $MnO_2 + H_2SO_4$ is a test for Chlorides.

Manganous oxide, MnO, a greyish-green powder, is the chief base of Manganesium. Its Hydroxide MnH_2O_2, is white, but browns speedily by oxydation. Its salts are more or less flesh-colored, when soluble. Neutral or faintly acid. Chief soluble salts, $MnSO_4,7H_2O$; $MnCl_2,4H_2O$. Sodic carbonate precipitates $MnCO_3,H_2O$, white. Ammonium chloride and Ammonic hydrate, used as Group III. Test, give no precipitate, but the solutions brown rapidly from the oxydation of the Manganous to Hydrated Manganic oxide, Mn_2O_3,H_2O, which precipitates.

Tests for Manganous, MnO, in its soluble salts.

IV. $NH_4Cl+(NH_4)_2S$, a flesh-tinted precipitate of MnS,H_2O, browning on exposure, and easily soluble in acids.

KHO, white MnH_2O_2, insoluble in excess: browning on exposure.

NH_4OH, white, largely soluble in excess. No ppt. if NH_4Cl present. Precipitate darkens by exposure, and becomes Mn_2O_3,H_2O.

$(NH_4)_2CO_3$, white carbonate, soluble in ammoniacal salts.

K_4FeCy_6, reddish-white Mn_2FeCy_6.

K_3FeCy_6, brown $Mn_3Fe_2Cy_{12}$.

Heated on Charcoal or Platinum, in the outer flame, with Na_2CO_3, into green manganate, Na_2MnO_4.

Borax bead, amethystine in the outer flame; colorless in the inner.

21. Ferrum, Fe = 56 (p. 25).

Ferrum in Ferrous salts. Ferrous oxide is black. The Hydroxide FeH_2O_2 is white, insoluble in water, oxydizing rapidly into blue-green, and, finally, red Ferric Hydroxide. Its soluble salts are more or less sea-green; faintly or strongly acid. Chief salt: Ferrous sulphate, $FeSO_4,7H_2O$. Sodium carbonate, white ppt. of $FeCO_3$, when free from a Ferric salt. *I.* HCl, changes the color to yellow. *II.* $HCl + H_2S$, no reaction unless a Ferric salt present (p. 26). *III.* $NH_4Cl + NH_4OH$, no immediate ppt., but rapidly oxydizing, separating red Ferric Hydroxide. If any Ferric present, Group-test $NH_4Cl + NH_4OH$ will give a dirty-green precipitate.

Tests in ferrous salts.

IV. $NH_4Cl+(NH_4)_2S$, black Ferrous sulphide FeS,H_2O, soluble in dilute Hydrochloric acid.

KOH, whitish ppt. of Hydroxide, insoluble in excess, changing to dirty green and at last to red Ferric on the surface.

NH_4OH, white ppt. largely soluble in excess, and changing more rapidly to $Fe_2H_6O_6$, passing through shades of dirty green.

K_4FeCy_6, white ppt. $K_2Fe_2Cy_6$; if a Ferric salt present, then more or less blue.

K_3FeCy_6, precipitates Turnbull's Blue.

KCNS, no change of color unless Ferric present; then more or less port-wine color.

22. COBALT, Co = 58·6.

White, reddish-tinted metal. Slightly magnetic, malleable, tenacious. Dyad. Sp. gr. 8·7. Melts at lower temperature than Iron. Readily dissolved by Nitric acid to Cobalt nitrate, $Co2NO_3$; slowly dissolved by dilute HCl and dilute Sulphuric acid.

Cobalt oxide, CoO, is greenish-brown, insoluble in water. Cobalt Hydroxide, CoH_2O_2, is rose-red; soluble in NH_4OH, with reddish color.

Chief salts: $CoSO_4,7H_2O$; $Co2NO_3,6H_2O$; $CoCl_2,6H_2O$. Acid reaction. Solutions blue, red or pink. HCl may change the red color to blue. $NH_4Cl + NH_4OH$ no precipitate, but becoming reddish-brown on exposure. Sodic carbonate, a lilac precipitate of $3CoO,2CoCO_3,4H_2O$.

Tests for Cobalt in soluble salts.

IV. $NH_4Cl+(NH_4)_2S$, black ppt. of CoS,H_2O, insoluble in dilute HCl: soluble in Aqua regia.

KOH blue basic Cobaltic salt precipitated. turning green on exposure; into pale-red hydroxide CoH_2O_2, on boiling.

NH_4OH, blue basic salt, readily soluble in excess, with greenish color, browning on exposure; ultimately red.

$(NH_4)_2CO_3$, peach-colored basic carbonate, readily soluble in excess with magenta color.

K_4FeCy_6, greenish precipitate.

K_3FeCy_6, brownish-red precipitate.

[On addition of tartaric acid to a fresh sample, then of ammonia, and then of ferricyanide of potassium, a deep yellowish-red color ensues. Thus may Cobalt be detected in presence of Nickel.]

[KNO_2, together with Acetic acid, yields after a time a bright yellow precipitate of cobalt-potassium nitrite.]

[KCy, brownish-white $CoCy_2$, easily soluble in excess as $2KCy, CoCy_2$, and precipitated by HCl; not precipitated after boiling, as Cobalticyanide of potassium, K_3CoCy_6 is formed.]

[Ca2ClO gives a black precipitate of Cobaltic hydrate $Co_2O_3, 3H_2O$.]

On Charcoal similar to Iron, but more metallic.

Borax bead colored blue in outer and inner flame.

23. NICKEL, Ni = 58·6.

White metal. Dyad. Sp. gr. 8·8. Melts more readily than Iron. Dilute Nitric acid a ready solvent, to Nickel nitrate. Concentrated HNO_3 renders it passive. Dilute Hydrochloric and Sulphuric acids slowly dissolve it. Kupfer-nickel, Ni_2S_2, is its chief Ore. Arsenical nickel, $NiAsS_2$, is also an Ore. The metal obtained from the Oxide by strongly heating with Carbon; or from the oxalate NiC_2O_4 by heat.

Nickel oxide is grey; Hydroxide, NiH_2O_2, unripe apple-green. Soluble salts are green, and redden litmus. Chief salts: $NiCl_2,9H_2O$; $NiSO_4, 7H_2O$; $Ni2NO_3,6H_2O$. Sodium carbonate precipitates green basic carbonate. $NH_4Cl + NH_4OH$, a plum-colored liquid, so that Nickel is really detected in Group III.

Tests for Nickel in soluble salts.

IV. $NH_4Cl+(NH_4)_2S$, black Sulphide NiS,H_2O, giving brown coloration to liquid, as it is slightly soluble. With difficulty soluble in HCl; easily in HNO_3 and in aqua regia.

KOH, apple-green hydroxide NiH_2O_2; insoluble in excess.

NH_4OH, greenish turbidity, soluble in excess with plum color; no precipitate in free acids, or in presence of ammonium salts.

$(NH_4)_2CO_3$, green basic carbonate of Nickel, readily soluble to greenish-blue fluid.

K_4FeCy_6, greenish-white ppt. of ferrocyanide Ni_2FeCy_6.

K_3FeCy_6, yellowish-brown precipitate of Nickel ferricyanide $Ni_3Fe_2Cy_{12}$.

KCN, yellowish green $NiCy_2$, soluble with brownish-yellow color, in excess, as $2KCy,NiCy_2$, and re-precipitated as $NiCy_2$ by acids.

On Charcoal, Nickel is found similarly to Iron and Cobalt.

Borax bead, in outer flame, violet while hot; reddish-brown on cooling; in inner, grey.

24. URANIUM, U = 238.

Silver-like in lustre, slowly tarnishing. Sp. gr. 18·7. Readily dissolved by acids. Chief ore is Pitchblende, a Uranous diuranate, $UO_2,2UO_3$. The metal obtained from uranous chloride, UCl_4, by Sodium.

Uranous oxide, UO_2, is brown. Its Hydroxide, $UO_2.2H_2O$, is reddish-brown. Salts are green. They slowly absorb oxygen, and become yellow instantly with Nitric acid.

Tests for Uranous salts.

IV. $NH_4Cl + (NH_4)_2S$, a black Sulphide.

KOH, yellowish-brown hydroxide, insoluble in excess. By absorption of oxygen into uranic hydrate.

Uranic oxide, UO_3, a brownish-yellow powder. Hydroxide, greenish-yellow. Salts yellow, with greenish fluorescence in solution. $NaHCO_3$, yellow carbonate of uranium and sodium.

Tests for uranic salts.

IV. $NH_4Cl + (NH_4)_2S$, dark-brown sulphide.

KOH, a yellow insoluble uranate of potassium.

NH_4OH, similar reaction.

$(NH_4)_2CO_3$, yellow precipitate of uranic and ammonium carbonate.

K_4FeCy_6, reddish-brown precipitate.

With borax bead, pale-green in inner flame.

Group V.—Metals which are precipitated by Sodic carbonate, but not by the Group tests *I.*, *II.*, *III.* and *IV.* Barium, Strontium, Calcium, and Magnesium are precipitated as Carbonates, readily soluble in free acids as their respective salts:

Chloride of ammonium to which **Ammonic carbonate** has been added, precipitates Barium, Strontium, and Calcium as **carbonates**, but not Magnesium.

Barium carbonate, $BaCO_3$, Strontium carbonate, $SrCO_3$, Calcium carbonate, $CaCO_3$.

25. Barium, Ba = 137.

Metal of pale-yellow color. Dyad. Sp. gr. 3·6. From the fused chloride by electrolysis. Fuses at red heat. Decomposes water: $Ba + 2H_2O = BaH_2O_2 + H_2$.

Barium oxide, BaO, the only basic oxide. By heating the Nitrate to redness; greyish-white. Unites with water to form the Hydrate, BaH_2O_2, soluble in 20 parts of cold, and 3 of boiling water. It is a test for CO_2, and is precipitated as white carbonate, $BaCO_3$, if exposed to the air. Solution strongly alkaline, precipitated by Na_2CO_3, but not by the preceding group-tests: with Silver nitrate, a grey-brown precipitate of Hydroxide, AgHO.

Chief soluble salts: $BaCl_22H_2O$; $Ba2NO_3$, neutral. Less soluble in HCl than in water, and may be precipitated by the strong acid.

Tests for Barium in soluble salts.

V. $NH_4Cl+(NH_4)_2CO_3$, a white granular precipitate of $BaCO_3$.

KOH, precipitates white hydroxide in concentrated solutions, soluble in boiling water.

NH_4OH, no reaction, unless it contains Carbonate.

$CaSO_4$, an immediate white precipitate of Sulphate $BaSO_4$.

All soluble Sulphates precipitate Barium as insoluble Sulphate $BaSO_4$.

Na_2HPO_4, white $BaHPO_4$.

$K_2Cr_2O_7$, yellow $BaCrO_4$, soluble in HCl (unless the test contains sulphate).

$2HF,SiF_4$ precipitates white Silico-fluoride, $BaF_2.SiF_4$.

Soluble Salts impart yellowish-green color to flame. Insoluble salts must be moistened with HCl, and then heated.

Barium chloride is insoluble in absolute Alcohol.

26. Strontium, Sr = 87·5.

Yellow. Dyad. Decomposes water: $Sr + 2H_2O = SrH_2O_2 + H_2$. Sp. gr. 2·5. Melts at red heat.

Strontia, SrO, is the only basic Oxide: by heating the nitrate to redness; forms with water Strontium hydroxide, SrH_2O_2, requiring 50 parts of water for solution. Precipitated by CO_2. Solution strongly alkaline, precipitated by Na_2CO_3 as $SrCO_3$, but not by Group-tests I., II., III., and IV. With Silver nitrate, a grey-brown precipitate of Silver hydroxide, AgHO.

Chief soluble Salts: $SrCl_2,6H_2O$; $Sr2NO_3,5H_2O$.

V. $NH_4Cl + (NH_4)_2CO_3$, precipitates white $SrCO_3$.

KOH, precipitates white SrH_2O_2, insoluble in excess, but soluble in much boiling water.

NH_4OH, no reaction.

$CaSO_4$, a white precipitate on heating, or on long standing.

As soluble sulphates remove both Ba and Sr, these may be separated from solutions containing Ca.

Soluble salts, carmine color to flame.

Strontium chloride, $SrCl_2$, is soluble in absolute alcohol, and thus separable, quantitatively, from Barium chloride.

27. Calcium, $Ca = 40$.

Yellow lustrous metal. Dyad. From the fused chloride by electrolysis. Melts at red heat. Decomposes water: $Ca + 2H_2O = CaH_2O_2 + H_2$. Sp. gr. 1·57. Sp. heat 0·167.

Calcium oxide, CaO, the only basic Oxide. White, infusible; lime-light. Quicklime is CaO; by heating Limestone, $CaCO_3$, to redness $= CaO + CO_2$. Slakes with water to Calcium hydroxide, CaH_2O_2, a white amorphous powder, requiring 723 parts of cold, and 1330 parts of boiling water for solution. Lime-water is such a solution. Milk of lime is Calcium hydroxide largely mixed with lime-water. Lime-water, alkaline, precipitated by CO_2 from air, and of course by Na_2CO_3; Silver nitrate is precipitated as Silver hydroxide, $AgHO$, grey-brown.

Chief soluble Salts: $CaCl_2,6H_2O$; $CaSO_4,2H_2O$; $Ca2NO_3,4H_2O$. (Chloride of lime, $2CaOCl_2$, dissolves in water as Calcium chloride, $CaCl_2$, and Calcium hypochlorite, $Ca2ClO$, bleaching litmus, and evolving Cl_2 on adding an acid.)

Tests for Calcium in soluble salts.

V. $NH_4Cl + (NH_4)_2CO_3$, white precipitate of $CaCO_3$. The Test should be used very sparingly, on account of the solubility of Calcium Bi-carbonate, $CaCO_3,H_2CO_3$. [Temporarily hard water contains the Bi-carbonate; it is softened by boiling: into $CaCO_3 + CO_2 + H_2O$. Such water is also softened by adding sufficiency of Calcium Hydroxide: $CaCO_3,H_2CO_3 + CaH_2O_2 = 2CaCO_3 + 2H_2O$.]

KOH, white precipitate of Hydroxide CaH_2O_2.

NH_4OH, no reaction.

$CaSO_4$, of course no reaction. Distinction between Ba, Sr, and Ca: Ba immediately precipitated, Sr on heating, Ca not at all.

Concentrated solutions of sulphates precipitate the Chloride, Nitrate, &c., as white Calcium sulphate $CaSO_4,2H_2O$.

Ammonium oxalate, $(NH_4)_2C_2O_4$, precipitates white Calcium oxalate, insoluble in acetic acid. This test is decisive if Calcium sulphate has given no precipitate.

Soluble salts communicate a yellowish-red color to flame.

28. Magnesium, $Mg = 24$.

Silvery lustrous metal. Dyad. Sp. gr. 1·74. Sp. heat 0·25. Melts at a red heat. By the action of Sodium upon the Chloride by heat: $MgCl_2 + Na_2 = 2NaCl + Mg$. Dissolves in the three dilute common acids with evolution of hydrogen; not in KOH. Burns brilliantly to Magnesium oxide, or Magnesia, MgO.

Magnesium oxide, MgO, the only base of magnesium. White, amorphous powder; when moistened, blues red litmus, but requires 5142 parts of cold water for solution. Practically insoluble in water, and precipitated by Lime-water from its soluble salts.

Chief soluble salts: Sulphate $MgSO_4,7H_2O$ is Epsom salts; Chloride, $MgCl_2,6H_2O$; Nitrate, $Mg2NO_3,6H_2O$.

Tests for Magnesium in soluble salts.

V. $NH_4Cl + (NH_4)_2CO_3$, no precipitate. But, if ammonium chloride has been forgotten, a precipitate, increasing, of basic magnesium carbonate. No precipitate in presence of free acids, as then an ammonium salt is formed with the ammonium of the carbonate.

KOH, white Magnesium hydroxide MgH_2O_2, insoluble in excess.

NH_4OH, white MgH_2O_2; increased by heat. No precipitate in presence of free acids.

$NaHCO_3$, no precipitate till warmed. Therefore a Mg salt a test for a bi-carbonate of sodium or potassium.

Na_2HPO_4, a white precipitate of $MgHPO_4$, greatly increased by NH_4OH.

Ammonium chloride, then NH_4OH, and then Na_2HPO_4, a white crystalline precipitate of $MgNH_4PO_4,6H_2O$.

Magnesium is precipitated as $MgNH_4PO_4,6H_2O$, after the separation of Calcium by oxalate of Ammonium.

No color to flame; MgO, rose-colored, when ignited on Platinum with Cobalt nitrate.

Group VI.—**Metals of the Alkalies.** The Carbonates are all soluble in water: (Lithium Carbonate, however, with difficulty soluble, and may be precipitated by Sodium carbonate). From any salt of Ammonium, in which the latter is not at once recognizable by the smell, the Carbonate of sodium test, on boiling, liberates Ammonic carbonate, recognizable by the smell, &c. *Group VI.* includes Ammonium, Potassium, and Sodium, Lithium, Rubidium, and Caesium.

29. AMMONIUM, $(NH_4)_2 = 36$.

A compound metal, resembling Potassium. Only known in combination.

Chief soluble salts: Ammonium chloride, NH_4Cl. Ammonic carbonate, $(NH_4)_2CO_3$. Ammonic nitrate, NH_4NO_3. Ammonic sulphate, $(NH_4)_2SO_4$. Ammonic phosphate, $(NH_4)_3PO_4,3H_2O$. Microcosmic salt, $NaNH_4HPO_4,4H_2O$. Sulphhydrate, NH_4HS. Ammonic sulphide, $(NH_4)_2S$.

Tests for soluble Salts. All volatile, except where the radicle is fixed.

Na_2CO_3, liberates $(NH_4)_2CO_3$ on heating, recognized by its smell, by bluing red litmus, and forming white fumes with a glass rod dipped into HCl.

VI. $PtCl_4,2HCl$, yellow crystalline powder of $2NH_4Cl,PtCl_4$.

$H_2C_4H_4O_6$ (Tartaric acid), in excess, a white crystalline precipitate of Ammonic hydrogen tartrate, $NH_4HC_4H_4O_6$, especially on stirring.

Nessler's test (HgI_2 in KI and KOH added), a brown precipitate (or yellow coloration, if a trace of ammonia), as Oxy-di-mercurammonium iodide, NH_2Hg_2IO.

Ammonic hydrate is a solution of NH_3 in H_2O, or of NH_4OH: it is colorless, alkaline, smells of Ammonia, leaves no residue on warming. $AgNO_3$, grey-brown precipitate of Silver hydroxide $AgOH$, readily soluble in excess: no ppt. if Ammonia in excess. If free from carbonate, no precipitate by lime-water. Fumes more or less with HCl. $PtCl_4,2HCl$, yellow precipitate of Ammonic-platinic chloride, $2NH_4Cl,PtCl_4$.

30. POTASSIUM, KALIUM, $K = 39$. $K_2 = 78$.

Silver-white metal, tarnishing in damp air. Monad. Oxydizes to K_2O. Kept under naphtha. Sp. gr. 0·865. Melts at 62·5° C. Sp. heat 0·166. By strongly heating K_2CO_3 with Charcoal $= K_2 + 3CO$. Decomposes water: $K_2 + 2H_2O = 2KHO + H_2$.

Its Oxide, K_2O, is white. Its Hydroxide, KOH, very soluble, deliquescent. Prepared by dissolving the Carbonate in 10 parts of water, boiling, and adding Calcium Hydroxide: $K_2CO_3 + CaH_2O_2 = 2KOH + CaCO_3$.

Its salts are legion. Nearly all soluble. Chief salts: $K_2CO_3,2H_2O$. $KHCO_3$. KCl. KI. KBr. KCy. K_2SO_4. $KHSO_4$. KNO_3. $KClO_3$. $K_4FeCy_6,3H_2O$. K_3FeCy_6.

Tests for soluble Salts.

Na_2CO_3, no reaction, even on boiling (see 29, Ammonium).

VI. $PtCl_4,2HCl$, yellow crystalline ppt. of $2KCl,PtCl_4$.

$H_2C_4H_4O_6$, in excess, a white crystalline precipitate of $KHC_4H_4O_6$.

H_2SiF_6, Fluosilicic acid, a white, crystalline precipitate of K_2SiF_6.

Violet color to flame; red through Cobalt-glass.

A solution of the Hydroxide is strongly alkaline. Na_2CO_3, no reaction, even on boiling. $AgNO_3$, grey-brown precipitate of $AgOH$, soluble both in NH_4OH and in HNO_3. Precipitates and re-dissolves the Hydroxides from soluble Zinc and Lead salts. $2HCl,PtCl_4$, yellow precipitate of Potassium Platinic chloride $2KCl,PtCl_4$. Liberates NH_4OH from any ammonium salts.

31. SODIUM OR NATRIUM, $Na = 23$. $Na_2 = 46$.

Lustrous, reddish-tinted metal. Monad. Sp. gr. 0·97. Sp. heat 0·293. Melts at 95·6° C. Oxydizes to Na_2O in dry air. Decomposes water: $Na_2 + 2H_2O = 2NaOH + H_2$. Kept under naphtha. Prepared from Na_2CO_3 by heating with Charcoal: $Na_2CO_3 + 2C = 3CO + Na_2$. Sodium oxide, Na_2O, is white. Hydroxide, $NaOH$, white, translucent, deliquescent. Solution of Hydroxide, by dissolving Na_2CO_3 in 10 of water, boiling, and adding CaH_2O_2 to the boiling liquor until operation complete: $Na_2CO_3 + CaH_2O_2 = 2NaHO + CaCO_3$.

All salts soluble, except pyrantimonate, $Na_2H_2Sb_2O_7,6H_2O$. Chief salts: $NaCl$. $Na_2CO_3,10H_2O$. $NaHCO_3$. $NaNO_3$. $Na_2HPO_4,12H_2O$. $Na_2S_2O_3,5H_2O$. $Na_2B_4O_7,10H_2O$. $Na_2SO_4,10H_2O$. $NaNH_4HPO_4,4H_2O$.

Tests in soluble salts.

Na_2CO_3, no reaction, even on boiling: absence of Ammonic salts.

VI. $2HCl,PtCl_4$, no precipitate, even on vigorous stirring; not a salt of potassium.

$H_2C_4H_4O_6$, no precipitate.

Yellow color to flame, absorbed by blue Cobalt glass.

32. Lithium, Li = 7.

Silvery metal. Monad. Sp. gr. 0·6. Decomposes water. Sp. heat 0·94. Melts at 180°. From the fused chloride by electrolysis. Oxide, Li_2O; hydroxide white, not deliquescent. Lithium chloride, $LiCl$, very soluble in alcohol.

Tests for soluble salts.

Na_2CO_3, in fairly strong solutions, white Li_2CO_3. After a time, in weaker solutions. Group-tests I., II., III., IV. and V., no precipitates.

Na_2HPO_4, slowly precipitates (or at once when heated) Li_3PO_4,H_2O, soluble in HCl, and not re-precipitated by NH_4OH until heated.

Carmine color to flame.

33. Rubidium, Rb = 85·3.

Yellowish-white, lustrous. Monad. Sp. gr. 1·5. Melts at 38·5° C. Like K_2, the H_2 kindles from the violent reaction upon water. Rubidium more electro-positive than potassium.

Chloride, $RbCl$, chief soluble Salt.

Tests for soluble Salts.

Na_2CO_3, no reaction, even on boiling. Rb_2CO_3, insoluble in alcohol.

$2HCl,PtCl_4$, yellow precipitate $2RbCl,PtCl_4$, even less soluble than Potassium-platinic chloride.

Violet color to flame.

34. Caesium, Cs = 133.

White, lustrous, easily oxydized. Monad. Decomposes water with violence. Sp. gr. 1·88. Melts at 26·5° C. One Oxide, Cs_2O; Hydroxide, $CsOH$. Most electro-positive metal.

Tests for soluble Salts.

Na_2CO_3, no reaction, even on boiling. Cs_2CO_3, soluble in alcohol.

$2HCl,PtCl_4$, yellow $2CsCl,PtCl_4$, most insoluble of all.

Violet color to flame.

GROUP-TESTS FOR SOME ACIDS IN THEIR SOLUBLE SALTS.

It must now be clear to the student that nearly all the salts of Potassium, Sodium and Ammonium are soluble in water, and that, in solutions of these, Sodium carbonate can give no precipitate.

As most metallic oxides are insoluble in water, only Salts of these can be found in solution in water, and in such solutions Sodium carbonate will give a ppt., because their Carbonates are also all insoluble in water

But not only are the Carbonates for the most part insoluble in water, but also the Phosphates, Borates, Chromates, Oxalates, Arsenites, Arsenates, Sulphides, Sulphites, Thiosulphates, Silicates and Fluorides, &c. So that, if Sodium carbonate Na_2CO_3, gives a ppt. in a solution of a metallic salt, we need not look for a Carbonate, a Phosphate, a Borate, a Chromate, an Oxalate, an Arsenite, &c., &c. Of course, if a solution is colorless, a Chromate is impossible, as the latter must be yellow, or yellow-red.

Certain combinations of Metallic oxides with water may be in aqueous solution, such as Potassium hydroxide, KHO, Sodium hydroxide NaHO, Barium hydroxide $Ba(HO)_2$, Strontium hydroxide $Sr(HO)_2$, Calcium hydroxide $Ca(HO)_2$, and Ammonium hydroxide NH_4HO. They are strongly alkaline, and in solutions of $Ba(HO)_2$, $Sr(HO)_2$, and $Ca(HO)_2$, Sodium carbonate gives a white ppt. (p. 32).

Organic acids may generally be distinguished, whether as salts or as free Acids, by the fact that they are Carbon-compounds, and are nearly all carbonized by heat.

The ordinary soluble salts of the Metals in the first five Groups are the Sulphates, Chlorides, Bromides, Iodides, Cyanides, Acetates, Nitrates and Chlorides.

If a solid has to be examined, it is advisable to moisten a very small portion in a watch-glass with Ammonic sulphide, so as to disclose the presence or absence of most metals of Groups I., II., III. and IV.: if blackened or browned, turned orange-red or yellow, there is reason to believe in the presence of some Metal, the Carbonate, Phosphate, Borate, Arsenite, Arsenate, &c., of which need not be looked for.

In the case of a white powder, like **Arsenious oxide,** Ammonic sulphide dissolves it to a colorless solution, which, when diluted with water, gives with HCl a bright yellow ppt. of Arsenious sulphide, soluble in Ammonia. A further test,—heat upon Platinum—would volatilize it with lavender-colored flame.—In the case of **Calomel,** Ammonic sulphide would form black Mercurous sulphide: heated on platinum, Calomel would volatilize. Complete volatility, together with the blackening, would suggest Calomel (Mercurous chloride): Ammonia added to a further portion would confirm Mercurous, as the white powder would be blackened, and the Chloride would be discovered by decanting the clear solution, acidulation with Nitric acid, and precipitation of white Silver chloride by Silver nitrate. Free acids and acid salts might occasion effervescence in the Ammonic sulphide, from escape of Hydric sulphide H_2S, together with a deposit of Sulphur if yellow Ammonic disulphide has been employed.

The condition of the Solution as to Alkalinity, Acidity, or Neutrality, is of first importance (pp. 2–7), and so also the effect of heat upon Platinum or upon Charcoal.

If a solution is colorless, Ferrous and Ferric salts, those of Nickel and Cobalt, of Cupric, as also Chromates, Manganates and Permanganates of the Metals must, under ordinary circumstances, be absent.

The absence of smell, or otherwise, must be noted, as a cultured scent will diagnose Ammonia, Hydric sulphide, Sulphurous acid, Chlorine, Bromine, Iodine, Hydric cyanide, &c., &c.

As a Group-test, Na_2CO_3, retains its value, and tells what the Acidity proceeds from.

If no precipitate, and no effervescence in a solution, it is advisable at once to heat a drop upon Platinum-foil, in order to ascertain whether we have to deal with anything beyond Distilled water. The best method is to take a drop in the upper part of a clean test-tube held horizontally, and evaporate gently: thus, the residue is more easily seen, and, if volatile, can be better examined.

In the analysis of simple solutions, containing but one acid and one base, of Salts soluble in water, such as satisfy most of the ordinary requirements, there is rarely need for filtration when Sodic carbonate has produced a ppt.; but we may continue the addition till slight excess is present (known by the alkaline character of the liquid and no further ppt.), warm, filter and examine the liquid that passes through the filter (called the *filtrate*) for the acids. The ppt. of Carbonate or Hydroxide may be washed with distilled water, dissolved in HCl, or HNO_3, and tested for the Metal which is then present as Chloride or Nitrate: many of the Metals are, however, best removed by excess of H_2S, in a solution acidulated with HCl.

REACTIONS OF THE ACIDS, WITH DESCRIPTION OF ORDINARY MODES OF PREPARATION.

A. Salts visibly or detectibly decomposed by the Group-test A Hydrochloric acid.

Hydrochloric acid, HCl, is a colorless, suffocating gas, fuming strongly in air. Water dissolves 500 volumes at 0°. Solution of the gas in water known as Hydric chloride or Hydrochloric acid. All Chlorides soluble in water, except Hg_2Cl_2 and AgCl. Dissolves Zn, Mg, Fe, Cd, Sn and Sb, as Chlorides with evolution of H_2: Bismuth, Tin and Antimony chlorides only possible in solution with free Hydrochloric acid. *Prep.* $2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$. **N.B.** As **HCl** is the first Group-test for the metals, a little attention enables the Student to detect the presence of **Carbonates, Silicates, Sulphides, Sulphites,** Thiosulphates, Nitrites, **Chlorates,** Chlorites, and Hypochlorites. If **Arsenites** are present, HCl sets free Arsenious acid, and the second Group-test **HCl + H_2S,** precipitates it in the form of Sulph-arsenious acid As_2S_3, soluble in NH_3. If **Chromates** are present, the bright yellow solution becomes yellow-red, and on addition of the second Group-test **HCl + H_2S,** the free Chromic acid is reduced to bluish-green Solution of Chromic chloride with deposit of Sulphur. If free **Nitric acid** is present, the addition of **HCl**, and heat, discovers the Nitric acid owing to the change of color (deep yellow) and evolution of Nitrosyl chloride NOCl, and Cl_2.

The important salts discoverable by the Group-test **A. HCl.** are: Carbonates, Sulphides, Sulphites, Thiosulphates, Nitrites, Chlorates, Hypochlorites, Hypobromites, Acetates, Cyanides, Arsenites, Chromates, Silicates.

I. Carbonates. Those of the alkaline metals alone soluble in water. Solutions colorless: alkaline to test-paper. The Hydro-carbonates, or bi-carbonates, $KHCO_3$, $NaHCO_3$, and NH_4HCO_3, are also alkaline: when solutions warmed, they evolve CO_2, with effervescence.

All bi-carbonates of the metals somewhat soluble and precipitated, when boiled, as carbonates.

The common soluble Carbonates are: $2K_2CO_3,3H_2O$. $KHCO_3$. $Na_2CO_3,10H_2O$. $NaHCO_3$. $2[(NH_4)_2CO_3],CO_2$.

A. HCl, effervescence from escape of inodorous CO_2, which can be decanted into a test-glass containing Lime-water, and yields ppt. of $CaCO_3$.

$BaCl_2$, white ppt. of $BaCO_3$, soluble with effervescence in HCl.

$AgNO_3$, white ppt. of Ag_2CO_3, soluble with effervescence in HNO_3, and also soluble in NH_4HO.

* Solution of Na_2CO_3, precipitates solution of Magnesium sulphate at once as white carbonate; but, solution of $NaHCO_3$, only on standing, or immediately on warming.

Carbon dioxide CO_2, a colorless gas, inodorous, soluble in water measure for measure. Its solution in water turns litmus paper port-wine red, evolves pearly bubbles of gas on heating, precipitates lime-water, and leaves no residue on evaporation. Hypothetical Carbonic acid H_2CO_3. Prep. of CO_2. $CaCO_3 + 2HCl = CaCl_2 + H_2O + CO_2$.

II. Sulphides. Yellow, or colorless. Smell of H_2S. Alkaline to test-paper. Those of Groups V. and VI., among the metals, alone soluble in water. The common soluble sulphides are: NH_4HS, $(NH_4)_2S$, $(NH_4)_2S_2$.

A. HCl evolves H_2S, which browns or blackens lead-paper. In the higher Sulphides, or Polysulphides, HCl precipitates Sulphur of white or yellow color, and evolves H_2S with effervescence and characteristic odor.

$AgNO_3$, black Ag_2S, insoluble in Ammonic hydrate.

Fe_2Cl_6, black sulphide.

Nitroprusside of sodium, $Na_2Fe(NO)Cy_5$, rich violet color (none with H_2S).

Hydrogen sulphide, H_2S, in solution in water, is recognized by its odor of putrid eggs, and acidity to test-paper. Either colorless, or slightly milky from Sulphur. Blackens lead-paper. No residue on heating. Prep. $FeS + H_2SO_4 = FeSO_4 + H_2S$.

A. HCl, no reaction. $HCl + H_2S$ is No. II. Group-test (pp. 18–25) precipitates many metallic Sulphides, and does not re-dissolve them.

Cl_2 precipitates S, with formation of 2HCl.

Br_2 and I_2, in aqueous solution decolorized, and changed into HBr and HI. $Br_2 + H_2S = 2HBr + S$. $I_2 + H_2S = 2HI + S$.

HNO_3 oxydizes the H_2 of H_2S, and deposits S. When heated with HNO_3, Sulphuric acid is found in solution.

As the quality of H_2S in solution is of great importance to the student, and as it spoils unless well stoppered, the following test of quality is recommended.

Add H_2SO_4 to 20 or 30 drops of $K_2Cr_2O_7$, and add to this mixture excess of H_2S solution: it should become milky blue-green.

$$2K_2Cr_2O_7 + 8H_2SO_4 + 6H_2S = 2(K_2Cr_24SO_4) + 14H_2O + 3S_2.$$

III. Sulphites. Those of the alkaline metals alone soluble. Normal sulphites alkaline to test-paper. Acid sulphites are all more or less soluble, redden litmus and then bleach it. Sodium sulphite, $Na_2SO_3,7H_2O$, the commonest salt.

A. HCl evolves odor of burning brimstone; but SO_2 is so soluble, that there is rarely effervescence.

HCl + Zn evolves H_2S, which browns lead-paper and deposits yellow sulphur.

$BaCl_2$, white ppt. $BaSO_3$, soluble in HCl if no sulphate present: rarely the case.

$AgNO_3$, white ppt. Ag_2SO_3, readily dissolved by original solution. By heat: $Ag_2SO_3+H_2O$ into metallic silver, Ag_2, and H_2SO_4. Silver either as grey powder, or metallic, lustrous.

Fe_2Cl_6, red color, then reduced to Ferrous salts: $Fe_2Cl_6 + SO_2 + 2H_2O = 4HCl + FeCl_2 + FeSO_4$.

H_3AsO_4 reduced to H_3AsO_3. Thus: $H_3AsO_4 + SO_2 + H_2O = H_3AsO_3 + H_2SO_4$.

Solution of **Sulphurous acid,** H_2SO_3, is odorous of burning brimstone; reddens and bleaches litmus. Decomposes H_2S with deposit of S_2, and formation of Pentathionic acid. $AgNO_3$, a ppt. No residue on platinum. Prep. of **Sulphur dioxide** SO_2 by burning S in air. Also by heating $Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2$. One vol. of water dissolves 50 vols. at 15°.

IV. Thiosulphates. Salts of alkaline metals, of Ca and Sr, soluble. The ordinary salt, $Na_2S_2O_3,5H_2O$. When heated on platinum, to Sulphate and Sulphide, burning then with yellow flame to Sulphate with blue and red tints on platinum. Alkaline reaction.

A. HCl, after short time—immediately on heating—precipitates yellow or white sulphur, and liberates SO_2. $Na_2S_2O_3 + 2HCl = 2NaCl + H_2O + SO_2 + S$.

$AgNO_3$, white ppt. $Ag_2S_2O_3$, changing rapidly to yellow, orange, and black Ag_2S. $Ag_2S_2O_3 + H_2O = Ag_2S + H_2SO_4$.

Silver chloride, bromide, or iodide readily dissolved by Thiosulphate of sodium as $NaAgS_2O_3$, with formation of NaCl, NaBr, or NaI.

$BaCl_2$, white BaS_2O_3.

In a free state, **Thiosulphuric acid** is unknown. See above.

V. Nitrites. For the most part soluble. KNO_2 the ordinary salt.

A. HCl evolves nitrous fumes, with yellow color to liquid, and orange in the tube: Nitric acid in solution. $FeSO_4$ added to HCl solution, rich olive-brown color, clearing to deep yellow: orange fumes.

$FeSO_4$, olive-brown color, with evolution of orange fumes. The color due to NO, which unites with $2FeSO_4$.

$CuSO_4$, emerald-green color, $Cu2NO_2$.

KI and starch-paste with acetic acid, blue Iodide of starch. Confirmed as Nitrite by coloring original solution with Potassium permanganate, and addition of Acetic acid: decolorized.

$AgNO_3$, white ppt. $AgNO_2$, soluble in much water.

Nitrous acid, HNO_2, unknown in pure state. By gentle heat: $3HNO_2 = HNO_3 + 2NO + H_2O$.

VI. Chlorates. All soluble in water. The ordinary salts: $KClO_3$ and $Ba2ClO_3$.

A. HCl decomposes Chlorates on warming: solution becomes greenish-yellow, and a mixture of Cl_2 and ClO_2 fills the tube.

Chlorates deflagrate on charcoal. Heated strongly on Platinum, they effervesce from escape of Oxygen, and become Chlorides: dissolve in water, acidulate with HNO_3 and add $AgNO_3$, and there will be a white, curd-like ppt. of AgCl, soluble in NH_4OH.

VII. Hypochlorites. Solutions alkaline, smell of Chlorine and bleach litmus papers. Bleaching powder, $2CaOCl_2$, dissolves in water as $Ca2ClO + CaCl_2$. So that a chloride is also always present. "Eau de Javelle" is KCl + KClO in aqueous solution. "Labarraque's liquid" is NaCl + NaClO in water.

A. HCl sets free Cl_2 and water. Indigo-blue decolorized. On boiling, into a Chlorate and Chloride.

Lead acetate, $Pb2C_2H_3O_2$, white ppt., changing from red to brown PbO_2.

VIII. Hypobromites. Alkaline. Bleach litmus. Used in Russell's and West's test for Urea, $CO(NH_2)_2$.

Potassium hypobromite is a mixture of KBrO with KBr. With Urea: $3KBrO + KHO + CON_2H_4 = 3KBr + KHCO_3 + 2H_2O + N_2$.

A. HCl evolves Bromine, easily recognized by its red-brown fumes, and orange color to starch-paste.

IX. Cyanides. Chief salt: Cyanide of potassium KCN, colorless, strongly alkaline, odorous of Prussic acid.

A. HCl liberates HCN, volatile, with smell of bitter almonds, and constriction of throat. A strip of filter-paper moistened with KOH, suspended in tube from which HCN escaping, gives Prussian blue when immersed in Ferrous sulphate, boiled, and HCl added in excess.

$AgNO_3$, white, curd-like ppt. of AgCN, very soluble in KCN, in NH_4OH and in strong, boiling HNO_3: but if a Chloride present, AgCl, insoluble in HNO_3. Silver cyanide AgCN, when dry, on ignition gives off Cyanogen, burning with peach-blossom-colored flame, and is reduced to metallic silver.

Again: AgCN, treated with Zn and dilute Sulphuric acid, yields HCN, which may be distilled.

$FeSO_4$, red ppt. of $2FeC_2N_2$,KCy. Boiled with KOH, on addition of HCl gives Prussian blue.

$(NH_4)_2S_2$ added to soluble Cyanide, and evaporated to dryness, leaves Ammonium sulphocyanate, NH_4CNS, which gives blood-red, soluble Ferric sulphocyanate, after adding Ferric chloride.

Mercuric cyanide, HgC_2N_2, is somewhat anomalous. Soluble in water, faintly acid, Na_2CO_3 no reaction. But HCl, in the usual mode of testing for bases and acids, evolves HCN, which may be detected as above. HCl + H_2S gives white Chloro-sulphide, changing through yellow, and orange, to black ppt. of Mercuric sulphide, HgS. HCl + KI, scarlet HgI_2. Heated in the solid state, gives C_2N_2, burning with peach-blossom-colored flame.

Hydrocyanic acid, HCN, smells of bitter almonds. Faintly acid. No effervescence with Na_2CO_3. No residue on Platinum. Prep. KCN + H_2SO_4 dilute = $KHSO_4$ + CNH.

A. HCl, no increased smell.

$AgNO_3$, white ppt. of AgCN, soluble in NH_4OH and in boiling HNO_3.

$FeSO_4$, no reaction: boil with KOH, and add HCl, Prussian Blue is obtained.

X. Silicates. Very alkaline. Those of alkaline metals alone soluble.

A. HCl precipitates gelatinous **Silicic acid,** H_4SiO_4, except in very dilute solutions: on evaporation to dryness, ignition, and boiling with HCl, **Silicon dioxide** SiO_2, is left as a white, amorphous, insoluble powder.

NH_4Cl, white ppt. of H_4SiO_4, with evolution of NH_3.

$BaCl_2$, white ppt. of Ba_2SiO_4, decomposed by HCl.

A dialyzed solution of **Silicic acid** is gelatinized by HCl, and is only faintly acid to test-paper.

On Platinum-wire with Na_2CO_3, fused in blowpipe-flame, to a clear glass, unless Na_2CO_3 in excess. SiO_2 expels CO_2, with effervescence, at a red heat.

XI. Titanates resemble Silicates.

A. HCl precipitates H_2TiO_3: with Zn first a blue ppt., becoming white.

In inner flame, with Microcosmic salt and Ferrous sulphate, a red bead.

Titanic acid is removed from Silica by fusion with $KHSO_4$, and subsequent treatment with water: SiO_2, undissolved.

XII. Tungstates of alkaline metals alone soluble.

A. HCl, white ppt. of tungstic acid, H_2WO_4, yellow on boiling, insoluble in excess, but soluble in NH_4OH.

Zn with HCl, blue color.

In inner flame, a blue bead with microcosmic salt, becoming red when heated with $FeSO_4$.

XIII. Molybdates of alkaline metals soluble. Colorless. Alkaline.

A. HCl, white Molybdic acid, soluble in excess of HCl. In HCl solution with Zn, blue, green, brown-black.

Salts of soluble molybdates, yellow by H_2S, and precipitated as brown-black MoS_3 by acids, soluble, when neutralized, in $(NH_4)_2S_2$.

Molybdate of ammonium in Nitric acid is a test for Ortho-phosphoric acid: so that Na_2HPO_4, a yellow ppt. when heated, of Ammonium-phosphomolybdate. $2(NH_4)_3PO_4,22MoO_3,12H_2O$.

Chromates, of the alkaline metals, soluble with lemon-yellow color.

A. HCl changes yellow color to bright yellow-red. See Group **B. XIX.**, p. 48.

Arsenites, of alkaline metals alone soluble: Alkaline reaction.

A. HCl to concentrated solutions, a white ppt. of Arsenious oxide, As_2O_3, soluble in excess. Confirmed by H_2S. See Group **B. XVI.**, p. 45.

Sulpharsenites. K_3AsS_3, alkaline, yellow.

A. HCl, yellow ppt. of As_2S_3, with H_2S, evolved.

Sulpharsenates. K_3AsS_4, alkaline, colorless.

A. HCl, yellow ppt. of As_2S_5 and H_2S.

Antimonites as $KSbO_2$, soluble, alkaline.

A. HCl, white ppt., soluble in excess. H_2S added, orange Sb_2S_3, soluble in strong HCl as $SbCl_3 + H_2S$.

Antimonates. Pyrantimonate of potassium, $K_2H_2Sb_2O_7$, is soluble in water. Alkaline.

A. HCl precipitates white $H_4Sb_2O_7$.

With Sodium salts, $K_2H_2Sb_2O_7$ gives white ppt. of $Na_2H_2Sb_2O_7$, the only insoluble sodium salt.

Sulphantimonites. K_3SbS_3. Alkaline.

A. HCl, orange Sb_2S_3.

Sulphantimonates. K_3SbS_4. Alkaline.

A. HCl, orange $Sb_2S_5 + H_2S$.

Acetates, all soluble: those of Ag and Hg_2 with difficulty. See Group **C. XXVIII.**

A. HCl sets Acetic acid free, recognized by odor of vinegar. P. 51.

Urates. Only of alkaline metals soluble.

A. HCl, white ppt. of Uric acid.

Hippurates, alkaline to test-paper.

A. HCl, white needles of hippuric acid. P. 57.

Benzoates. All more or less soluble.

A. HCl, white, glittering scales of benzoic acid. P. 56.

Salicylates. All more or less soluble.

A. HCl, precipitates Salicylic acid in small, white needles.

Gallates. Alkaline to test-paper.

A. HCl, minute white crystals of Gallic acid. P. 55.

Ferrocyanides. When soluble, bright-yellow.

Also decomposed by HCl. P. 51.

A. HCl, either a bluish tint, or bluish-white ppt. in strong solutions. P. 51.

B. Salts, the radicles (or electro-negative elements) of which form insoluble compounds with Barium chloride $BaCl_2$. Includes Sulphates, *Selenates*, *Silico-fluorides*, Ortho-phosphates, *Pyro-phosphates*, *Metaphosphates*, *Phosphites*, *Fluorides*, Arsenates, Arsenites, Borates, *Iodates*, *Bromates*, Chromates, Oxalates (Tartrates, Citrates). Also: Carbonates, Sulphites, Thiosulphates, Silicates, already discovered by *A.* **HCl.**

B. **$BaCl_2$**, the Group-test here suggested to follow upon *A.* HCl, is employed because so many of the Barium salts are insoluble in water. Barium chloride $BaCl_2$, $2H_2O$, crystallizes in lustrous rhombic tables, soluble in two parts of water at 15° C. Much less soluble in HCl, and in HNO_3: insoluble in alcohol. The action of $BaCl_2$, may be thus given:

$$\begin{aligned}
BaCl_2 + Na_2SO_4 &= 2NaCl + BaSO_4.\\
BaCl_2 + Na_2HPO_4 &= 2NaCl + BaHPO_4.\\
BaCl_2 + Na_2CO_3 &= 2NaCl + BaCO_3.\\
BaCl_2 + K_2CrO_4 &= 2KCl + BaCrO_4.\\
BaCl_2 + K_2C_2O_4 &= 2KCl + BaC_2O_4.
\end{aligned}$$

XIV. Sulphates. All Sulphates are soluble in water, except Barium, Strontium and Lead sulphates. Neutral or acid to test-papers.

B. **$BaCl_2$**, white ppt. of Barium sulphate, $BaSO_4$, insoluble in HCl. If HCl has produced no reaction, $BaCl_2$ gives a ppt. of $BaSO_4$.

$Pb2C_2H_3O_2$, white ppt. of $PbSO_4$.

Any ordinary Sulphate when fused on charcoal with Na_2CO_3, in the inner blowpipe-flame, gives a Sulphide, causing a brown-black stain of Silver sulphide when laid on a clean Silver coin, and moistened.

Free Sulphuric acid, H_2SO_4, an oily liquid, volatile with white suffocating fumes. Heats with water. When dilute, acid to test-paper, effervescence with Na_2CO_3, no ppt. HCl no reaction. $BaCl_2$, white ppt. of $BaSO_4$, insoluble in HCl. No residue on Platinum, but concentrates to an oily drop, moving towards cooler parts and volatilizing as white, pungent acid. A drop of the dilute Acid on filter-paper, heated over flame, chars the paper. *Prep.* of Sulphuric acid: $SO_2 + H_2O + N_2O_3 = H_2SO_4 + 2NO$. Then $2NO + O = N_2O_3$; and so on.

Selenates resemble sulphates.

B. $BaCl_2$, white ppt. of $BaSeO_4$, insoluble in HCl; when this mixture boiled, Cl_2 evolved, and then H_2SO_3 separates red Selenium. The original solution, on charcoal, in blowpipe-flame, gives off odor of horse-radish.

Silico-fluorides, for the most part insoluble in water.

B. $BaCl_2$, ppt. white BaF_2, SiF_4, insoluble in HCl.

KCl, ppt. white $2KF, SiF_4$: gelatinous.

Salts heated with H_2SO_4 corrode Glass.

Silico-fluoric acid, $2HF, SiF_4$, colorless, acid. Effervesces with Na_2CO_3.

B. $BaCl_2$ and also KCl produce precipitates. NH_4OH separates Silicic acid.

On Platinum, volatilizes as 2HF and SiF_4; therefore etches Glass.

XV. Ortho-phosphates. Colorless. Mostly insoluble. Acid, alkaline or neutral. The common salt, soluble, Na_2HPO_4, $12H_2O$, alkaline. Microcosmic salt, $NaHNH_4PO_4,4H_2O$. Salts of alkaline metals alone soluble in water.

B. $BaCl_2$, white ppt. of $BaHPO_4$, soluble in HCl.

$AgNO_3$, canary-yellow ppt. of Silver ortho-phosphate, Ag_3PO_4, soluble in NH_4OH and in HNO_3.

$HCl+H_2S$, no reaction (not an arsenite).

$Pb2C_2H_3O_2$, white ppt. Pb_32PO_4, soluble in HNO_3.

$CaCl_2$, white Ca_32PO_4, soluble in acetic acid.

Fe_2Cl_6, white ppt. $FePO_4$, soluble in the test, insoluble in Acetic acid.

$MgSO_4$, after addition of NH_4Cl+NH_4OH, white, crystalline ppt. of $MgNH_4PO_4,6H_2O$. This ppt. is changed by heat, into Magnesium pyro-phosphate, $Mg_2P_2O_7$, Water and Ammonia.

Ammonium molybdate in HNO_3, by heat, a yellow ppt. containing Ammonic ortho-phosphate. (*Arsenates* give similar reaction.)

Orthophosphoric acid, H_3PO_4, syrupy liquid.

Very acid, even dilute. Na_2CO_3, effervescence without ppt.

By heat, into clear glass of Metaphosphoric acid, HPO_3.

B. **$BaCl_2$**, no ppt. till neutralized by NH_4OH.

Pyrophosphates, like orthophosphates, as to insolubility. Boiled with dilute mineral acids into orthophosphates, and detected as under.

B. $BaCl_2$, white ppt. of $Ba_2P_2O_7$, soluble in HCl.

$AgNO_3$, white, gelatinous $Ag_4P_2O_7$. Precipitate boiled and evaporated with little Nitric acid, in which it readily dissolves, and carefully neutralized with NH_4OH, a yellow ppt. of Ag_3PO_4.

Magnesium ammonium orthophosphate, $MgNH_4PO_4,6H_2O$, by heat into Water, NH_3 and Pyrophosphate of Magnesium $Mg_2P_2O_7$.

Pyrophosphoric acid, $H_4P_2O_7$, on evaporation, loses Water, and becomes Metaphosphoric acid.

Metaphosphates, like Ortho- and Pyro-phosphates, as to insolubility.

B. $BaCl_2$, white $Ba2PO_3$, soluble in HCl.

$AgNO_3$, white $AgPO_3$, soluble in HNO_3 and in NH_4OH. When $AgPO_3$ is just dissolved in HNO_3, and boiled for a few seconds, NH_4OH carefully added, gives yellow ppt. of Orthophosphate. Acidulated with Acetic acid, HPO_3, precipitates albumen. By boiling with mineral acids into Orthophosphoric acid, and easily distinguished by NH_4OH, $NH_4Cl,+MgSO_4$.

Metaphosphoric acid, acid, fusible to clear glass. Very soluble; effervesces with Na_2CO_3.

Phosphites of alkaline metals soluble: others with difficulty.

B. $BaCl_2$, white ppt., soluble in HCl.

$AgNO_3$, white ppt., by heat into metallic silver.

$Hg2NO_3$, white ppt., by heat into metallic mercury.

CaH_2O_2, white ppt. of phosphite.

$CaCl_2$, white ppt., soluble in Acetic acid.

H_2SO_3, with separation of S, changes Phosphorous into Orthophosphoric acid.

Phosphorous acid, $P(OH)_3$. Very acid. Slowly absorbs Oxygen, and reduces salts of Ag, Hg and Au.

When heated, into Phosphoric acid and Phosphine. Thus: $4P(OH)_3 = 3H_3PO_4 + PH_3$.

Fluorides of alkaline metals soluble.

B. *$BaCl_2$*, white ppt. soluble in HCl.

$CaCl_2$, white, gelatinous CaF_2, nearly insoluble in HCl.

$AgNO_3$, no ppt., as AgF soluble.

Heated with H_2SO_4, fumes of HF, which etch glass.

Hydrofluoric acid, HF, very acid even when very dilute. Prep. $CaF_2 + H_2SO_4 = CaSO_4 + 2HF$. Etches glass. Action upon SiO_2. $4HF + SiO_2 = SiF_4 + 2H_2O$. Water decomposes Silicon fluoride into Silico-fluoric acid and Ortho-silicic acid: $3SiF_4 + 4H_2O = 2(2HF,SiF_4) + H_4SiO_4$.

XVI. Arsenites of alkaline metals alone soluble in water. Alkaline reaction. K_2HAsO_3, the chief soluble salt. In strong solutions of Arsenites, HCl may give a white ppt. of Arsenious anhydride, As_2O_3, soluble in excess.

N.B. Arsenites will be indicated in Group II., in the search for Metals by $HCl+H_2S$ (p. 18).

$HCl+H_2S$, bright yellow ppt. of As_2S_3, soluble in NH_4OH, in $(NH_4)_2CO_3$, and, when free from acid, in $(NH_4)_2S$, forming Sulpharsenite of ammonium. As_2S_3 is insoluble in HCl.

B. **$BaCl_2$**, white ppt. of $BaHAsO_3$, soluble in HCl.

$AgNO_3$, yellow ppt. Ag_3AsO_3, soluble in NH_4OH, and in HNO_3.

$CuSO_4$, green ppt. $CuHAsO_3$, Scheele's green.

Arsenious acid, H_3AsO_3, in solution in water is faintly acid. Very little soluble. No visible reaction with Na_2CO_3. On evaporation, white residue, completely volatile with lavender color to flame.

HCl no reaction.

$HCl + H_2S$, bright yellow ppt. of As_2S_3, soluble in NH_4OH.

$BaCl_2$, no reaction until drop of NH_4OH added; then white ppt. of $BaHAsO_3$.

$CuSO_4$, no reaction until drop of NH_4OH, forming an Arsenite, gives Scheele's green, Cupric arsenite, $CuHAsO_3$, as a ppt.

$AgNO_3$, slight clouding, with yellow ppt. of Arsenite Ag_3AsO_3 on addition of drop of NH_4OH. ppt. is sol. in HNO_3, and in NH_4OH.

Marsh's test applies to Arsenious acid and Arsenites; Mg or Zn, in presence of dilute sulphuric acid, yields Arsine AsH_3, burning with bluish-white flame to H_2O, and Arsenious oxide As_4O_6. If incompletely burnt, Arsenicum is deposited on a cold surface, soluble in Chloride of lime. Also filter-paper, moistened with $AgNO_3$, may be suspended in a test-tube over escaping AsH_3, and there will be a black deposit of Silver upon the paper. $AsH_3 + 6AgNO_3 + 3H_2O = 6HNO_3 + 6Ag + H_3AsO_3$.

Reinsch's test applies to both. HCl first added, and then strips of pure clean Copper to solution in Test-tube, and boiled; a steel-grey deposit of Cu_3As_2. The metal with Alloy withdrawn, washed, dried in water-bath, heated in glass tube, As_2O_3, sublimed in octahedra.

On Charcoal, mixed with Na_2CO_3, in oxydizing flame, a garlic odor, and bluish-white flame.

Heated with black flux in narrow glass tube closed at one end, Arsenicum As_4 volatilizes: $2As_2S_3 + 6K_2CO_3 + 6C = 6K_2S + 6CO + 6CO_2 + As_4$.

XVII. Arsenates. Those of the alkaline metals soluble, colorless. Chief Salt, Di-sodium hydrogen arsenate $Na_2HAsO_4,12H_2O$: alkaline.

$HCl + H_2S$, no reaction till evaporated to within a drop or so; then H_2S again, when $As_2S_3 + S_2$, soluble in NH_4OH.

B. *$BaCl_2$*, white ppt. of Ba_32AsO_4, soluble in HCl.

$AgNO_3$, liver-brown ppt. Ag_3AsO_4, soluble in HNO_3, and in NH_4OH.

$CuSO_4$, greenish-blue, $CuHAsO_4$, soluble in NH_4OH to deep blue.

$NH_4Cl + NH_4OH + MgSO_4$, white, cryst. ppt. $MgNH_4AsO_4,6H_2O$.

Molybdate in HNO_3, on heating yellow ppt. P. 42.

Reinsch's and Marsh's tests, on charcoal as with XVI.

Some arsenates, such as $FeAsO_4$, give no distinct mirror of As_4, with Na_2CO_3 and charcoal when heated.

Arsenic acid, H_3AsO_4, is very deliquescent. Very strong acid, effervescence with Na_2CO_3. By heat into $(As_2O_3)_2,H_2O$ and O_2; volatile. $AgNO_3$, red-brown ppt. of Ag_3AsO_4.

B. **$BaCl_2$**, no ppt. till neutralized; then white Arsenate.

$CuSO_4$, no ppt. till neutralized; then greenish-blue ppt.

XVIII. Borates. Salts of alkaline metals soluble. Colorless. Chief salt, Borax, $Na_2B_4O_7,10H_2O$; alkaline reaction. All Borates somewhat soluble; easily in acids, and salts of Ammonium.

B. *$BaCl_2$*, white ppt. $Ba2BO_2$, soluble in HCl.

$CaCl_2$, white ppt. $Ca2BO_2$, soluble in NH_4Cl, and in Acetic acid.

$AgNO_3$, white ppt. $AgBO_2$, soluble in HNO_3, and in NH_4OH.

Intumesces when heated on Platinum, fuses, yellow color to flame, if Sodium bi-borate; moistened with H_2SO_4 and re-heated, green color to flame.

HCl to a Borate, then turmeric paper dipped in; on drying, the latter red-brown, and the stain blued by soda.

Boracic acid, HBO_2,H_2O, in white scales, fusible. Green color to flame. Turmeric paper browned.

B. *$BaCl_2$*, no reaction till NH_4OH added: then white ppt.

$CaCl_2$, no reaction.

$AgNO_3$, no reaction.

Iodates. Alkaline soluble. Deflagrate on Charcoal.

HCl, brown I_2, soluble in Chloroform with amethystine color, and with starch, dark-blue iodide.

B. *$BaCl_2$*, white ppt. of Barium iodate $Ba2IO_3$, soluble in HCl.

$AgNO_3$, white ppt. of $AgIO_3$, soluble in NH_4OH, and with difficulty in HNO_3.

Sulphurous acid, H_2SO_3, reduces Iodates to Iodine and Hydriodic acid.

By heat into Iodides (p. 49); some evolve Iodine when thus heated, and give off characteristic violet vapors.

Iodic acid, HIO_3, very soluble, reddens and then bleaches litmus Reduced by H_2S, as well as by SO_2, to I_2.

With Morphia (p. 95), Iodic acid is reduced to brown-tint of Iodine, discoverable by Starch-paste which is blued.

Bromates: colorless. Salts of alkaline metals readily soluble. Deflagrate on charcoal. On platinum into bromides. HCl and heat, orange vapors of bromine, soluble with orange color in chloroform.

B. $BaCl_2$, white Barium bromate, $Ba2BrO_3$.

$AgNO_3$, white $AgBrO_3$.

Bromic acid, $HBrO_3$, reddens and bleaches litmus.

HCl separates Br_2, with formation of Chloride of Bromine.

XIX. Chromates. Yellow or yellow-red. Salts of alkaline metals very soluble. Chief salts: K_2CrO_4, yellow; $K_2Cr_2O_7$, yellow-red; $(NH_4)_2Cr_2O_7$, yellow-red. Di-chromates, acid reaction.

Na_2CO_3, with effervescence, changes yellow-red Di-chromate to yellow Chromate.

HCl changes Chromate to yellow-red Di-chromate, and Chromic anhydride. When heated, Chlorine evolved. $K_2Cr_2O_7 + 14HCl = 2KCl + Cr_2Cl_6 + 7H_2O + 3Cl_2$. Solution of Cr_2Cl_6 green.

$HCl + H_2S$ to blue-green, $Cr_2Cl_6 + S_2$. A test for H_2S, P. 40.

B. $BaCl_2$, yellow Barium chromate $BaCrO_4$, soluble in HCl.

$AgNO_3$, crimson Ag_2CrO_4, soluble in NH_4OH and in HNO_3.

$Pb2C_2H_3O_2$, yellow $PbCrO_4$, soluble in KOH.

$CaCl_2$, no ppt., as many Chromates are somewhat soluble.

H_2SO_4 and alcohol, reduce Salts of Chromic acid to blue-green chromic oxide salts. Dichromate of Potassium is much used as an oxydizing agent. Thus for estimating the amount of Iron in solution of a Ferrous salt: $6FeCl_2 + K_2Cr_2O_7 + 14HCl = 3Fe_2Cl_6 + 2KCl + Cr_2Cl_6 + 7H_2O$.

Chromic Anhydride, CrO_3. Acid, in crimson prisms very soluble in water. No ppt. with $BaCl_2$ or with $AgNO_3$.

Alcohol reduces CrO_3 to Cr_2O_3, with violent reaction, and changes the color to blue-green.

XX. Oxalates. Many insoluble. Chief salts: $KHC_2O_4,H_2C_2O_4$. $K_2C_2O_4$. $NH_4HC_2O_4$. $(NH_4)_2C_2O_4$. $Na_2C_2O_4$; colorless. Acid, or alkaline, or neutral.

B. $BaCl_2$, white Barium oxalate, BaC_2O_4, soluble in HCl.

$CaCl_2$, white CaC_2O_4, insoluble in Acetic acid.

$CaSO_4$, white CaC_2O_4, insoluble in Acetic acid.

$AgNO_3$, white $Ag_2C_2O_4$, soluble in NH_4OH, and in HNO_3.

$FeSO_4$, yellow ppt. of Ferrous oxalate, FeC_2O_4.

Heated on platinum into Carbonates, much darkening, and effervescing with HCl. Ammonium salts volatile.

Oxalic Acid, $H_2C_2O_4,2H_2O$, crystallizes in prisms, soluble in eight parts of water. Acid reaction.

Na_2CO_3, effervescence.

B. $BaCl_2$, white ppt. BaC_2O_4, soluble in HCl.

$CaCl_2$, white ppt. of CaC_2O_4, insoluble in Acetic acid.

$CaSO_4$, white ppt. of CaC_2O_4, insoluble in Acetic acid.

CaH_2O_2, white Calcium oxalate, CaC_2O_4.

H_2SO_4, heated with Oxalic acid into $CO + CO_2 + H_2O$. CO may be kindled with blue flame; no darkening of the acid.

On Platinum, heated, white, suffocating, coruscating vapors. Fuses and volatilizes without blackening, or residue.

Tartrates, Citrates, and **Malates** also precipitated white by *B.* $BaCl_2$.

C. Salts, the radicles of which are precipitated by Silver nitrate, $AgNO_3$.

Comprises, besides many of the preceding, the Chlorides, Bromides, Iodides (Cyanides), Ferrocyanides, Ferricyanides, Sulphocyanates of Silver, insoluble in dilute Nitric acid.

XXI. Chlorides. All soluble, except AgCl and Hg_2Cl_2.

$BaCl_2$, no reaction.

C. $AgNO_3$, white, curd-like ppt. of AgCl, soluble in NH_4OH, precipitated therefrom by Nitric acid, and therefore insoluble in Nitric acid. If HNO_3 added first, Bromides and Iodides detected before employment of $AgNO_3$.

Hg_22NO_3, whitish ppt. of Calomel, Hg_2Cl_2, blackened by NH_4OH.

$Pb2C_2H_3O_2$, white $PbCl_2$, soluble in boiling water.

$MnO_2 + H_2SO_4$ to a Chloride, gives off Cl_2, yellow-green, bleaches. Glass-rod, moistened with KI and starch-paste, blued.

If a trace of a Chloride be added to a bead of Sodium metaphosphate containing a trace of CuO, heated in reducing flame, blue flame observed.

Dried Chlorides mixed with $K_2Cr_2O_7$ in powder, and heated with H_2SO_4, give off blood-red drops of CrO_2Cl_2 condensed from its dark-red vapours.

Hydrochloric acid or *Hydrogen chloride,* HCl, is acid, volatile, suffocating. Na_2CO_3, effervescence without ppt. No residue on Platinum. With Nitric acid, on heating, yellow; aqua regia. Chlorine is evolved, with Nitrosyl chloride NOCl, and water.

Fumes with glass-rod dipped in NH_4OH.

$BaCl_2$, no reaction, except in strong acid, when ppt. of Barium chloride $BaCl_2$, soluble in water.

C. $AgNO_3$, white AgCl, soluble in NH_4OH. insoluble in HNO_3

MnO_2 gives off Cl_2 on heating. $4HCl + MnO_2 = MnCl_2 + Cl_2 + 2H_2O$.

Chlorine water, reddens and bleaches litmus. Odorous of Cl_2. $AgNO_3$, white AgCl. Added to a drop of KI, separates I_2 with sherry color to solution, soluble with amethystine color in Chloroform.

XXII. Bromides. Bromides resemble the Chlorides. KBr, the chief salt.

$BaCl_2$, no reaction.

C. $AgNO_3$, yellowish-white Silver bromide, $AgBr$, soluble in much NH_4OH: insoluble in Nitric acid.

Hg_22NO_3, yellowish-white Mercurous bromide, Hg_2Br_2.

$Pb2C_2H_3O_2$, white $PbBr_2$, less soluble than $PbCl_2$.

Cl_2 water, colors a soluble Bromide yellow, or yellow-red, as it sets Bromine free, soluble with orange-color in Chloroform; starch-paste is colored orange.

HNO_3, separates Br_2 on warming a soluble Bromide, either coloring the solution yellow, or even red-brown, with vapors of Br_2 which may condense to blood-red drops.

$AgCl$ by KBr into soluble KCl + insoluble $AgBr$.

Hydrobromic acid, HBr, is acid, colorless, and completely volatile. Soon yellow, by oxydation of H_2, and separation of a little Br_2. Na_2CO_3, effervescence.

$BaCl_2$, no reaction.

c. $AgNO_3$, yellowish-white $AgBr$, soluble in much NH_4OH, insoluble in Nitric acid.

Cl_2 also separates Br_2 and forms $HCl + Br_2$. HNO_3 decomposes it, and separates Br_2.

MnO_2, evolves Br_2.

Bromine water is rich red-brown, odorous of Br_2. Reddens and bleaches litmus. Volatilizes without residue. H_2S gives colorless HBr and S_2. Starch-paste, orange. Chloroform added, gives rich orange color. $AgNO_3$, yellowish-white $AgBr$.

XXIII. Iodides: many insoluble. Of alkaline metals, very soluble. KI the chief salt: faintly alkaline.

$BaCl_2$, no reaction.

C. $AgNO_3$, pale yellow ppt. of Silver iodide AgI, insoluble in Ammonia, as well as in HNO_3.

$HgCl_2$, scarlet ppt. of HgI_2, soluble in excess.

Hg_22NO_3, finch-green Mercurous oxide, Hg_2I_2.

Cl_2 water separates I_2, which gives sherry color to liquor. Shaken with Chloroform, the latter becomes amethystine. Excess of Cl_2 forms ICl_3, colorless.

Heated with MnO_2 and H_2SO_4, Iodine evolved, which colors blue a glass-rod dipped into more starch-paste.

Mixed $CuSO_4 + FeSO_4$, white ppt. of Cuprous iodide, Cu_2I_2.

HNO_3, separates I_2 as a characteristic solid deposit like Graphite, volatile with violet vapor, condensing to solid I_2.

Bead of $NaPO_3$ colored with CuO, heated on Platinum wire with an Iodide, imparts green color to reducing flame.

Hydriodic acid, HI, acid, volatile. Browns rapidly by oxydation of H_2 to H_2O, and separation of I_2. Free iodine always detectible, except when quite freshly made. Na_2CO_3, effervescence, and combines with free I_2.

c. $AgNO_3$ pale-yellow ppt. of Silver iodide AgI, insoluble in NH_3 and in HNO_3.

Solution of I_2 in water, sherry-colored. Smells of I_2. No residue, but violet vapor when heated. Decolorized by $2H_2S = 4HI + S_2$. Shaken with Chloroform, colored amethyst by I_2. Bleached by Cl_2. Starch-paste blued.

Cyanides. See **IX.**

c. $AgNO_3$, white, curd-like ppt. of Silver cyanide, $AgCN$, soluble in NH_4HO, and in strong boiling HNO_3. In soluble Cyanides, the ppt. re-dissolved.

XXIV. Sulphocyanates. Chief salts: $KNCS$ and NH_4NCS. Colorless. Slightly alkaline. Fe_2Csy_6, blood-red, very soluble.

c. $AgNO_3$, white, curd-like $AgNCS$, soluble in NH_4OH and in $KNCS$; not in dilute HNO_3.

Fe_2Cl_6, blood-red solution of $Fe_2(NCS)_6$, decolorized by KOH, by $HgCl_2$: not by HCl. Zn and H_2SO_4, evolve H_2S and decolorize.

$Pb2C_2H_3O_2$, white $Pb2Csy$, very soluble in Acetic acid.

$CuSO_4$, black ppt. $Cu2Csy$, changing to white Cu_22Csy: changed at once by added $FeSO_4$.

Boiled with HCl, pungent Sulphocyanic acid evolved.

XXV. Ferrocyanides. Chief salt, $K_4FeCy_6,3H_2O$: lemon-yellow. Solution yellow. Na_2CO_3, no reaction.

HCl may ppt. white, or bluish-white H_4FeCy_6, very soluble in water.

$BaCl_2$, white ppt. of BaK_2FeCy_6.

c. $AgNO_3$, white Ag_4FeCy_6, not soluble in dilute Ammonia, or dilute HNO_3.

Fe_2Cl_6, ppt. Prussian blue, $2Fe_2Cy_6,3FeCy_2,18H_2O$, insoluble in HCl.

$CuSO_4$, ppt. claret-colored Cu_2FeCy_6

$FeSO_4$, free from Ferric, white or blue-tinted $K_2Fe_2Cy_6$.

Distilled with dilute H_2SO_4, evolve HCN.

XXVI. Ferricyanides. K_3FeCy_6 chief salt; colored brown-red.

c. $AgNO_3$, orange ppt. of Ag_3FeCy_6, soluble in Ammonium hydrate, but not in dilute HNO_3.

Fe_2Cl_6, only deepens brown color.

$FeSO_4$, ppt. Turnbull's blue, $Fe_2Cy_6,3FeCy_2 = Fe_5Cy_{12}$, insoluble in HCl.

Distilled with dilute H_2SO_4, evolve HCN.

XXVII. Nitroprussides. $Na_2FeNOCy_5,2H_2O$ is the chief salt: ruby-red. A test for soluble sulphides (p. 39), with which a rich violet color.

$BaCl_2$, no reaction.

Fe_2Cl_6, no reaction.

c. $AgNO_3$, pale salmon-colored ppt., insoluble in HNO_3.

$FeSO_4$, salmon-colored ppt.

XXVIII. Acetates. All soluble in water, but $AgC_2H_3O_2$, and $Hg_22C_2H_3O_2$ with difficulty. Salts colorless, or colored. Chief salts: $KC_2H_3O_2$. $KC_2H_3O_2,C_2H_4O_2$. $NaC_2H_3O_2.3H_2O$. $NH_4C_2H_3O_2$. $Pb2C_2H_3O_2,3H_2O$. Basic Lead acetate $Pb2C_2H_3O_2,2PbO$, in Goulard water. Cupric acetate $Cu2C_2H_3O_2,H_2O$.

HCl should have detected Acetic acid by its smell of Vinegar.

$Ba\,Cl_2$, no reaction.

C. $AgNO_3$, shiny, scum-like ppt. of Silver acetate $AgC_2H_3O_2$, easily soluble on boiling. No ppt. in weak solutions.

Hg_22NO_3, white, greasy ppt. of $Hg_22C_2H_3O_2$, soluble on heating.

Fe_2Cl_6, rich red coloration, bright yellow by HCl, owing to re-formation of Fe_2Cl_6.

Heated with Alcohol and H_2SO_4, Acetic ether, $C_2H_5C_2H_3O_2$, recognized by its pleasant odor of apples.

On Platinum, slight darkening; conversion into Carbonates, or Oxides. Potassium acetate $KC_2H_3O_2$ becomes fused K_2CO_3, entirely soluble in water, alkaline, effervesces with HCl.

Acetic acid, $HC_2H_3O_2$, or CH_3COOH. Colorless, odorous of Vinegar. Sharp, pungent. No residue on Platinum. Effervescence with Na_2CO_3: therefore strongly reddens litmus.

C. $AgNO_3$, no reaction.

Fe_2Cl_6, deepens the color, but not much, till neutralized by NH_4OH. Red color changed to yellow by HCl.

XXIX. Formates. All more or less soluble.

c. $AgNO_3$, white $AgCHO_2$, rapidly into grey $Ag_2 + HCOOH + CO_2$.

$Hg_22C_2H_3O_2$, white Hg_22CHO_2, changing to grey Hg.

Fe_2Cl_6, deep red: yellow color by HCl.

H_2SO_4 decomposes formic acid from formates into H_2O and CO, which may be burnt with blue flame.

Formic acid, $HCHO_2$ or HCOOH, colorless, pungent liquid.

The acid of ants. Very acid. Na_2CO_3, strong effervescence. By $H_2SO_4 = H_2O + CO$. No residue on Platinum.

c. $AgNO_3$, no reaction till neutralized.

XXX. Meconates. Salts of alkaline metals colorless. Readily soluble.

c. $AgNO_3$, white ppt. $Ag_3C_7HO_7$, soluble in HNO_3 and in NH_4OH.

Fe_2Cl_6, deep cherry-red coloration, not bleached by $HgCl_2$ (sulphocyanate). nor by little HCl (Acetates), but by much HCl.

$Pb2C_2H_3O_2$, white ppt. of $Pb_32C_7HO_7$ (none with an Acetate, of course).

$CaCl_2$, white ppt. of $Ca_32C_7HO_7$.

Meconic acid, $H_3C_7HO_7,3H_2O$. In scales, sparingly soluble to colorless liquid. Strongly acid. Na_2CO_3, effervescence.

Fe_2Cl_6, deep cherry-red coloration: removed, and prevented, by much free HCl.

c. $AgNO_3$, no reaction till neutralized.

$CaCl_2$, no reaction till neutralized.

$Pb2C_2H_3O_2$, white ppt. of $Pb_32C_7HO_7$.

On Platinum, heated, Meconic acid loses water, melts, inflames, leaving coaly residue which burns away.

D. Salts, the radicles of which are precipitated by calcium chloride, $CaCl_2$, either at once (oxalates, tartrates, or urates), or on heating (citrates and malates).

Includes (besides XX., Oxalates), Tartrates, Citrates, Malates, and Urates.

Oxalates, XX., p. 48.

XXXI. Tartrates. Neutral Tartrates of alkaline metals soluble; Cream of tartar, $KHC_4H_4O_6$, and Ammonium hydrogen Tar trate $NH_4HC_4H_4O_6$, with difficulty. $KNaC_4H_4O_6,4H_2O$ is Rochelle salt: very soluble. $2(KSbOC_4H_4O_6),H_2O$ is Tartar emetic.

HCl, in solution of neutral Tartrates of K and NH_4, a white, crystalline ppt. of $KHC_4H_4O_6$ or of $NH_4HC_4H_4O_6$, readily soluble in excess of HCl.

HCl, a white ppt. in solutions of Tartar emetic, $KSbOC_4H_4O_6$, of Antimonous oxy-chloride, $SbOCl$, soluble in excess as $SbCl_3$, and precipitated as orange-red Sb_2S_3, by H_2S.

Fe_2Cl_6, no precipitate. $BaCl_2$, white ppt. soluble in HCl.

D. $CaCl_2$, immediate white ppt. of $CaC_4H_4O_6$, soluble in KOH when freed from $CaCl_2$, by washing. $CaC_4H_4O_6$ heated with NH_4OH, and a crystal of $AgNO_3$, a beautiful mirror of silver.

K_2SO_4, on stirring, a white crystalline ppt. of $KHC_4H_4O_6$.

$AgNO_3$, white ppt. of Tartrate, soluble in NH_4OH, and in HNO_3. Easily reduced.

Heated on Platinum, they carbonize, with smell of burnt sugar: leave Carbonates, Oxides or Metal. The soluble salts of K_2 and Na_2 leave K_2CO_3 or Na_2CO_3. The ash alkaline, and perfectly soluble: if of K_2, violet color to flame, and with HCl effervescence, and the $2KCl$ precipitated by $PtCl_4$ as $2KCl,PtCl_4$.

Tartaric acid, $C_2H_2(OH)_2(COOH)_2$, in colorless, oblique-rhombic prisms, very soluble. Very acid. Effervescence with Na_2CO_3.

CaH_2O_2, white ppt. of Tartrate, when Lime in excess, soluble in Acetic acid.

KOH, white crystalline $KHC_4H_4O_6$, when acid in excess.

NH_4OH, white crystalline ppt. when acid in excess.

H_2SO_4, boiled with Tartaric acid, decomposes it, blackens from Carbon, and CO evolved, then SO_2.

On Platinum, it fuses, becomes yellow like Sucrose, browns, gives off burnt sugar smell, burns with flame, carbonizes, and the C burns away in outer flame.

XXXII. Citrates. Many soluble. Neutral, alkaline, or acid.

HCl, no reaction.

Fe_2Cl_6, no reaction.

$BaCl_2$, white ppt. soluble in HCl.

D. $CaCl_2$, no ppt. till boiled. Insoluble in KOH.

$AgNO_3$, white citrate, soluble in NH_4OH and in HNO_3. Does not darken on heating.

$Pb2C_2H_3O_2$, white Citrate of Lead, very soluble in NH_4OH.

On Platinum, with carbonization, into Carbonates, Oxides, or Metals.

Citric acid, $C_3H_4OH(COOH)_3 = C_6H_8O_7$. Colorless, oblique-rhombic prisms, very soluble. Acid reaction. Effervescence with Na_2CO_3.

Ferric chloride only brightened in color.

CaH_2O_2, no ppt. at all, even in excess, until boiled for a minute or more. Lime-water must be fresh, and litmus blued before boiling.

D. $CaCl_2$, no ppt. till neutralized and boiled.

$AgNO_3$, no reaction till neutralized.

H_2SO_4 and heat, dissolves Citric acid, with copious evolution of inflammable CO. Solution only yellow.

On Platinum fuses, and gives off suffocating fumes; but *burns* quietly and inoffensively.

XXXIII. Malates. Solutions colorless.

$BaCl_2$, white ppt., soluble in HCl.

Fe_2Cl_6, no ppt.

D. $CaCl_2$, no ppt. till alcohol added, or heated in strong solutions.

CaH_2O_2, no precipitate, even on boiling.

$AgNO_3$, white ppt. of $Ag_2C_4H_4O_5$, soluble in NH_4OH and in HNO_3. Becomes grey on boiling.

$Pb2C_2H_3O_2$, white, crystalline Lead malate $PbC_4H_4O_5$, fusible in hot water, resembling resin.

Malic acid, $C_2H_3OH(COOH)_2 = C_4H_6O_5$. White, indistinctly crystalline. Very deliquescent. Strongly acid. Effervescence with Na_2CO_3.

CaH_2O_2, no reaction possible.

Ferric chloride Fe_2Cl_6, brightened in color.

D. $CaCl_2$, no reaction till neutralized, and after addition of Alcohol.

$Pb2C_2H_3O_2$, white, crystalline, fusing like resin under water.

$AgNO_3$, no reaction till neutralized.

H_2SO_4, heated with Malic acid or Malates, browns and blackens: CO evolved.

On Platinum it fuses, and gives off pungent acid vapors, with frothing effervescence: burns away.

Heated carefully in a dry test-tube, Malic acid melts: Maleic acid $C_4H_4O_4$, volatilizes, and solid Fumaric acid $C_4H_4O_4$, remains.

N.B. *Lime-water distinguishes these four acids, Oxalic, Tartaric, Citric and Malic.*

Two or three drops of lime-water precipitates white Oxalate, insoluble in Acetic acid. Lime-water in excess, precipitates white Tartrate, soluble in Acetic acid. Lime-water in excess, precipitates white Citrate only after boiling for some time. Lime-water no visible effect upon Malic acid under any conditions.

XXXIV. Urates. Only of alkaline metals somewhat soluble. Strongly alkaline.

HCl precipitates white powder of Uric acid, $C_5H_4N_4O_3$, insoluble in excess.

D. $CaCl_2$, white ppt. of urate, decomposed by HCl with separation of white Uric acid.

Uric acid, $C_5H_4N_4O_3$. White powder. Insoluble in water. Na_2CO_3 dissolves it without effervescence. Dissolved by KOH heated.

Heated with two or three drops of Nitric acid, evaporated to dryness in porcelain basin, gives yellow-red residue, turned purple by NH_4OH (Murexid or Purpurate of ammonium, $C_8H_4(NH_4)N_5O_6$).

On Platinum, when heated, Uric acid carbonizes without flame, and the Carbon burns away. CNH is evolved. There is also a smell as of burnt feathers.

Urate of ammonium evolves $(NH_4)_2CO_3$, when heated with Na_2CO_3.

E. Salts, the radicles of which are discoverable by the Group-test Ferric chloride.

A. Only coloration in presence of Hydrochloric acid.

Ferricyanides, XXVI., p. 51.
E. Fe_2Cl_6. Red-brown coloration.
Sulphocyanates, XXIV., p. 51.
E. Fe_2Cl_6. Deep-blood-red solution. With zinc, H_2S evolved, and solution bleached.

B. A blue precipitate, in presence of HCl.

Ferrocyanides, XXV., p. 51.
E. Fe_2Cl_6. Prussian blue.

C. The red or black coloration disappears on addition of HCl, and solution yellow.

Acetates, XXVIII., p. 51.
E. Fe_2Cl_6. Dark-red coloration.
Formates, XXIX., p. 52.
E. Fe_2Cl_6. Dark-red coloration.
Meconates, XXX., p. 52.
E. Fe_2Cl_6. Deep cherry-red coloration. Large excess of HCl necessary to change the color.

XXXV. Tannates. Of alkaline metals, very soluble. Strongly alkaline. Turn brown in air.
HCl, no visible reaction, as Tannin so very soluble in water.
E. Fe_2Cl_6, blue-black coloration (very finely divided ppt.), yellow by HCl.
$Pb2C_2H_3O_2$, white precipitate.
Gelatin precipitates Tannin, as white Tanno-gelatin.
Tannin or *Tannic acid*, $C_6H_2(OH)_3COO.C_6H_2(OH)_2COOH$. Yellowish powder. Very soluble. Acid reaction. Na_2CO_3, effervescence. Sparingly soluble in ether. Precipitates gelatin.
E. Fe_2Cl_6, blue-black, yellow by HCl.
H_2SO_4, dark brown.
On Platinum, Tannin fuses, blackens and burns away.

XXXVI. Gallates. Colorless. Alkaline to test paper. Turn brown in air.
HCl, minute white crystals of Gallic acid, easily soluble in HCl.
E. Fe_2Cl_6, black, but by HCl, yellow, with ppt. of Gallic acid.
$Pb2C_2H_3O_2$, white ppt. of Gallate.
$AgNO_3$, white ppt. of Gallate, blackened by heat.
Gelatin, no reaction.
Gallic acid, $C_6H_2(OH)_3COOH = C_7H_6O_5$. In delicate, silken needles, soluble in 100 of cold and 3 of boiling water. Reddens litmus. Effervescence with Na_2CO_3.
E. Fe_2Cl_6, black color, yellow by HCl. No precipitate.
Gelatin, no reaction.

Ether, the great solvent.
$Pb2C_2H_3O_2$, white ppt. of Lead gallate.
H_2SO_4, gives magenta color.
On Platinum, when heated, blackens instantly, and slowly burns.

XXXVII. Salicylates. More or less soluble.

HCl precipitates Salicylic acid in tiny white needles, soluble in excess.

E. Fe_2Cl_6, a deep violet color to salts and free acid, decolorized by HCl.

Salicylic acid, $C_6H_4OHCOOH = C_7H_6O_3$, in needles, soluble in 1800 parts of cold water and easily in boiling water.

E. Fe_2Cl_6, deep violet color, not removed by acetic acid.

H_2SO_4 does not darken it. Melts at 155°; into CO_2 and *Phenol* C_6H_5OH, recognised by its odor.

D. A precipitate is occasioned by Ferric chloride in neutral solutions.

Ferric benzoate, bulky, flesh-colored. Ferric succinate is pale cinnamon-colored. Ferric hippurate, cream-colored.

XXXVIII. Benzoates. All more or less soluble.

HCl precipitates Benzoic acid, in white scales, very soluble in ether.

E. Fe_2Cl_6, flesh-colored, bulky ppt. of Ferric benzoate, decomposed by HCl, giving yellow Ferric chloride, Fe_2Cl_6, and scales of Benzoic acid undissolved.

$CaCl_2$, no reaction.

$AgNO_3$, white ppt. of Silver benzoate, sparingly soluble.

Benzoic acid, $C_6H_5,COOH = C_7H_6O_2$. Shiny scales, often odorous of gum benzoin, requiring 200 parts of cold, and 25 of boiling water for solution. Melts at 120°. Easily sublimed. Vapors acrid, irritating. Burns with sooty flame.

H_2SO_4, no blackening.

E. Fe_2Cl_6, no reaction till neutralized.

XXXIX. Succinates. Mostly soluble.

HCl, no visible reaction. (Excludes Gallates, Benzoates, Hippurates.)

E. Fe_2Cl_6, a cinnamon-colored ppt. of Succinate, completely soluble in HCl.

$BaCl_2$, and Ammonia, no ppt. till alcohol added.

$Pb2C_2H_3O_2$, white ppt., readily soluble in Lead acetate.

$AgNO_3$, white precipitate of Silver succinate.

H_2SO_4, slightly browned on boiling.

Succinates, by heat, into Carbonates (blackening) Oxide, or Metal.

Succinic acid, $C_2H_4(COOH)_2 = C_4H_6O_4$. Colorless, inodorous prisms, readily soluble in water. Strongly acid. Effervescence with Na_2CO_3.

E. Fe_2Cl_6, deepened in color.

$BaCl_2$, and Ammonia, a white ppt. after addition of alcohol.

On Platinum, fuses to clear liquid, and burns away with sootless flame. Volatile; can be sublimed. Vapors most irritating.

XL. Hippurates. Colorless. Alkaline.

HCl. white needles of Hippuric acid, easily soluble in boiling water, but separating on cooling.

E. Fe_2Cl_6, cream-colored ppt., decomposed by HCl, separating the acid. $CaCl_2$, no ppt.

$AgNO_3$, white ppt., soluble in NH_4OH.

Hippuric acid, $CH_2NHC_7H_5OCOOH = C_9H_9NO_3$. White needles, requiring 600 parts of cold water for solution.

E. Fe_2Cl_6, no reaction till neutralized.

On platinum, fuses to clear liquid, evolving somewhat of urinous odor: color becomes rich brown-red, and it burns with sooty flame, with coaly residue easily burnt. Evolves CNH.

KOH gives off Benzene and Ammonia.

Boiled with acids, assimilates H_2O, and is changed into Benzoic acid, C_6H_5COOH, and Glycocine, CH_2NH_2COOH.

Sulphides, Sulphites, Thiosulphates, Arsenites, Arsenates, Phosphates and some others, also give **reactions** with $\mathbf{Fe_2Cl_6}$.

F. Salts, the radicles of which are not precipitated, or discovered, by any of the above reagents. Includes ***Nitrates, Perchlorates*** **and** ***Chlorates*** **if the latter has been missed by** A. **HCl.**

XLI. Nitrates. All soluble, except $Bi(OH)_2NO_3$.

HCl, no reaction. But strong HCl evolves Cl_2—which dissolves Gold-leaf, and NOCl which is set free.

$BaCl_2$, no reaction.

Fe_2Cl_6, no reaction.

$AgNO_3$, of course no reaction.

$FeSO_4$ in solution, and H_2SO_4 poured to the bottom of the mixed liquors, there will be a dark-brown coloration ($2FeSO_4,NO$) at the point of junction; increasing on agitation, then disappearing, the solution becoming yellow-red, and red nitrous fumes evolved.

H_2SO_4 and copper-turnings, NO evolved, and copper sulphate in solution: red fumes are evolved: $2NO + O_2 = N_2O_4$.

On Platinum, KNO_3, or $NaNO_3$, fuse with characteristic violet or yellow flames, and by greater heat into a nitrite. This, dissolved, gives green Nitrite with Cupric sulphate, and with Acetic acid, Potassium iodide, and starch, blue iodide of starch.

Nitrates deflagrate on red-hot charcoal.

Nitric acid, HNO_3, is colorless. Very acid to test paper. Na_2CO_3, effervescence. No residue on Platinum. If concentrated, caustic in odor.

HCl, more or less of a yellow, or even orange color, with fumes of Nitrosyl chloride, NOCl, and gaseous Cl_2, dissolving Gold-leaf, bleaching litmus. $3HCl + HNO_3 = 2H_2O + NOCl + Cl_2$.

Sulphindigotic acid bleached, or turned yellow.

Stains wool yellow. Beware of spilling HNO_3 on clothes.

3Cu gives when heated with $8HNO_3 = 3Cu2NO_3 + 4H_2O + 2NO$:

preparation of Nitric oxide. $2NO+O=N_2O_3$; $2NO+O_2=N_2O_4$. Therefore orange fumes in air.

$FeSO_4$, browns. Heat, if necessary.

If Nitric acid very dilute, neutralize with $CaCO_3$, filter, evaporate to dryness, and decompose with mixture of Ferrous sulphate and Sulphuric acid.

Perchlorates.

HCl, added, indigo-solution not bleached.

H_2SO_3, no reducing effect.

On Platinum, fuse, evolve O_2, and into Chlorides (XXIII., p. 49).

Perchloric acid, $HClO_4$, separated from $KClO_4$ by H_2SO_4. White vapors on heating.

Chlorates, VI., p. 41.

RECAPITULATION OF GROUP-TESTS FOR THE ACIDS, IN COMBINATION.

A. Salts visibly, or detectibly (by color or smell, or precipitate) decomposed by Hydrochloric acid.

Comprises: Carbonates, Sulphides, Sulphites, Thiosulphates, Nitrites, Chlorates, Hypochlorites, *Hypobromites*, Cyanides, *Silicates*, neutral Chromates, Acetates, *Titanates, Tungstates, Molybdates*, Arsenites, *Sulpharsenites, Sulpharsenates, Sulphantimonites, Sulphantimonates, Antimonites, Antimonates, Urates, Hippurates, Benzoates, Salicylates, Gallates, Ferrocyanides.*

B. Salts, the Radicles of which form insoluble compounds with Barium chloride.

Includes: Sulphates, Ortho-phosphates, *Pyro-phosphates, Metaphosphates, Phosphites*, Arsenites, Arsenates, Borates, Chromates, Oxalates, Tartrates, Citrates, Malates, *Selenates, Fluorides, and Silico-fluorides.*

C. Salts, the Radicles of which are precipitated by Silver nitrate.

Includes: Chlorides, Bromides, Iodides, Cyanides (A), *Sulphocyanides, Ferrocyanides, Ferricyanides, Nitroprussides*, Acetates (A), *Formates, Meconates.*

D. Salts, the Radicles of which are precipitated by Calcium chloride.

Includes: Oxalates (B), Tartrates, Citrates, *Malates*, and *Urates.*

E. Salts, the Radicles of which are discoverable by the group-test Ferric chloride.

a. Only coloration in presence of HCl. Comprises Ferricyanides (red-brown), Sulphocyanates (blood-red).

b. Blue precipitate in presence of HCl. Ferrocyanides.

c. Red or black color, disappearing on addition of HCl, and solution yellow. Acetates, *Formates*, Meconates, *Tannates, Gallates, Salicylates.* In the case of Gallates and Salicylates, HCl precipitates Gallic and Salicylic acids.

d. A precipitate in neutral solutions, includes: *Benzoates, Succinates,* and *Hippurates.*

F. Salts, the radicles of which are not precipitated, or discovered, by any of the above reagents. Includes Chlorates (A), *Nitrates and Perchlorates.*

APPEARANCES OF THE MORE COMMONLY OCCURRING BODIES.

Metallic lustre more or less marked. The Metals, Graphite, Iodine, many metallic Sulphides, and Arsenides as ores (Lead, Silver, Copper, Iron, Tin, Antimony, Bismuth, Nickel, Cobalt); Ferric, Ferroso-ferric, and Stannic oxides as ores, Manganese peroxide (Pyrolusite, crystallized), anhydrous Ferric chloride.

Black. Most of the above in a finely divided state: the precipitated sulphides of Lead, Iron, Bismuth (brownish), Mercury, Gold, Platinum, Silver, Cobalt and Nickel; Manganese, Nickel, and Cobalt peroxides; reduced Iron, Lead, and Platinum; Ferrous, Ferroso-ferric, Stannous, Mercurous, and Cupric oxides; Lead suboxide, Cupric and other phosphides, Ferric tannate and Ferric gallate (ink).

White or colorless. Salts of the following, unless the acid radicle be colored:—Alkalies and Alkaline earths, Zinc, Tin, Aluminum, Bismuth, Antimony, Cadmium, Silver, Mercury (neutral salts), Lead, and Copper in the Cuprous form. Alkaloids, Sugars, Starches, Glycerine, Alcohol, Urea; if pure. Distilled water. Free acid radicles or Hydrogen salts; except Chlorine, Bromine, Iodine, and Sulphur, Chromic, Bismuthic, Hypochlorous and Nitrous acids. Oxides and Hydroxides of Alkalies, Alkaline earths, Zinc and Aluminum; Plumbic and Cadmic hydroxides; Ferrous and Manganous hydroxides (rapidly changing); Ferric phosphate; most Ferrous salts when anhydrous.

Yellow. Ferric salts (acid), most neutral Chromates, basic salts of Mercury, Silver orthophosphate and arsenite; Sulphur, soluble Persulphides, Cadmic, Arsenious, and Stannic sulphides; Plumbic oxide ("massicot"), Oxychloride ("Turner's yellow"), and iodide; Mercuric oxide (precipitated), Cuprous hydrate, Zinc oxide when heated; Potassio-cobaltous nitrite ("Aureolin"); Bromide of starch; Cadmium, Nickel, Mercuric and Bismuth ferricyanides; Auric oxide and chloride, Ammonio- and Potassioplatinic chlorides.

Pale or Light yellow. Hypochlorous acid, Chlorine water and gas, Silver iodide, precipitated Sulphur, Lead antimonate ("Naples yellow"), Ferrous oxalate, Antimonic anhydride, Tannic acid, Potassium ferrocyanide ("honey yellow"), Mercuric chlorosulphide (changing from white to yellow, orange, red, brown, black).

Green. Cupric chloride, Hydrocarbonate (Malachite), basic Acetate (also blue "verdigris"), Ferricyanide, Arsenite (Scheele's green), Aceto-arsenite (Emerald green); Nickelous hydroxide, most Ferrous and Nickel salts; Chromic oxide, Hydroxide, and salts (also violet); Aurous, Nickelous and Manganous oxides (dark olive); Zinc cobaltate ("Rinman's green," blowpipe test), Cobalt ferrocyanide (dirty green to grey), Mercurous iodide (yellowish), Manganates (intense bluish green, blowpipe test), Nitrous acid (varies), Potassium ferrocyanide solution (yellowish).

Blue. Cupric hydrate, Hydrocarbonate (Chessylite), nitrate, sulphate, acetate, arsenate, &c.; basic and anhydrous Cobalt salts, Cobalt glass ("smalt"), Cobalt aluminate ("Thénard's blue," blowpipe test), Ultramarine, solution of Nickelous hydroxide in Ammonia.

Dark blue. Cupric salts with excess of Ammonia, Fehling's test, Prussian blue, Iodide of starch.

Violet or Purple. Chromic salts (also green), some Cobalt compounds, purple of Cassius (auric stannate); Ferrates and Perchromic acid (unstable); Murexide, solution of I_2 in CS_2 or $CHCl_3$; Iodine vapor.

Crimson. Permanganates, Argentic chromate.

Pink or flesh-colored. Manganous sulphide, chloride, sulphate, &c.; Cobaltous hydroxide and many salts in solution; Magnesium cobaltate (blowpipe test).

Orange. Nitric acid containing Nitrous, Bromine water, Antimonous sulphide, some Chromates and Ferric salts, Zinc and Argentic ferricyanide, Auric chloride (dry), Nitrogen peroxide, Bromine vapor.

Brick-red. Plumbic oxide (litharge) and Chlorosulphide, Arsenic and Phosphorus iodides, Realgar (As_2S_2), Mercurous chromate.

Orange-red. Acid Chromates, some Ferric compounds, Mercuric chromate (yellow at first).

Red. Basic Lead chromate, red Lead, Cinnabar and Vermilion (Mercuric sulphide), Cuprous oxide, Chromic anhydride, Mercuric oxide ("red precipitate"), and Iodide.

Rose-red. Cobalt Salts.

Brown-red. Ferric oxide, Mercuric oxycarbonate ($NaHCO_3 + HgCl_2$), amorphous Phosphorus, solid Potassium ferricyanide, Sodium nitroprusside, Manganic salts (unstable), reduced Copper, Ferric acetate, formate, meconate, and sulphocyanide, Bromine, Chlorochromic acid, CrO_2Cl_2, Cupric ferrocyanide (maroon).

Brown. Reduced Gold, Ferric hydroxide (varies), Plumbic peroxide, Ferric succinate and Urate (reddish), Ferric benzoate (pale), Blende (ZnS), Cadmium oxide, Bismuth iodide and Bismuthic acid, Stannous Sulphide, Silver arsenate, Iodine water (light), Iodine tincture and alkaline triiodides (deep), Platinic chloride and other compounds, neutral Ferric solutions, some oxides of Chromium, Uranium ferrocyanide (dark), Manganous ferricyanide, Cobalt ferricyanide (purple-brown), Mercurammonium iodide (Nessler precipitate), Cupric chromate (orange-brown), solution of Cobalt hydroxide in ammonia (becomes red), Sulphur vapor, plastic Sulphur.

Grey. Precipitated Antimony, Arsenicum, Mercury and Silver; Silver oxide (brown-grey), Cobaltous oxide, Silver antimonide, anhydrous Cupric sulphate.

[Many organic substances may be brown, yellowish, or grey, from impurity.]

USUAL APPEARANCES OF CRYSTALS.

Transparent needles. Oxalic acid (also thicker and more opaque). Magnesium, Zinc, Sodium, Ammonium and Quina sulphates, Calcium chloride (deliquescent) Urea, Calcium sulphate (rather rare), Ammonium nitrate, chloride, and oxalate, Gallic acid (minute), Sodium acetate, Cupric chloride, hydrated Ferric chloride (brown, deliquescent), soluble Succinates, Potassium picrate (yellow), Urea oxalate, [Thein, and many alkaloids.]

Opaque needles. Hippuric acid, Morphia, Strychnia, Magnesium phosphate (minute), Stannous chloride, Lead acetate, Mercuric and Lead chlorides, Potassium permanganate (dark purple), Calcium benzoate, prismatic Sulphur, Potassium nitrate.

Pearly or resinous lustre: (*a*) **needles;** Silver acetate, Aluminum sulphate, Potassium ferricyanide.

(*b*) **Plates or scales;** Benzoic acid and soluble Benzoates, Barium chloride, Boracic acid, Urea nitrate, Potassium ferrocyanide (also massive square tables), Barium hydrate, Cadmium and Lead iodides, Chromic chloride (anhydrous, violet), Potassium chlorate (?), [Croton chloral, Santonine, Leucine, Picric acid (also octahedra), some fatty acids, Cholesterine, Sebacic acid,] Mercurous acetate.

Short, thick crystals: (*a*) **efflorescent;** most Sodium salts, Alums (octahedra), Tartar emetic, Cupric and Ferrous sulphates, Lead acetate, Mercurous nitrate.

(*b*) **deliquescent;** malic, phosphorous and phosphoric acids, zinc acetate, cadmium nitrate, hydropotassic sulphate.

(*c*) **permanent;** Potassium chromate, dichromate, hydro-carbonate, sulphate, binoxalate, &c., Tartaric and Citric acids (if pure), Strontium nitrate, Calc-spar ($CaCO_3$), Rochelle salt (sodio-potassic tartrate), Sucrose, Gypsum, &c.

(*d*) **opaque;** Plumbic nitrate (very marked), Succinic acid, Lactose, Potassium hydrogen tartrate, Mercuric cyanide, Cinchonine salts.

Cubes. Chlorides, Bromides and Iodides of alkaline metals, (cyanides usually in mass), Iron pyrites, FeS_2, Galena, PbS, Fluorspar, CaF_2. Potassium bromide is usually more transparent than the iodide.

Substances commonly met with in masses, cakes, or lumps; fused salts generally, especially the following:—

Structure pearly flakes: pure Sodium and Potassium hydroxides, Potassium and Sodium acetates. **Fibrous**: Ammonium chloride. **Granular crystalline**: Aluminum sulphate, Mercuric chloride, Potassium disulphate, fused Calcium chloride, Glucose, Camphor, Silver nitrate (sticks), Potassium nitrate ("sal prunella," sticks or balls, "glob. prunel."), roll Sulphur. These may also appear amorphous.

Amorphous: (*a*) **opaque**; Arsenious anhydride, common caustic Potash and Soda (sticks or cakes), fused Antimonous sulphide (dark-brown), Potassium cyanide and nitrite, Manganates (dark green), Silicates, Zinc chloride (deliquescent sticks), Barium oxide.

(*b*) **transparent**; glacial Phosphoric acid (deliquescent sticks or lumps), Quartz and mixed Silicates (glass), Phosphorus (waxy, becomes opaque white, yellow, orange, red), Sucrose in the form of barley sugar, [Gelatine, soluble Albumen, Gums, Resins, &c.]

Gelatinous or flocculent bodies (Colloids). Hydric and many other silicates, most precipitates from solutions of aluminum, iron, chromium, manganese, nickel, and cobalt salts, potassium and barium silicofluorides, calcium fluoride, gelatine, albumen, starch when boiled, &c. Many precipitates, at first flocculent, become granular, or even crystalline, by heat, or standing.

Crystalline precipitates. Potassium and Ammonium hydrotartrates, Benzoic, Hippuric, Boracic, Arsenious, Chromic, Uric, Gallic, Salicylic and Picric acids, Ammonio- and Potassio-platinic chlorides, Magnesium and Ammonio - Magnesium phosphates (minute), Plumbic chloride, Bromide, Iodide, and Sulphocyanate, Cuprous chloride, Barium chloride, and nitrate (by strong acids), Silver acetate, Potassic perchlorate, Urea nitrate and oxalate.

Syrupy liquids. Concentrated solutions of very soluble bodies, such as Potassium and Sodium hydroxides, Potassium carbonate, Zinc and Ferric chlorides, Tartaric, Malic and Citric acids, Sucrose, &c.; Glycerine; Phosphoric, Arsenic, Sulphuric and Lactic acids, [Gum, Albumen, Gelatine, &c.]

The above list embraces the substances most frequently met with, including a few characteristic ones out of the range of ordinary analysis, and omitting the majority of bodies enumerated in the table of colors.

The **amorphous powders** are too numerous to specify. Opaque, dead-looking powders are usually insoluble in water. If colored, a heavy metal is generally present. "Scale preparations," such as citrates and tartrates of iron, simulate crystals, but are irregular in form. Substances may be colored yellowish, brownish, &c., by impurity; this is frequently the case with Glucose, Tannin, Alkaloids, Malic, Uric, and Meconic acids. Pulverization generally diminishes color in proportion to the fineness of the division; sometimes the tint is removed or entirely changed. As a rule, colored bodies, if soluble in water, give solutions of the same or similar hue, Ferricyanides being notable exceptions. Lead and Mercuric iodides give colorless solutions, so also do many other bodies in dissolving in acids. The deep blue tint of Ammonio-cupric solutions is removed by Potassium cyanide. The color of precipitates often varies with different circumstances of precipitation.

Fluorescent bodies. Quina salts in solution [Chlorophyll, Aesculin, Eosin, "Paraffin oil," Uranium compounds].

Substances more or less dichroic. Some salts of Chromic oxide, Potassium ferricyanide, Platino-cyanides, Nickel hydroxide in Ammonia, [most Aniline dyes, Indigo,] Prussian blue, Potassium permanganate crystals.

Characteristic odors. Cl_2, Br_2, I_2, SO_2. H_2S, [H_2Se, H_2Te], HCl, HBr, HI, HCN, $(CN)_2$, HF, NO_2, NH_3; PH_3 (stinking fish). As and AsH_3 (garlic); Cl_2O (from Hypochlorites); Acetic, Formic, and Benzoic acids; burnt Sugar (sugars and Tartaric acid, on heating); Burnt feathers (protein compounds by heat); pleasant ethereal (Acetic and Formic ethers, from Acetates and Formates, by heating with Alcohol and H_2SO_4); Aldehyd (from alcohol by $K_2Cr_2O_7$ and H_2SO_4); Alcohol (nearly inodorous when pure), Ether, Chloroform, CS_2, Chloral, and a large number of organic compounds; Acrolein (intensely pungent, from glycerin by $KHSO_4$ and heat; Phenyl isocyanide; pungent odors from Oxalic, Benzoic, Citric and Succinic acids by heat.

II. THE SUBSTANCE IS INSOLUBLE IN WATER.

If the substance is insoluble in water, it is boiled with strong HCl. The following gases may be evolved: CO_2 from a Carbonate; H_2S from a Sulphide; SO_2 from a Sulphite, or Thiosulphate; HCN from a Cyanide; Cl_2 from a Peroxide, or Chromate (turns green); I_2 (violet vapor) from an Iodate; Br_2 (orange) from a Bromate. Many Silicates gelatinize; in such case, evaporate to dryness, ignite gently, and re-dissolve in HCl; SiO_2 remains behind as a white, insoluble powder, while the Basyls pass into solution as Chlorides.

If the main part of the substance has dissolved, filter or decant, boil off any large excess of HCl, dilute with a little water, and proceed with the use of Group-tests as given at pp. 11 and 14.

N.B. If crystals form in the solution on cooling, e.g. Arsenious, Boracic, Benzoic, Hippuric, Uric, and Gallic acids, Lead chloride, Barium chloride, Calcium, Barium, Strontium and Magnesium phosphates and oxalates,—more water should be added.

A yellow residue may be Sulphur, or Tungstic acid: an orange one, with odor of CNH, a Sulphocyanide.

A turbidity, on dilution, indicates Sb or Bi.

If the solution gives a precipitate with NH_4Cl+NH_4OH, a Phosphate or Oxalate may be present, as well as Fe_2, Al_2 or Cr_2. In this case, test the original substance as follows:

a. Heat on platinum foil, treat the ash with HCl; effervescence indicates oxalate; test for the probable basyl Ca, Ba, Sr.

b. To a solution of Ammonium molybdate in HNO_3, add a drop of the HCl solution, and warm,—a yellow precipitate indicates a Phosphate.

c. To a fresh portion of the HCl solution, add sodium acetate in excess: $CrPO_4$, is green, $FePO_4$, and $AlPO_4$ are white and gelatinous. Test for Fe (p. 25); if absent, nearly neutralize another portion with Na_2CO_3 boil with pure KOH and $BaCO_3$ and filter; to the filtrate add HCl in excess, then NH_4OH in excess, and warm,—white gelatinous Aluminum hydroxide will be precipitated. The Barium precipitate on the filter is dissolved in hot dilute HCl, H_2SO_4 added to remove Ba as $BaSO_4$, the solution boiled, filtered, and tested with NH_4Cl, NH_4OH and $MgSO_4$ for the presence of a Phosphate, which will be indicated by a white, crystalline deposit of NH_4MgPO_4, $6H_2O$.

d. If Sodium acetate has produced a precipitate, filter and add to the filtrate NH_4OH: a precipitate indicates excess of $Al_2(OH)_6$, $Fe_2(OH)_6$ or $Cr_2(OH)_6$.

e. If no reaction with Sodium acetate, add Fe_2Cl_6 till solution reddish,—a white precipitate indicates Calcium, Barium, Strontium or Magnesium phosphate; boil till liquid colorless, filter, test the filtrate for these metals (pp. 32, 33). If necessary, the Ferric precipitate can be tested for Orthophosphoric acid, by dissolving in warm HCl, adding Tartaric acid to prevent the separation of Ferric, NH_4OH and then $MgSO_4$ to the clear solution: crystalline ppt. of NH_4MgPO_4 $6H_2O$ occurs, if Phosphate present.

f. Fluorides and Borates of Ba, Sr, Ca and Mg may also be precipitated by NH_4OH; therefore the original substance must be tested on Platinum with H_2SO_4,—a Borate gives green color to flame.

Fluorides evolve HF, which corrodes glass. If either present, add more NH_4Cl and test for Ba, Sr, Ca or Mg.

If insoluble in HCl, boil with HNO_3. Remove nearly all the free acid by evaporation, and test the solution for the various bases under the different Groups.

If insoluble in HNO_3, boil with Aqua regia. Remove free acids, dilute and test. Be careful to remove both HNO_3 and Cl_2, as they decompose H_2S, with deposition of Sulphur.

As regards the examination for the radicle in substances only soluble in acids, indications have already been noted (p. 118).

All Borates are soluble in HCl; on Platinum with H_2SO_4, all Borates give green color to flame.

In the HCl solution, $BaCl_2$ discovers a Sulphate (p. 44); in any Sulphide, the action of Nitric acid would be to create a Sulphate.

In the case of Silicates, evaporate to dryness, ignite and re-dissolve in HCl; Silica SiO_2, remains undissolved.

Phosphates are all decomposed by acids; their detection has been explained at pp. 75, 82.

In the case of an Organic salt, blackening with a residue would occur; dissolve the residue in HNO_3, evaporate, re-dissolve in water, and in the filtrate test for the Base.

If a substance is insoluble in acids as well as in water, various methods must be employed.

Carbon disappears when strongly ignited, and deflagrates with KNO_3.

AgCl, AgBr and AgI melt when heated, and give metallic Silver when heated with Na_2CO_3.

Al_2O_3, is white, infusible, and blued when ignited with $Co2NO_3$. It is unlocked by fusion with $KHSO_4$.

SnO_2 and Sb_2O_5 give malleable or brittle metallic beads, respectively of Sn or Sb, when heated on charcoal with Na_2CO_3. In a platinum capsule they may be reduced by Zn + HCl; Sb will stain the Pt black.
They may also be unlocked by fusion with Na_2CO_3.

Silica and certain Silicates are untouched by acids; heated in the Sodium metaphosphate bead they yield a skeleton of SiO_2.
They can be unlocked by HF; or by fusion with $Ba(OH)_2$; or with 3 times their weight of Na_2CO_3, treatment with HCl, evaporation to dryness, moistening with HCl, and addition of water which leaves SiO_2 undissolved.

If K or Na to be sought for, then $Ba(OH)_2$ must be used.

Fluorides are white: all evolve HF when heated with H_2SO_4, and corrode a watch-glass placed over the Platinum-capsule.

Chromic oxide gives a green bead with Borax. It is best unlocked with a mixture of Na_2CO_3 and KNO_3 yielding soluble yellow Chromate.

Some Alloys are best heated in an atmosphere of Chlorine after admixture with Sodium chloride.

SHORT TABLE FOR DETECTION OF THE BASYL IN A SOLUTION OF A SIMPLE SALT.

Note at once the absence of Arsenites and of Arsenates except of potassium, sodium and ammonium, if Na_2CO_3 produces a precipitate.

Remember the application of $AgNO_3$ as important, not only when solutions alkaline, but also when Na_2CO_3 gives no precipitate, as Arsenates (or even Arsenic acid) will be discovered by a liver-brown (or a rich red-brown) precipitate. Both Arsenious and Arsenic acids are precipitated in Group II. as yellow As_2S_3, but the latter is difficult to produce except on evaporation and re-addition of H_2S, see p. 74. Arsenious and Arsenic acids are included among the Basyls, because they are precipitated by the Group-test HCl + H_2S. The full discovery of them is mentioned at pp. 73, 74, under the Heading of **TESTS FOR ACIDS**, and again at pp. 45, 46.

GROUP-TESTS.	COLOR OF PPT.	CHARACTERS OF PRECIPITATE.	BASYL PRESENT.	CONFIRMATORY TESTS.	REFER TO PAGE
Group I. HCl.	White.	Soluble in NH_4OH.	**Silver.**	KI, pale yellow ppt. $K_2Cr_2O_7$, crimson.	18.
	White.	Insol. in NH_4OH.	**Lead.**	KI, bright yellow. ,, yellow.	15.
	White.	Blackened by NH_4OH.	**Mercurous.**	KI, finch-green. ,, brick-red.	17.
Group II. HCl and H_2S.	Yellow.	Soluble in $(NH_4)_2CO_3$.	**As(ous).**	$AgNO_3$, yellow ppt. $CuSO_4$, green ppt.	45.
a. Sulphides soluble in Ammonium sulphide, after neutralizing with NH_4OH.	Yellow, after concentration.	Insoluble in HCl.	**As(ic).**	$AgNO_3$, liver-brown. $CuSO_4$, light-blue.	46.
	Dull yellow.	Soluble in $(NH_4)_2CO_3$.	**Stannic.**	On charcoal with Na_2CO_3 with blowpipe, metallic beads of tin.	17.
	Orange.	Insoluble in $(NH_4)_2CO_3$ soluble in HCl.	**Antimonous.**	$SbCl_3$, very acid; volatile on platinum with greenish-white flame. Pr. by water, soluble in tartaric acid. Tartar-emetic pr. by HCl, soluble in excess, and then orange by HCl + H_2S.	19.
	Brown.	Insoluble in Ammonium carbonate.	**Stannous.**	$HgCl_2$, white calomel, turning by heat into grey mercury.	20.

GROUP-TESTS.	COLOR OF PPT.	CHARACTERS OF PRECIPITATE.	BASYL PRESENT.	CONFIRMATORY TESTS.	REFER TO PAGE
b. Sulphides insoluble in ammonium sulphide after neutralizing.	Yellow.	Insoluble in Cyanide of Potassium: soluble in dilute HNO_3.	**Cadmium.**	KI, no reaction. Brown incrustation on charcoal.	24.
	Brown-black ppt.	Soluble in dilute HNO_3.	**Bismuth.**	Sols. very acid. Precipitated by water, ppt. increased by Tartaric acid. KI, dark brown. $K_2Cr_2O_7$, yellow ppt., insoluble in KOH.	23.
	Black.	Insoluble in dilute HNO_3.	**Mercuric.**	Precipitated by $HCl + H_2S$, white, yellow, orange, black. KI, scarlet.	23.
	Slate-colored.	Soluble in dilute HNO_3.	**Lead.**	KI, yellow. $K_2Cr_2O_7$, yellow, soluble in KOH.	16.
	Black.	Soluble in KCN, and in dilute HNO_3.	**Cupric.**	Sols. blue or green. KI, grey: I_2, free. Potassium ferrocyanide, maroon ppt Iron precipitates metallic copper.	22.
Group III. $NH_4Cl +$ NH_4OH to fresh portion of original solution.	Dull blue, or greenish, slight ppt.	Changing to red-brown. Some Ferrous generally pr. in this group: not to be mistaken for Cr_2.	**Ferrous,** unless free from Ferric.	Ferrous salts pale green: acid reaction. Potassium ferrocyanide, bluish-white. Potassium ferricyanide, deep blue precipitate.	29.
	Red-brown hydroxide.	Flocculent.	**Ferric.**	Sols. yellow or yellow-red: strongly, acid. K_4FeCy_6, deep blue ppt. K_3FeCy_6, brown-red coloration.	25.
	White hydroxide.	Gelatinous.	**Aluminum.**	Sols. colorless: acid reaction. KOH, white ppt., soluble in excess. Ignited on platinum with $Co2NO_3$, blue.	26.

Group III. (*cont.*) **NH_4Cl +** **NH_4OH**	Pale green hydroxide.	Soluble in excess with rose-color, when heated.	**Chromic.**	Sols. violet-red, or green : acid reaction. KOH, emerald green solution. Ignited on Platinum with Na_2CO_3, into yellow Na_2CrO_4.	27.
Group IV. **NH_4Cl +** **NH_4OH +** **$(NH_4)_2S$.**	Black sulphide.	Soluble in HCl.	**Ferrous.**	Sols. pale green : acid reaction. NH_4OH, ppt. dirty greenish-white, to bluish : somewhat soluble. Potassium ferricyanide K_3FeCy_6, a blue ppt.	29.
	Black sulphide.	Insoluble in dilute HCl.	**Cobalt.**	Sols. pink to red and blue : acid reaction. NH_4OH, blue, basic ppt. sol. in excess, slowly browning. K_3FeCy_6, brownish-red ppt. Borax bead blue.	30.
	Black sulphide.	Insoluble in dilute HCl.	**Nickel.**	Sols. green : acid reaction. NH_4OH, greenish ppt. soluble with plum-color. K_3FeCy_6, a yellowish-brown ppt. Borax bead purple-brown.	30.
	Flesh-tinted sulphide.	Browning on exposure.	**Manganous.**	Sols. pale pink to colorless, acid reaction. NH_4OH, white, considerably soluble, on exposure deep red-brown. K_3FeCy_6, red-brown ppt. Ignited on Platinum with Na_2CO_3, blue-green fused mass.	28.
	White sulphide.	Insoluble in KOH.	**Zinc.**	Sols. colorless, acid reaction. NH_4OH, white, soluble in excess. K_3FeCy_6, brownish-yellow ppt. Ignited, yellow whilst hot, white on cooling : with $Co2NO_3$ ignited, green mass.	28.

GROUP-TESTS.	COLOR OF PPT.	CHARACTER OF PRECIPITATE.	BASYL PRESENT.	CONFIRMATORY TESTS.	REFER TO PAGE
GROUP V. **NH_4Cl +** **NH_4OH +** **$(NH_4)_2CO_3$** to original solution.	White carbonate.		**Barium.**	Sols. colorless. $CaSO_4$ immediate white ppt. Flame yellow-green.	32.
	White carbonate.		**Strontium.**	Sols. colorless. $CaSO_4$ ppt. on heating. Flame crimson.	32.
a. Precipitate.	White carbonate.		**Calcium.**	Sols. colorless. $CaSO_4$ of course no reaction. Oxalate of ammonium, white ppt. Flame yellow-red.	33.
b. No precipitate, but by Na_2CO_3 used at commencement.			**Magnesium.**	Sols. colorless. NH_4OH, white ppt. increased by heat (none with Ba, Sr, and Ca). $NH_4Cl + Na_2HPO_4 + NH_4OH$, white ppt. of $NH_4MgPO_4, 6H_2O$.	33.
GROUP VI. No precipitate with Sodium carbonate or with previous Group tests.			**Ammonium.**	Salts volatile on Platinum, except with fixed acid. No color to flame. Boiled with Na_2CO_3, $(NH_4)_2CO_3$ evolved, fuming with HCl, bluing red litmus, smelling of hartshorn. $2HCl,PtCl_4$ yellow ppt. of $2NH_4Cl, PtCl_4$.	34.
			Potassium.	Violet color to flame: red through blue glass. $2HCl,PtCl_4$ yellow pr. $2KCl, PtCl_4$.	35.
			Sodium.	Strong yellow flame: cut off by blue glass. $2HCl,PtCl_4$, no ppt., as Sodium salt soluble in water.	35.

TABLE OF SALTS AND ACIDS.

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FRESH PORTIONS FOR EACH TEST.
I. a. HCl.	Effervescence with no marked odor.	**Carbonates,** p. 39.	By decanting the gas into Lime-water, a white ppt. of $CaCO_3$. $AgNO_3$, white Ag_2CO_3 soluble in HNO_3 with effervescence. Soluble carbonates, alkaline. *Carbonic acid* in solution turns litmus paper port-wine-red. Leaves no residue on Platinum. Lime-water, white ppt. soluble in excess of original solution.
	Smell of burning brimstone on warming: rarely effervescence from escape of SO_2.	**Sulphites,** p. 40.	Confirm smell of SO_2 by addition of dilute Sulphuric acid to a fresh portion. $AgNO_3$, white ppt., by heat into metallic silver, or grey powder. With Zinc and dilute Sulphuric acid, H_2S evolved, blackening lead-paper, and depositing yellow Sulphur. $BaCl_2$ white ppt. of $BaSO_3$, soluble, if pure, in HCl. *Free acid* H_2SO_3 smells of SO_2; acid reaction; no residue on Platinum. $AgNO_3$ white ppt.
	Red fumes.	**Nitrites,** p. 40.	$AgNO_3$, white ppt. reduced to metallic Silver on boiling. KI + starch paste and Acetic acid, blue Iodide of starch. Solution of permanganate of potassium bleached after addition of acetic acid.
	Smell of bitter almonds.	**Cyanides,** p. 41.	$AgNO_3$ white ppt. AgCy, not soluble in dilute, but in concentrated Nitric acid, and in Ammonia. $FeSO_4$, in Cyanides, red ppt. of $FeCy_2$: then KOH and HCl, Prussian blue. Warmed with Tartaric acid, gives vapors of HCN, whitening a glass rod dipped in $AgNO_3$. Soluble Cyanides strongly alkaline, except HgC_2N_2. *Free acid* CNH, faintly reddens litmus, smells of Prussic acid, no effervescence with Na_2CO_3, no residue. $AgNO_3$, precipitates AgCy.

TABLE OF SALTS AND ACIDS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FRESH PORTIONS FOR EACH TEST.
I. a. (*cont.*) **HCl.**	Smell of rotten eggs and sometimes deposit of S_2.	**Sulphides,** p. 39.	All soluble sulphides alkaline to test-paper. $AgNO_3$, black ppt. Vapors, brown or blacken lead-paper. Nitroprusside of sodium a violet color. *Free acid* H_2S, faintly acid, odorous of rotten eggs, no residue on Platinum.
	Smell of burning Sulphur SO_2, and deposit of yellow Sulphur on heating.	**Thiosulphates,** p. 40.	$AgNO_3$, a white ppt. of $Ag_2S_2O_3$, turning yellow, orange, red and finally to black Ag_2S. Heated on platinum, melt, burn with yellow flame, blue and red tints on platinum. Soluble salts alkaline. *Free acid unknown.*
	Yellow color on warming and yellow-green gas(euchlorine $Cl_2 + ClO_2$) evolved.	**Chlorates,** p. 41.	Vapors by HCl bleach litmus. $AgNO_3$ no reaction. Salts deflagrate on charcoal. Heated strongly on platinum, into chlorides, soluble in water, ppt. by $AgNO_3$ as white AgCl, insoluble in HNO_3, soluble in NH_3.
	White, gelatinous ppt. except in very dilute solutions.	**Silicates,** p. 42.	Solutions strongly alkaline. Acidulated with HCl, evaporated to dryness, leaves a white powder of Silica SiO_2, insoluble. $AgNO_3$ brown ppt. NH_4Cl, white gelatinous ppt. of H_4SiO_4, unless very dilute.
	Smell of vinegar.	**Acetates,** p 51.	All soluble. $AgNO_3$, white ppt. soluble in boiling water: no ppt. in weak solutions. Hg_22NO_3, white scum-like ppt. soluble in much water. Fe_2Cl_6, port-wine color removed by HCl. Heated with H_2SO_4 and alcohol, smell of apples—acetic ether. *Free Acetic acid*, CH_3COOH, smells of vinegar, acid to test-paper, no residue upon platinum. $AgNO_3$ no reaction. Fe_2Cl_6 slight reddening.

	White ppt. of uric acid, insoluble in excess.	**Urates,** p. 54.	Solutions strongly alkaline. Na_2CO_3, no reaction, as only urates of K_2, Na_2 or $(NH_4)_2$, soluble. Evaporated and HNO_3 added in excess, and re-heated, yellow-red, purple by NH_3. *Uric acid*, white powder, insoluble in water and in HCl; soluble in KOH. On Platinum, carbonizes, gives smell of burnt hair, and slowly combusts. HNO_3 on evaporation, yellow-red, purple by NH_3 (murexid).
	Shiny scales, generally smelling of gum benzoin.	**Benzoates,** p. 56.	Fe_2Cl_6, pale salmon-colored ppt. depositing scales of *Benzoic acid* on addition of HCl. Group IV.
	Small needles, dissolved on boiling, and re-crystallizing in long needles.	**Hippurates,** p. 56.	Fe_2Cl_6, pale buff-colored ppt. depositing needles of *Hippuric acid* on addition of HCl. Group IV.
	Tiny needles, readily soluble in excess of Group-test.	**Gallates,** p. 55.	Fe_2Cl_6, blue-black ppt. bleached by HCl, separating *Gallic acid* in needles. Group IV.
	Small needles.	**Salicylates,** p. 56.	Fe_2Cl_6, deep purple color. Group IV.
	White cryst. ppt. readily soluble in HCl.	**Neutral tartrate of potassium or ammonium,** p. 53.	Fe_2Cl_6, no reaction. Group II.
I. b. **HCl** **+** **H_2S.**	Immediate yellow precipitate, soluble in NH_4OH, in $(NH_4)_2CO_3$, and in $(NH_4)_2S$ when neutralized.	**Arsenites,** p. 45.	Soluble salts alkaline. $AgNO_3$ yellow ppt. soluble both in HNO_3 and in NH_4OH. $CuSO_4$, green ppt. of $CuHAsO_3$, Scheele's Green. Boiled with HCl, and strip of copper, grey deposit of Cu_3As_2, Reinsch's test. Lavender color to flame. *Arsenious acid* H_3AsO_3 faintly acid, no reaction with Na_2CO_3, no residue, but lavender color to flame. No ppt. with $CuSO_4$.

TABLE OF SALTS AND ACIDS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FRESH PORTIONS FOR EACH TEST.
I. b. (*cont.*) **HCl** + **H_2S.**	Yellow ppt.	**Arsenious acid,** p. 46.	Slight ppt. with $AgNO_3$. $HCl + H_2S$, precipitates As_2S_3, soluble in NH_4OH. *Arsenious oxide* As_2O_3, white powder, very little soluble in water, volatile with lavender color to flame, soluble in $(NH_4)_2S$, and precipitated as As_2S_3, yellow, by HCl.
	After evaporation of 20 drops nearly to dryness in test-tube, add further H_2S: yellow ppt. of $As_2S_3 + S_2$.	**Arsenates,** p. 46.	$AgNO_3$, liver-brown ppt. of Ag_3AsO_4, soluble in NH_4OH and in HNO_3. $CuSO_4$, light blue ppt. Chief salts alkaline to test-paper. *Arsenic acid* H_3AsO_4, very soluble, very acid, effervescence with Na_2CO_3. Volatilised on platinum with lavender flame as $As_2O_3+O_2$. $AgNO_3$, red-brown ppt. $CuSO_4$, no ppt.
	Solution changes from yellow-red to bluish-green, with deposit of sulphur.	**Chromates,** p. 47.	Neutral Chromates yellow: acid chromates yellow-red. $AgNO_3$, crimson ppt. of Ag_2CrO_4. $Pb2C_2H_3O_2$, yellow ppt. of $PbCrO_4$. $BaCl_2$, yellow ppt. of $BaCrO_4$. H_2SO_4 and alcohol reduce salts of Chromic acid, to Sulphate of chromic oxide, with smell of Aldehyde.
II. a. **$BaCl_2$.**	White precipitate of Barium sulphate $BaSO_4$, insoluble in HCl, and also in HNO_3.	**Sulphates,** p. 43.	All Sulphates soluble, except of Ba, Sr and Pb: therefore soluble salts of Ba, Sr and Pb are tests. Fused with Na_2CO_3, upon charcoal, sulphates are reduced to sulphides, and mass moistened on a silver coin, gives black stain. Free Sulphuric acid, even when very dilute, reddens litmus, effervesces with Na_2CO_3,

N.B.—Radicles of many Salts in Group I., as Carbonates, Sulphites, Thiosulphates, Silicates, Arsenites, Arsenates, and Chromates also give precipitates, respectively, of Barium carbonate, sulphite, thiosulphate, silicate, arsenite, &c., with Barium chloride, soluble in HCl. Sulphites always contain Sulphates. The following acids, in soluble salts of Group II., also give a precipitate with Barium chloride. We use now further Calcium chloride $CaCl_2$ as a Group-test.

II. a. (*cont.*) **$BaCl_2$.**		**Sulphates** (*cont.*).	is precipitated by $BaCl_2$, and the ppt. is insoluble in HCl. A drop of the free acid, though dilute, chars blotting-paper when heated. Sets free Nitric acid from Nitrates.
	White ppt. of BaF_2.	**Fluorides,** p. 45.	Heated with H_2SO_4, fumes of HF which etch glass. $CaCl_2$ gives white ppt. of CaF_2. Nitrate of silver no ppt. as AgF soluble.
II. b. **$CaCl_2$.**	White ppt. soluble in acetic acid, insoluble in NH_4Cl, and in cold KOH.	**Ortho-phosphates,** p. 44.	Phosphates of alkaline metals soluble. $AgNO_3$, yellow ppt. of Ag_3PO_4, soluble in HNO_3 and in NH_4OH. *No reaction with* $HCl + H_2S$*:* distinguished from arsenites. $CuSO_4$, pale blue ppt. Ammonium molybdate in HNO_3, yellow ppt. on heating. $NH_4Cl + NH_4OH + MgSO_4$, white, crystalline ppt. of $MgNH_4PO_4, 6H_2O$. *Free phosphoric acid*, strongly acid, effervescence with Na_2CO_3, glassy residue on platinum.
	White ppt. soluble in acetic acid and in ammonium chloride NH_4Cl. Insoluble in cold KOH.	**Borates,** p. 47.	Borates of alkaline metals the chief soluble. Borax $Na_2B_4O_7, 10H_2O$, chief salt: alkaline. $AgNO_3$, white ppt. soluble in HNO_3 and in NH_4OH. With H_2SO_4 on Platinum, green color to flame. Acidified with HCl, and evaporated on turmeric paper, gives red-brown stain, blued by KOH. *Free Boric acid* HBO_2, H_2O, faintly acid, no effervescence with Na_2CO_3, green color to flame, glassy residue on Platinum. Red-brown at once to turmeric. $AgNO_3$, no reaction. $CaCl_2$ none. $BaCl_2$ none, till neutralized.
	White ppt. insoluble in acetic acid or in NH_4Cl, or in KOH.	**Oxalates,** p. 48.	Scarcely char on Platinum, when heated: carbonates left. Evaporated to dryness, and heated with H_2SO_4, CO_2 and CO, evolved, without darkening: CO burns with blue flame. Lime-water, white oxalate. **Oxalic acid** reddens litmus; effervescence with Na_2CO_3. Lime-water immediate white ppt. insoluble in acetic

TABLE OF SALTS AND ACIDS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FRESH PORTIONS FOR EACH TEST.
II. b. (*cont.*) **$CaCl_2$.**	White ppt. insoluble in Acetic acid.	**Oxalic acid,** p. 48.	acid. H_2SO_4 heated, gives CO and CO_2. Suffocating vapors, with white coruscations, and no residue, when heated on Platinum, if quite pure.
	White ppt. soluble in acetic acid, and, when well washed, in KOH.	**Tartrates,** p. 52.	Char with burnt-sugar odor, when heated on Platinum: carbonates generally left. Evaporated and heated with H_2SO_4, blacken, with evolution of CO and CO_2. Calcium tartrate, a crystal of $AgNO_3$, addition of NH_4OH, and heat, a mirror of Silver. KOH and Acetic acid in excess, on shaking, cryst. ppt. of hydro-Potassic tartrate. **Tartaric acid,** reddens litmus, effervescence with Na_2CO_3. Lime-water, in excess, white ppt. of tartrate, soluble in Acetic acid, but $CaCl_2$ no reaction till neutralized. KOH or NH_4OH, white, cryst. ppt. if acid kept in excess. On Platinum, fuses, turns yellow, smells of burnt sugar, inflames, carbonizes, and entirely burns away. In sols. of neutral Potassium and Ammonium tartrate, HCl gives white cryst. ppt. of acid salts of K and NH_4.
	White ppt. *when heated*, soluble in Acetic acid, soluble in NH_4Cl, insoluble in cold KOH.	**Citrates,** p. 53.	Char on platinum, evolving irritating fumes: carbonaceous heaps slowly combusting, and generally leaving Carbonates. Evaporated to dryness, and heated with H_2SO_4, with only tinge of yellow, evolves CO, combustible with blue flame. KOH and Acetic acid no precipitate. $AgNO_3$, white ppt. only grey by heat. **Citric acid** reddens litmus, effervesces with Na_2CO_3. Lime-water in excess, on boiling for a

			minute or more, white ppt. of Citrate of calcium. $CaCl_2$ no ppt. until neutralized and heated. Heated with H_2SO_4, torrents of CO, and change to yellow color. On Platinum fuses, gives off suffocating odor, burns quietly, carbonizes, and completely burns away.
	White ppt. only after addition of alcohol, or by heat, in very concentr. solutions.	**Malates,** p. 54.	Char on Platinum. Evaporated to dryness, and heated with H_2SO_4, blacken, and evolve combustible CO. $Pb2C_2H_3O_2$, white ppt. fusing under boiling water. **Malic acid** reddens litmus; effervesces with Na_2CO_3. No reaction with CaH_2O_2. No reaction with $CaCl_2$ till neutralized, and alcohol added. With H_2SO_4 like Tartaric acid. Fused on Platinum, gives off pungent vapors, with frothing effervescence, and burns away.
III. $AgNO_3$.	White, curd-like ppt. of AgCl, soluble in NH_4OH, insoluble in HNO_3.	**Chlorides,** p. 49.	All chlorides soluble in water, except Silver chloride AgCl, and Mercurous chloride Hg_2Cl_2. Lead acetate $Pb2C_2H_3O_2$, white, crystalline $PbCl_2$, soluble in much boiling water. Hg_22NO_3, white ppt. of Hg_2Cl_2, Calomel, blackened by $2NH_3$. Soluble chlorides heated with $MnO_2 + H_2SO_4$, evolve Chlorine as a yellow gas, odorous and bleaching litmus. *Free Hydrochloric acid*, HCl, in solution, is acid, effervesces with Na_2CO_3, leaves no residue: vapors acid. Fumes with NH_3. HNO_3 and heat, becomes yellow, evolves Cl_2 and NOCl, and dissolves Au: also bleaches litmus paper. $MnO_2 + 4HCl = MnCl_2 + Cl_2 + 2H_2O$. Liberated chlorine blues glass rod steeped in starch paste containing KI.
	Yellowish-white precipitate of AgBr, soluble in much NH_4OH, insoluble in HNO_3.	**Bromides,** p. 49.	*All soluble Bromides decomposed by HNO_3, with separation of Bromine with red-brown irritating vapors, sometimes condensing in blood-red drops.* HNO_3, separates Br on heating: glass rod dipped into starch paste, orange color. Chlorine water to a Bromide,

TABLE OF SALTS AND ACIDS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FRESH PORTIONS FOR EACH TEST.
III. (*cont.*) **$AgNO_3$.**	Yellowish - white ppt., p. 49.	**Bromides** (*cont.*).	separates Br_2 with yellow color; soluble with orange color, when solution shaken with Chloroform. With MnO_2 and H_2SO_4, Bromine free. *Hydrobromic acid*, HBr, generally yellow from free Bromine, acid, volatile. HNO_3 separates Br_2 at once. $AgNO_3$ gives AgBr. Chlorine decomposes it: $Cl_2 + 2HBr = 2HCl + Br_2$.
	Light yellow precipitate of AgI, insoluble both in NH_4OH, and in HNO_3.	**Iodides,** p. 50.	*All soluble Iodides decomposed by HNO_3, with separation of solid Iodine, resembling graphite: violet vapors on heating, bluing starch paste on glass rod.* HNO_3, separates I_2 or gives brown color to solution, evolving violet vapors on heating. Chlorine water gives brown color to solution, bluing starch: shaken with chloroform, the latter amethystine from the dissolved Iodine. With MnO_2 and H_2SO_4, Iodine separated. *Hydriodic acid*, HI, always brown from free Iodine. Acid reaction, volatile, and when free I_2 present, violet vapors.
	White precipitate of AgCy, soluble in NH_4OH, and only soluble in concentrated boiling HNO_3.	**Cyanides,** p. 41.	All Cyanides decomposed by HCl. Group I. p. 71.
	White precipitate, insoluble in dilute HNO_3.	**Ferrocyanides,** p. 51.	Group IV., p. 79.

	White precipitate, insoluble in dilute HNO_3.	**Sulphocyanates,** p. 51.	Group IV.
	Orange precipitate, insoluble in dilute HNO_3.	**Ferricyanides,** p. 51.	Group IV.
IV. Fe_2Cl_6.	Red color, changed to yellow at once by dilute HCl.	**Acetates,** p. 51.	See Group I. p. 72. Hg_22NO_3, white scum-like ppt. of $Hg_22C_2H_3O_2$.
	Cherry-red color, removed with greater difficulty by HCl.	**Meconates,** p. 52.	Solution evaporated blackens with H_2SO_4 when heated. $CaCl_2$, white ppt. Lead acetate gives white ppt. Chars on Platinum.
	Deep purple color.	**Salicylates,** p. 56.	HCl, white ppt. of needles. On Platinum burns, blackens slowly, evolving pungent fumes and odor of Phenol, which whitens rod dipped in Bromine water.
	Blood-red color, not removed by HCl, but by $HgCl_2$.	**Sulphocyanates,** p. 51.	With HCl, give smell of HCNS like SO_2, and on warming, H_2S which blackens lead paper. $Zn+H_2SO_4$ dilute, gives also H_2S. On Pt. fuses, burns, evolving SO_2, darkens the Pt, leaves a Sulphate.
	Olive-brown color, not removed by HCl.	**Ferricyanides,** p. 51.	$FeSO_4$ deep blue ppt. H_2SO_4 gives HCN (Group I.). On Platinum burn with scintillations, leaving brown oxide of iron. $AgNO_3$, orange ppt. soluble in NH_4OH, insol. in dil HNO_3.
	Prussian blue.	**Ferrocyanides,** p. 51.	$FeSO_4$, pale blue or white ppt. In strong solutions HCl white ppt. turning blue on exposure. $CuSO_4$, maroon ppt. Dil. H_2SO_4 gives HCN : strong H_2SO_4 on solid, gives CO, combustible with blue flame.

TABLE OF SALTS AND ACIDS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FRESH PORTIONS FOR EACH TEST.
IV. (*cont.*) **Fe_2Cl_6.**	Blue-black precipitate.	**Tannates,** p. 55.	HCl no ppt. in Tannates. Heated with H_2SO_4 or on Platinum, blacken. KOH brown color. Precipitate gelatine from solution.
	Blue-black precipitate.	**Gallates,** p. 55.	HCl ppt. Gallic acid in minute white needles. Same as tannate but does not ppt. gelatine, and HCl does ppt. *Gallic acid*, but little soluble in cold water: easily on boiling.
	Pale buff precipitate.	**Benzoates,** p. 56.	HCl gives cryst. plates of Benzoic acid. Heated on Pt. aromatic pungent fumes and smoky flame. *Free acid* no ppt. with Fe_2Cl_6 till neutralized. Burns completely away: vapors most irritating.
	Pale buff precipitate.	**Hippurates,** p. 56.	HCl in moderately strong solutions of Hippurates gives needles of the free acid. With H_2SO_4 blackens slightly. *Free acid* little soluble. No reaction with Fe_2Cl_6. On Pt. fuses to clear liquid, with urinous odor, turns brown-red, burns with sooty flame, and coaly residue burning away. Soluble in alkalies to form Hippurates.
	Cinnamon-red precipitate.	**Succinates,** p 56.	On Platinum fuse to clear liquid, pungent vapors, and burn away with sootless flame, leaving carbonate, unless free acid or salt of ammonium. $BaCl_2+NH_4OH+$alcohol, white ppt., but not with benzoate. *Free acid* no ppt. till neutralized: effervescence.

	Reddish brown precipitate.	**Hydrates,** p. 2.	$AgNO_3$ grey-brown ppt. sol. in NH_4OH, and in HNO_3.
V.	No precipitate with group-tests.	**Nitrates,** p. 57.	All salts soluble, except trisnitrate of Bismuth. Deflagrate on charcoal. H_2SO_4+Cu, orange-red fumes. $FeSO_4$ first added to small portion in a test tube, then H_2SO_4 poured to the bottom of the liquid, a brown line, where liquids meet. H_2SO_4 separates HNO_3 in the liquid, bleaching sulphindigotic acid. *Free nitric acid* reddens litmus, effervesces with Na_2CO_3, volatilizes on platinum when heated, without residue and with caustic vapors. Decomposes Bromides and Iodides at once: see Bromides and Iodides. With HCl, gold-leaf dissolved, when heated: see Chlorides. Sulphindigotic acid bleached.
		Chlorates, p. 41.	Group I.
		Perchlorates, p. 58.	KCl precipitates $KClO_4$, from perchlorates other than of K. HCl does not evolve Cl_2: no bleaching therefore of indigo solutions as with a chlorate. By heat upon platinum into chloride: then dissolve in water, acidulate with HNO_3, and precipitate AgCl by $AgNO_3$. Deflagrate on charcoal.

ILLUSTRATIONS OF THE ANALYSIS OF SINGLE BASES, SINGLE ACIDS, AND SINGLE SALTS SOLUBLE IN WATER, OR DISSOLVED BY THE SAME ACID.

RECAPITULATION.

DIVISION A. **Carbonate of Sodium** Na_2CO_3, with or without effervescence and usually without the application of heat, gives a ppt. in solutions of Metallic salts.
If no ppt. pass on to Division B.

Group I. **HCl,** a ppt. Pb. Ag. Hg_2. No ppt., pass on to Group II.

Group II. **HCl + H_2S,** a ppt. Pb. in dilute solutions. Sb. Sn. Au. Pt. Hg. Cd. Bi. Cu. No ppt., pass on to Group III.

Group III. **NH_4Cl + NH_4OH,** a ppt. Fe_2. Al_2. Cr_2. No ppt., pass on to Group IV.

Group IV. **NH_4Cl + $(NH_4)_2S$,** a ppt. Fe. Co. Ni. Mn. Zn. No ppt., pass on to Group V.

Group V. **NH_4Cl + $(NH_4)_2CO_3$,** a white ppt. Ba. Sr. Ca. No ppt. Magnesium.

DIVISION B. **Carbonate of Sodium** Na_2CO_3, no precipitate. *a.* On boiling with Na_2CO_3, there is an odor of Ammonia, Litmus is blued, and fumes are formed with Hydrochloric acid: **(NH_4)**. *b.* No reaction. Yellow color to flame. **Na.** Purple color to flame. **Li.** Violet color to flame. **K.** *c.* No reaction: absence of all metals in the form of salts.

1. Solution colorless, inodorous. Strongly alkaline. Carbonate of Sodium no reaction, even on boiling: absence of all metals in Groups I., II., III., IV. and V. The base is either Potash or Soda, or it is a salt of Potash or Soda. Silver nitrate gives a bright yellow ppt., soluble in HNO_3 and in NH_3: it is either a phosphate or an arsenite. HCl + H_2S no reaction: it is not an arsenite, p. 45, but a **phosphate.** Confirmed by tests, p. 44. On Platinum a white fusible residue, yellow color to flame: it is **Soda,** p. 35. The salt is **Sodium orthophosphate.**

2. Solution colorless, inodorous. All the tests as in 1, except that HCl + H_2S gives a bright yellow ppt. soluble in NH_3: it is an **arsenite,** p. 45. On Platinum, a white fusible residue, with violet color to flame. Platinic

chloride gives a yellow ppt. of $2KCl,PtCl_4$. The salt is **Arsenite of Potassium.** Confirm, p. 35.

3. Solution colorless, inodorous. It is neutral. Carbonate of sodium gives no reaction till heated, then an odor of NH_3, litmus is blued when held in upper part of the test tube, and a glass rod dipped into HCl forms white fumes in the tube. It is a salt of **Ammonium,** p. 34, and gives a white residue on Platinum, completely volatile. As Barium chloride gives no reaction, it is not a sulphate. Silver nitrate gives a white curd-like ppt., easily soluble in Ammonia, but insoluble in Nitric acid. It is a **Chloride,** p. 48, and is proved to be **Chloride of Ammonium.**

4. Solution colorless, inodorous, strongly alkaline. Carbonate of sodium no reaction, even on boiling. Absence of all bases in Groups I., II., III., IV. and V.: also of Ammonium in Group VI. It is either Potash KHO, or Soda NaHO, or a salt. Nitrate of silver gives a white ppt., soluble with effervescence in Nitric acid, and also soluble in NH_3: it is a **Carbonate.** p. 39. On Platinum a white residue, fusible, with yellow color to flame. The salt is **Carbonate of Sodium,** p. 35.

5. Solution is colorless, inodorous, strongly alkaline. Carbonate of sodium gives no reaction, even on boiling. The base must be Potassium or Sodium. Silver nitrate gives a grey-brown ppt., soluble in Nitric acid and in Ammonia. The solution contains either caustic Potash or caustic Soda. On Platinum, violet color to flame, fuses. Confirm Potassium by addition of Platinic chloride, which gives a yellow ppt. The grey-brown ppt. of Silver hydroxide with $AgNO_3$, further confirms the presence of Potassium in the form of **Potassium hydroxide** KHO, p. 35.

6. Solution colorless, inodorous, alkaline. Carbonate of Sodium gives no reaction, even on boiling: absence of all bases in all Groups but VI. A salt of **Sodium** or **Potassium.** Silver nitrate gives a white ppt. soluble without effervescence in Nitric acid, and soluble in Ammonia: therefore neither a carbonate, nor a chloride, nor a cyanide; neither Potash nor Soda. Chloride of Barium gives a white ppt., soluble in HCl; therefore not a Sulphate. Calcium sulphate no reaction: not an oxalate. On Platinum, a white residue, with yellow color to flame: intumesces and melts to a clear glass, which, moistened with H_2SO_4, and re-heated, gives green color to outer flame. It is a **Borate,** p. 47, **of Sodium**; probably **Borax.**

7. Solution colorless, inodorous, strongly acid. Carbonate of sodium produces effervescence without any ppt. It is either a free acid or an acid salt of Potassium or Sodium. Heated on Platinum, a white residue giving violet color to flame: further heated, a dark color spreads over the powder, and the latter fuses at length to a clear liquid. The strip of Platinum transferred to a test tube, and moistened, gives a clear liquid, alkaline, effervescent with HCl, owing to its conversion by heat into a carbonate, and a yellow ppt. with Platinic chloride. Calcium sulphate, white ppt. insoluble in Acetic acid. It is an **acid oxalate of Potassium,** probably the **Binoxalate,** p. 48. A portion of the dry salt heated with H_2SO_4, gives gas which burns with blue flame: confirmation of an Oxalate.

8. Solution colorless, inodorous, strongly acid. Carbonate of sodium gives effervescence without any precipitate even on boiling. On evaporation, a white fusible residue, with white suffocating vapors and emission of coruscations on all sides. No residue. Probably **Oxalic acid.** Lime-water, even drop-wise, an immediate white ppt. insoluble in Acetic acid. Confirm Oxalic acid in the free state : p. 48.

9. Solution colorless, inodorous, neutral. Carbonate of Sodium gives no reaction, even on boiling. Violet color to flame: volatile. Platinic chloride, rich red-brown coloration with deposit slowly of yellow ppt. **Potassium iodide.** The iodide further proved by Chlorine water (Sherry color and the free Iodine dissolved by Chloroform with amethystine color), and by Mercuric chloride which gives a scarlet ppt. Silver nitrate a yellowish curd-like ppt., insoluble in HNO_3 and in NH_3. P. 49.

10. Solution colorless, inodorous, neutral. Carbonate of sodium, no reaction, even on boiling. Violet color to flame: volatile. Platinic chloride gives a yellow ppt. : **Potassium.** HCl no reaction. HCl + H_2S no reaction. $BaCl_2$ no reaction : absence of Carbonates, Sulphites, Chlorates, Sulphates, Phosphates, Borates, Arsenites, Arsenates, and Oxalates. $AgNO_3$, a yellowish-white curd-like ppt., insoluble in HNO_3, soluble in much NH_3. Chlorine water a rich yellow color, owing to liberation of Bromine, giving an orange color to Chloroform when shaken with a few drops. A **Bromide,** p. 49. **Bromide of potassium.**

11. Solution colorless, inodorous ; acid reaction. Na_2CO_3, white, gelatinous ppt. HCl + H_2S no reaction : absence of Pb, Ag, Hg_2, Sn, Hg, Sb, Cd, Bi. NH_4Cl + NH_3 no reaction : absence of Cr_2, Fe_2, Al_2. NH_4Cl + $(NH_4)_2S$ white, gelatinous ppt. Probably **Zinc,** p. 28. Confirmed by KOH, white, gelatinous ppt., soluble in excess. $K_3FeC_6N_6$ dirty orange ppt. It is **Zinc sulphate,** as $BaCl_2$ gives a white ppt. insoluble in HCl. P. 43.

12. Solution colorless, inodorous, neutral. Na_2CO_3 white ppt. Therefore a salt in Groups I., II., III., IV. or V. HCl no reaction : absence of Pb, Ag and Hg_2. HCl + H_2S no reaction : absence of (Hg), Pb, (Cu), Bi, Cd, Sn. NH_4Cl + NH_3 no ppt. : absence of (Cr_2, Fe_2) Al_2. NH_4Cl + $(NH_4)_2S$, no reaction : absence of (Fe, Co and Ni), Mn and Zn. NH_4Cl + $(NH_4)_2CO_3$, white ppt. It contains either Ba, Sr or Ca. $CaSO_4$, an immediate white ppt., therefore **Barium.** Besides yellowish green color to flame, see p. 32. As it is a salt of Barium, and Barium chloride is a Group-test for Sulphates, Carbonates, Sulphites, Phosphates, Borates, Oxalates, Tartrates, Arsenates and Arsenites, these need not be looked for. Nitrate of Silver gives no reaction, therefore it is not a Chloride, Bromide, Iodide, Cyanide or Sulphide. Ferrous sulphate first added, and then H_2SO_4 gives an olive-brown coloration, with orange fumes. It is a **Nitrate of Barium.**

[N.B. The basyls in brackets cannot be present, as the ppt. with Na_2CO_3 was white, and the solution was colorless.]

13. Solution colorless, inodorous, strongly acid. Na_2CO_3, effervescence, but no reaction even on boiling. No basyl possible except Potassium or Sodium. On evaporation, liquid becomes syrupy, changes to yellow color,

intumesces, inflames, gives off smell of burning sugar, leaves a carbon residue which quietly burns away. Examine for **Tartaric acid,** p. 53. KOH white ppt., if acid in excess. NH_4OH. also a white ppt. The solution contains free Tartaric acid. Confirm by Lime-water in excess: a white ppt. soluble in Acetic acid.

14. Solution colorless, inodorous, alkaline. Na_2CO_3 no reaction, even on boiling. $AgNO_3$ a white ppt. soluble in both HNO_3 and in NH_3. As the salt must be of Potassium or Sodium, evaporate. Residue becomes yellow, gives off burnt sugar smell, carbonizes, inflames in part tinging the flame violet, fuses, the Carbon burns away, and a fused mass remains. Place Platinum foil in test tube, add several drops of water and boil: the clear solution blues litmus, effervesces with HCl (as the salt has become a carbonate) and is precipitated yellow by $PtCl_4$. It is neutral **Tartrate of Potassium.** Confirm the Tartrate, p. 52. HCl a white crystalline ppt. of Cream of tartar, soluble in excess. $BaCl_2$, white ppt. $CaCl_2$, white ppt., soluble in Acetic acid.

15. Solution colorless, inodorous, strongly acid. Na_2CO_3 effervescence, but no ppt. even on boiling. It is either a free acid, or an acid salt of Potassium or Sodium. On evaporation, a white residue, fusing, turning yellow, and burning with a pale flame, leaving very little Carbon which burns away. A free acid, probably **Citric acid.** The vapors, inhaled before they kindle, are suffocating. Lime-water no visible reaction, showing absence of Oxalic and Tartaric acids. With slight excess of Lime-water, so that solution alkaline, on boiling a short time gives a white ppt. Confirmation of Citric acid, p. 53. $CaCl_2$ no reaction, but on neutralizing with NH_3, and boiling, a white ppt. of Calcium citrate.

16. Solution colorless, inodorous, neutral. Na_2CO_3, a white ppt. HCl a white, curd-like ppt. insoluble in boiling water, soluble in NH_3. It is probably **Silver,** p. 17. Confirm by KOH, a grey-brown ppt. soluble in NH_3 and in HNO_3. $K_2Cr_2O_7$, a crimson ppt. Probably a **nitrate.** Confirm by $Ba2NO_3$, and by $AgNO_3$: no reactions. $FeSO_4 + H_2SO_4$ proves the nitrate, p. 57. It is **Nitrate of Silver.**

17. Solution colorless, inodorous, strongly acid. Na_2CO_3 with strong effervescence, a white ppt. HCl, no reaction: absence of Pb, Ag and Hg_2. $HCl + H_2S$, a rich brown ppt. insoluble in NH_3 and in $(NH_4)_2S$. KOH, white ppt. insoluble. Probably **Bismuth,** p. 23. Confirm by $K_2Cr_2O_7$, orange ppt., insoluble in KHO. Water occasions a ppt., increased by Tartaric acid. $BaCl_2$ no reaction. $AgNO_3$, no reaction. Look for a **nitrate.** $FeSO_4$, a white ppt. of Sulphate of Bismuth; with added H_2SO_4, olive-brown coloration with burst of orange nitrous fumes. It is **Bismuth nitrate** in free nitric acid.

18. Solution pale-blue, inodorous, acid. Na_2CO_3, blue ppt. at once, with only slight effervescence. Probably **Cupric.** HCl changes blue to green, but no ppt. $HCl + H_2S$, a brown black ppt. insoluble in $(NH_4)_2S$. KHO, blue ppt. insoluble. NH_3, bluish-green ppt., soluble with bright blue color. $K_4FeC_6N_6$, maroon-colored ppt. It is **Cupric.** P. 22. $BaCl_2$, white ppt., insoluble in HCl. It is **Cupric sulphate.**

19. Solution colorless, inodorous, faintly alkaline. Na_2CO_3, no reaction even on boiling. $AgNO_3$, white, scum-like, greasy ppt. Probably an **acetate.** P. 51. Evaporated, gives yellow color to flame, burns, darkens much, and after some time, Carbon burns away and colorless, crystalline fused mass remains. Place Platinum foil in test tube, add a few drops of water, boil: solution is alkaline, effervesces with HCl, and gives no ppt. with $PtCl_4$. It is a Salt of **Sodium.** $BaCl_2$, no reaction. Fe_2Cl_6, rich port wine color, turned to yellow Fe_2Cl_6 by HCl. It is **Sodium acetate.** P. 35.

20. Solution colorless, odorous of Prussic acid, alkaline. Na_2CO_3 no reaction even on boiling: must be a salt of Potassium or Sodium. $AgNO_3$ carefully added, a white, curd-like, ppt. first re-dissolved and then permanent, soluble in NH_3 and in strong, boiling HNO_3. Probably a **Cyanide,** p. 41, confirmed. A strip of paper moistened with KHO is held in the vapor of a portion in test tube acidulated with HCl and boiled; paper transferred to clean test tube, moistened with $FeSO_4$ solution, warmed and HCl in excess: Prussian Blue. Platinic chloride confirms Potassium. It is **Cyanide of Potassium.**

21. Solution colorless, odorless, neutral. Na_2CO_3, white ppt.: therefore some Metal of Groups I., II., III., IV. or V. HCl no ppt., but on warming color changes to yellow-green, and greenish-yellow gas given off. It is a **Chlorate,** p. 41. $HCl+H_2S$ slight reaction. NH_4Cl+NH_3, no reaction. $NH_4Cl + (NH_4)_2S$, no reaction. $NH_4Cl + (NH_4)_2CO_3$, white ppt. It is either Barium, Strontium or Calcium. $CaSO_4$, immediate white ppt. It is **Chlorate of Barium.** Confirmed by yellow-green color to flame and deflagration on Charcoal.

22. Solution yellow-red, inodorous, acid to test paper. Na_2CO_3, changes the color to lemon-yellow, with effervescence, and with no ppt. and no evolution of Ammonia. It is an acid **chromate** probably of Potassium. $PtCl_4$ gives a yellow ppt. It is **Dichromate of Potassium.** $HCl + H_2S$, changes solution to dingy-green with ppt. of Sulphur, p. 47.

23. Solution more or less reddish-yellow, according to its concentration, inodorous, acid. Na_2CO_3 with effervescence, gives a red-brown gelatinous ppt.: probably **Ferric.** HCl no reaction, except a deepening of color. $HCl + H_2S$, a white ppt. of Sulphur. Divide into two parts: to one, NH_3 gives black ppt., to the other add $K_3FeC_6N_6$, a bright blue. **Ferric,** p. 25. $BaCl_2$ no reaction. $AgNO_3$, white, curd-like ppt.; on washing several times with distilled water, insoluble in HNO_3, soluble in NH_3. [N.B. If the ppted Chloride of Silver is not well washed with water, NH_4OH would precipitate gelatinous Ferric hydroxide from the solution. After washing, it is best to add HNO_3 first, to boil, rinse the ppt., and then add Ammonia.] It is **Ferric chloride.**

24. Solution is colorless, inodorous, strongly acid. Na_2CO_3, effervescence but no ppt. even on boiling. It is either a free acid, or an acid salt of Potassium or Sodium. Heated on Platinum, vapors slightly irritating, and leaves no residue. It is a free inorganic acid, either dilute HCl or HNO_3. Silver nitrate, a white curd-like ppt. soluble in NH_3 and re-precipitated by

HNO_3. Confirm by MnO_2: Chlorine is evolved which bleaches litmus paper. It is a solution of **Hydrochloric acid,** p. 49.

25. Solution colorless, inodorous, strongly acid. Na_2CO_3, effervescence but no ppt. even on boiling. It is either a free acid or an acid salt of K or Na. Heated on Platinum foil, concentrates to an oily residue, which volatilizes in white suffocating vapor. No base present. $BaCl_2$, white ppt. insoluble in HCl. It is free **Sulphuric acid,** p. 44. A drop of the liquid, carefully dried over flame on blotting-paper, chars the latter.

26. Solution colorless, inodorous, strongly acid. Na_2CO_3 effervescence, but no ppt. Heated on Platinum, evaporates without residue with caustic vapor. It is a free, volatile mineral acid. $BaCl_2$ no reaction. $AgNO_3$, no reaction. Boiled with Copper turnings to a blue liquid with nitrous fumes. It is free **Nitric acid,** p. 57. $FeSO_4$ dark coloration, unless very weak: then, aided by H_2SO_4.

27. Solution colorless, with smell of Ammonia: blues litmus. Alkaline. Sodium carbonate by heat increases the smell of the gas, which blues red litmus when suspended in the vapor and fumes with HCl. $AgNO_3$, in excess, a grey-brown ppt. at first re-dissolved, and soluble in HNO_3. HCl occasions white fumes and $PtCl_4$ a yellow ppt. The basyl is **Ammonium,** p. 34. No residue on Platinum when carefully evaporated. Solution of **Ammonic hydrate,** confirmed by $CuSO_4$ and by $MgSO_4$.

PREPARATION OF THE COMMONER SALTS OF THE METALS, OF OXIDES, HYDROXIDES, &c.

The student is supposed to be thoroughly acquainted with the previous analytical portion, and will have learnt what salts are insoluble or soluble. He is therefore supposed to have studied the action of Hydrochloric, Nitric and Sulphuric acids upon the respective metals.

The following notes are simply suggestive.

I. Soluble Salts. Dissolve the Oxide or Hydroxide of the Metal or the Carbonate (with effervescence), in the diluted acid (or salt of Hydrogen) whose salt is required, until the acid is saturated. In the case of Copper, Mercury, Lead, Iron, &c., excess of the Oxide must be avoided, or basic salts will be formed. It is therefore more scientific to calculate and roughly weigh out the quantities. Then filter and evaporate the filtrate until a crystalline pellicle forms on the surface, or until a glass rod, dipped and withdrawn, shows ready crystallization. Allow the solution to cool slowly and quietly. Pour off the "mother-liquor" from the crystals, drain and press these upon blotting-paper till dry. Compounds like Chromic anhydride CrO_3, and Permanganate of Potassium $K_2Mn_2O_8$ must not be filtered or dried on paper, but on a porous tile. It is often necessary to dry in a Desiccator, in vacuo over Sulphuric acid.

II. Insoluble Salts. To a solution of a soluble salt of the Metal add a solution of a salt of the radicle, till precipitation ceases. If the ppt. is heavy and subsides quickly, wash by *decantation, i.e.* allow settlement, pour off the supernatant liquor, add more water, stir, again settle, and repeat, until the liquid, on being tested, is free from impurities.

If the ppt. is light and will not readily settle, it must be collected on a paper filter moistened and pressed close to a glass funnel and not coming up beyond ¼ inch from the brim. Wash with successive small quantities of hot water, stirring up the ppt. with the jet of the wash-bottle, until a few drops of the runnings, tested, are free from impurities.

Decantation is often used first, and filtration for completion. Dry the filter and detach the ppt. carefully.

Potassium, Sodium, Ammonium, Silver, Barium, Strontium, Calcium, Magnesium, Zinc, Lead and Cadmium, have each only one Basic oxide or Base, the Monoxide: Mercury, Copper, Iron, Tin, Chromium and Manganesium have each two basic Oxides.

The *Hydroxides* of K, Na, NH_4, Ba, Sr and Ca are the only ones soluble in water: their Oxides easily combine with water to form Hydroxides. Inasmuch as they also greedily absorb Carbon dioxide, that gas must be excluded in their preparation.

General method for Oxides. 1. Ignite the *nitrate* of the metal: the oxides of Nitrogen and Oxygen are given off, and the Oxide remains. $Ba2NO_3 = BaO + 2NO_2 + O$. The Oxides of Silver, Mercury and Gold are reduced to the metallic state. 2. All *metals* except Silver, Platinum and Gold give their *Oxides* when heated in air. 3. The *Hydroxides* may be precipitated from solutions of their salts by KHO or by CaH_2O_2: wash the hydroxide, and expel the water by heat. *E.g.* $Fe_2Cl_6 + 6KHO = Fe_2H_6O_6 + 6KCl$. Then by heat: $Fe_2H_6O_6 = Fe_2O_3 + 3H_2O$. *Note.* KHO and NaHO do not lose water by heat.

General method for Hydroxides. The most useful are those of the Alkalies and Alkaline earths. Their Oxides become Hydroxides by exposure to the moist air. The *Hydroxides of Potassium* and *Sodium* are best prepared from solutions of their Carbonates by means of Calcium hydroxide: $K_2CO_3 + CaH_2O_2 = 2KHO + CaCO_3$. A salt may be precipitated by a soluble Hydroxide, the precipitate collected, washed and dried on the water-bath. $Pb2NO_3 + CaH_2O_2 = PbH_2O_2 + Ca2NO_3$. *Calcium* and *Magnesium carbonates* become *Oxides* at a bright red-heat: $CaCO_3 = CaO + CO_2$. $MgCO_3 = MgO + CO_2$. Then, with water, they become Hydroxides: $CaO + H_2O = CaH_2O_2$. *Note.* The lower Oxides and Hydroxides of Copper, Tin, Iron, Chromium and Manganesium absorb Oxygen from the air: hence they must be prepared out of contact with it, or in a current of Hydrogen. *Cupric hydroxide* CuH_2O_2 is obtained by precipitating a solution of Cupric sulphate with Potassium hydroxide: $CuSO_4 + 2KHO = CuH_2O_2 + K_2SO_4$. The solution must not be boiled, or the Hydroxide becomes black Oxide. *Cuprous hydroxide* may be obtained by boiling a solution of a Cupric salt with Glucose: first $Cu_2H_2O_2$, then Cu_2O.

General method for peroxides. *Peroxide of Barium* BaO_2, by passing O over heated Oxide BaO. Or by heating Barium oxide with Potassium chlorate, dissolving out Potassium chloride and washing the insoluble Hydrate of the Peroxide. *Lead peroxide* PbO_2, by precipitating a warm solution of a Lead salt with Calcium hypochlorite Ca2ClO. $Ca2ClO + 2PbO = 2PbO_2 + CaCl_2$. Or from red lead Pb_3O_4 by warming with Nitric acid, and removing the insoluble Peroxide by filtration and washing: $Pb_3O_4 + 4HNO_3 = 2(Pb2NO_3) + PbO_2$. *Manganese peroxide* MnO_2. Warm a Manganous salt with Chloride of Lime or Calcium hypochlorite. Also by precipitation of Manganous chloride by Calcium hydroxide, and free exposure to the air.

General method for salts. E.g. *Zinc sulphate* $ZnSO_4,7H_2O$ may be prepared by dissolving Zinc, its Oxide or Carbonate, in dilute five per cent. Sulphuric acid: evaporate and crystallize as above. *Phosphate of Calcium* Ca_32PO_4 may be obtained by precipitating Calcium chloride by Sodium orthophosphate: collect on a filter, wash with water until $AgNO_3$ shows absence of Chloride in the filtrate, then dry.

Sometimes **sublimation** is employed to obtain certain salts: this is a kind of distillation in which the volatile body collects as a solid. *Mercuric sulphate* $HgSO_4$ pounded with an equivalent weight of dry Sodium chloride, and sublimed, yields *Mercuric chloride* $HgCl_2$, which sublimes as Corrosive sublimate, leaving the non-volatile Sodium sulphate. Again: *Mercuric chloride* $HgCl_2$ rubbed up with Mercury, and sublimed, yields *Mercurous chloride* or Calomel Hg_2Cl_2.

EXAMINATION OF AIR.

If pure, should be clear, inodorous, and neutral to test-paper. When a quantitative analysis has to be made, a large volume of air must be taken and an aspirator employed, so that impurities which are soluble may be passed through various solutions which will absorb them and in which they can be recognized.

For ordinary examinations quart bottles with wide mouths, are often of sufficient capacity, and they can be filled by suitable bellows with the air required for testing.

To determine the presence of **Carbon dioxide**, Lime-water or Baryta-water is employed. According to Angus Smith, if a bottle of 10½ ozs. capacity is employed, and it is shaken with half-an-ounce of Lime-water, there will be no precipitate if the air is normal or contains even 0·06 per cent. of CO_2. For the estimation of the Carbon dioxide we require:

a. Freshly-prepared Lime-water.

b. Oxalic acid solution consisting of 2·25 grammes of crystallized Oxalic acid per Litre of Distilled water (hemi-deciequivalent p. 125).

c. Cochineal or turmeric paper.

Pour into the bottle of known capacity 60 c.c. of Lime-water, shake vigorously, allow the ppt. of Calcium carbonate to settle, pour off 30 c.c. of the clear liquid and determine the remaining alkalinity by the standard Oxalic solution, using turmeric paper as an indicator. (Also determine the alkalinity of the Lime-water, if necessary.) The loss of alkalinity multiplied by two (as only one-half was taken) equals the amount of CO_2 in the volume of air. 1 c.c. Oxalic acid $=0·0011$ gramme of $CO_2=0·56$ c.c. of CO_2. (See Alkalimetry, p. 123.)

If the air is alkaline, **Ammonia** must be present. By shaking with a little water, it will be dissolved and can be determined by Nessler's Test (p. 136).

The presence of **Hydrogen sulphide** can be recognized by the odor, and by moistened Lead-paper. The paper will be faintly tinted, browned or blackened.

Sulphur dioxide, in air purposely contaminated, will redden moistened litmus paper and probably have the well-known odor of burning brimstone. It is incompatible with H_2S, if in excess. Shaken up with a little water, Sulphur dioxide dissolves as Sulphurous acid H_2SO_3. Litmus paper will be slowly bleached after strong reddening. Lead-paper will not be discolored. Starch-paper moistened with solution of iodide of potassium will be blued. Shaken up with Chlorine water, Sulphurous becomes Sulphuric acid ($H_2SO_3+Cl_2+H_2O=H_2SO_4$) and precipitates Chloride of Barium as Sulphate, insoluble in Hydric chloride (233 $BaSO_4=64$ SO_2). A solution of Potassium permanganate will be decolorized, oxydizing Sulphurous to Sulphuric acid ($K_2Mn_2O_8+5SO_2+2H_2O=K_2SO_4+2MnSO_4+2H_2SO_4$). To determine quantitatively, weigh out 0·316 gramme of Potassium permanganate, transfer to a stoppered Litre flask, dissolve in water by shaking, and fill up to the 1000 c.c. mark. This is a so-called centinormal solution, 1 c.c. $=0·00032$ gramme of

SO_2. Add this drop-wise to the air in the bottle, or to the solution obtained by shaking with distilled water, and shake after each addition until the Permanganate is no longer decolorized. Each c.c. added = 0·00032 grm. of SO_2 present in the air. Of course $BaCl_2$ will give a white ppt. in the decolorized solution, insoluble in HCl. Equally, of course, Lime-water will give no reaction.

If **Chlorine** has been added to the air contained in a sample bottle, the smell will announce it, litmus will be reddened and immediately bleached. Silver nitrate will give a white curd-like ppt., insoluble in HNO_3 and soluble in NH_3. Ozone paper will be immediately blued, if moistened. Permanganate will not be bleached. Lime-water, no visible reaction.

If **Hydrochloric acid gas** has been added, there will be an irritant odor. Litmus strongly reddened but not bleached. Permanganate will not be bleached. Silver nitrate when shaken up with the solution of the gas in water will give a white ppt. as above with Chlorine: the amount of acidity can be determined by standard alkali, p. 124, and by Silver nitrate, p. 129. Ozone paper will not be blued. Lime-water, no visible reaction.

If **Nitrous fumes** in the sample of air, there may be red color and peculiar odor. Acid to test-paper. Ozone paper will be blued. Permanganate, bleached. $AgNO_3$ no reaction. $BaCl_2$ no reaction. Solution of Ferrous sulphate, when shaken up with the air, becomes olive-brown. Lime-water, no visible reaction.

If **Coal gas** has been added, the smell most characteristic. Lime-water will give no reaction. Neutral to test-paper. Platinum-sponge or foil, heated to redness, determines oxydation, and Carbon dioxide can be detected by Lime-water.

FIRST M.B. EXAMINATION, UNIVERSITY OF LONDON.

One of the following substances may be given:

A. **Neutral bodies:** Alcohol, Urea, Sucrose, Glucose, Starch or Glycerol.

B. **Alkaloids, or their salts:** Morphia, Strychnia, Quina or Cinchona.

C. **Acids, or their salts:** Oxalic, Tartaric, Citric, Malic or Uric acid; Succinic, Benzoic or Hippuric acid; Acetic, Meconic, Tannic, Gallic, Sulphocyanates, Ferrocyanides, Ferricyanides, or Cyanides.

Notice color and smell. Ascertain, by use of Ammonium sulphide, whether Salt of any heavy metal present, the Sulphide of which is discoverable by color. Look also for effervescence from escape of H_2S, if any strong acid present such as evolves CO_2 from a carbonate. Mercuric cyanide, $HgCy_2$, which might be overlooked, as Sodium carbonate occasions no precipitate, will be changed into black HgS.

If a solid, at once try effects of careful heating, after employment of ammonium sulphide.

Thus the alkaloids fuse, redden, and burn with a sooty flame, leaving but little carbon, which burns away. Benzoic acid melts to a clear liquid, and burns with sooty flame, only sooting the platinum, and then burning away. The vapors, before burning, most irritating. Hippuric acid melts to a clear liquid, becomes blood-red, gives off irritating vapors before kindling, burns with sooty flame, leaving a mass of carbon readily combusted. HCN perceptible. Succinic acid melts and burns with bluish flame, leaving no residue; only the unburnt vapors irritating to a degree. Meconic acid gives off irritating vapors, burns with sooty flame, leaving carbon, which burns away. Oxalic acid fuses: its vapors are very irritating, it inflames, but leaves no residue. Tartaric acid fuses, turns yellow, smells of burnt sugar, inflames, carbonizes and burns away. Sucrose and glucose are very similar, but these latter are neutral to test paper. Citric acid melts, its vapors are very irritating, but when burning no such perceptible; carbonizes and burns away. Malic acid fuses, and, with frothy effervescence, burns away; unburnt fumes pungent. Starch, without fusing, burns with yellow flame, and leaves carbon, which can be burnt away. Uric acid simply carbonizes with smell as of burnt feathers, and slowly combusts. Gallic acid fuses, becomes yellow-red, combusts, and leaves much carbon easily oxydized. Tannic is much like gallic acid. Nitrate of urea melts, gives off pungent fumes, deflagrates with yellow flame, without blackening or residue.

Salts of the alkaline metals K_2 and Na_2 leave fused carbonates, the metals of which are recognised by the violet, or the yellow flame. The ash dissolves without residue in water, alkaline, is converted into a chloride with effervescence by HCl, and the K_2 determined by the yellow ppt. of $2KCl,PtCl_4$ (none with Na_2). Salts of Ba, Sr and Ca, will leave carbonates and oxides, giving turbid solutions with water, as these carbonates are not dissolved. Other metallic salts may leave a residue of oxide, or of metal. Anyhow, the acids, or salts of ammonium, the alkaloids or mercury will leave no residue. Cyanide of mercury gives off cyanogen, burning with peach-blossom colored flame. Oxalate of urea fuses, does not blacken, gives off ammonia, and leaves no residue.

Dissolve carefully in water, notice whether sparingly or easily soluble, and the character of the solution.

Test the solution with litmus paper. Practically, as we have made the solution, the alkaloids and uric acid cannot be present, except as salts. Starch is at once recognised, or proved to be absent (see below).

Now add Na_2CO_3 very carefully to a small portion; a precipitate either at once, or on stirring, indicates a heavy Metal or an Alkaloid in Group B. But, in presence of Tartaric, Citric, and Malic acids, of Sucrose and Glucose, many heavy Metals, such as Fe, Cu, &c., may give no precipitate. Metals of this kind should have been already indicated by the Sulphide of Ammonium test. If any of these organic substances are present, they will carbonize on platinum, and the metal may be obtained from the ash, dissolved in nitric acid, and examined in the usual way.

If Na_2CO_3 gives effervescence, but no precipitate, it indicates a free acid, or an acid salt of Potassium, Sodium or Ammonium, or else *Nitrate* or *Oxalate of urea*. Test at once for these, if heating on platinum has not already drawn attention to them by their unique behaviour. Add Calcium hypochlorite (Chloride of lime in solution), or better, Potassium hypobromite: if no effervescence, urea is absent.

If Na_2CO_3 has given no effervescence, and no precipitate, and the solution is neutral, heat a portion upon platinum.

1. **Starch,** $C_{18}H_{30}O_{15}$, is a white powder, with micaceous feel, crunching between the fingers when in mass. Insoluble in cold water. Neutral to test paper. Forms a jelly when boiled. Carbonizes with flame, and carbon burns away. Solutions gelatinous or opalescent. A drop of aqueous iodine gives a blue compound in the cold, removed by heat, and reappearing on cooling. Boiled for a minute with dilute sulphuric acid, it is changed into Glucose: then a few drops of Cupric sulphate, and excess of Potash, on boiling, give red precipitate of Cuprous oxide.

a. It fuses, gives off Ammonia, re-solidifies, and then volatilizes without residue. It is probably **Urea.**

2. **Urea,** $CO(NH_2)_2$. Transparent, colorless, four-sided prisms, very soluble in water and in alcohol. Neutral to test paper. Does not blacken when heated.

On evaporation of solution to dryness, it first melts and gives off NH_3, discoverable by red litmus; suddenly re-solidifies, and then volatilizes, without residue, as Cyanic acid.

Concentrated Nitric acid, free from Nitrous acid, precipitates Urea nitrate on stirring and cooling. By Nitrous acid into CO_2, N_2 and H_2O.

If Hypobromite of Potassium is added to the *neutral* solution of Urea, there is brisk effervescence from escape of Nitrogen: $3KBrO + KHO + CON_2H_4 = KHCO_3 + 3KBr + 2H_2O + N_2$.

If there is effervescence with Sodium carbonate, examine further.

Urea nitrate, $CO(NH_2)_2HNO_3$. White, crystalline plates, readily soluble in water, strongly acid, effervescence without a precipitate on addition of Na_2CO_3, and without odor of NH_3. On platinum it melts, gives pungent fumes, deflagrates with yellow flame, without blackening or residue. On addition of concentrated HNO_3 to a fairly concentrated solution, white crystalline plates of Urea nitrate are precipitated. Mercuric nitrate gives white ppt. Ca2ClO, or Nitric acid containing N_2O_3, decomposes it into N_2, H_2O, and CO_2. (See tests for Urea.) Evolves NH_3 when boiled down with KOH. The nitrate will be discovered by Ferrous sulphate and heat (p. 57.)

Urea oxalate, $2[CO(NH_2)_2],H_2C_2O_4$. White, granular crystals, with acid reaction. Does not deflagrate when heated on platinum, nor blacken.

With Lime-water, immediate white ppt. insoluble in Acetic acid.

Calcium hypochlorite as with urea nitrate, but with considerable white ppt.

b. It has a spirituous odor, burns with bluish flame, and leaves no residue upon platinum. Probably **Alcohol.**

3. **Alcohol**, C_2H_5OH. Colorless, inflammable liquid, neutral if pure, volatile. Even a ten per cent. solution of Alcohol gives a streaky distillate, and a blue flame, when boiled in a test-tube, and lighted.

$K_2Cr_2O_7$, with H_2SO_4, is reduced to blue-green Chrome alum, with odor of Aldehyde, C_2H_4O.

$NaC_2H_3O_2$, with added H_2SO_4, on heating with a portion of the original solution, gives Acetic ether, $C_2H_5C_2H_3O_2$, of pleasant apple-like odor.

c. The substance gives solid residue, fusing to clear glass, coloring yellow, gives off odor of burnt sugar as it blackens and burns with flame, leaving a voluminous charcoal, which burns away. May be **Sucrose** or **Glucose.**

4. **Sucrose**, $C_{12}H_{22}O_{11}$. Colorless, transparent, four-sided oblique rhombic prisms, very soluble in water.

Solution neutral to test-paper.

Heated to 160°, into Glucose, $C_6H_{12}O_6$, and Laevulosan, $C_6H_{10}O_5$.

A drop of $CuSO_4$ to a small portion, then excess of KOH, gives a blue solution, not changed if just boiled; but, if a fresh portion boiled for a minute with three or four drops of dilute sulphuric acid, and then similarly treated with $CuSO_4$ and excess of KOH, Sucrose is changed into Glucose, and behaves as such.

KOH, no reaction.

H_2SO_4, in excess, decomposes a solution, with separation of a mass of carbon. (Take care of fingers.)

In taste sucrose is very sweet: do not taste until you have tested.

5. **Glucose**, $C_6H_{12}O_6,H_2O$. In white masses, easily crushed between the fingers. Less soluble and less sweet than Sucrose. Solution colorless, or yellow tinted.

$CuSO_4$ and KOH in excess, a deep blue solution, from which either yellow cuprous hydroxide is precipitated on warming, or red cuprous oxide before the liquid boils.

KOH, deep brown coloration.

H_2SO_4, converts glucose, without much darkening, into sulpho-saccharic acid, $C_6H_{11}O_5,HSO_3$.

At 170° into Glucosan, $C_6H_{10}O_5$.

d. A colorless solution, becoming syrupy on concentration, neutral to test-paper, burning with steady white flame, without blackening and without residue, remaining liquid until the end. Probably **Glycerol.**

6. **Glycerol,** $C_3H_5(OH)_3$. When pure: colorless, viscid liquid, of sp. gr. 1·27, boiling at 290° C. Readily soluble in water and in alcohol. By loss of water into Acrolein, C_2H_3CHO.

Does not reduce $CuSO_4$ + KOH.

Evaporated nearly to a syrup, and then re-heated with solid $KHSO_4$, gives the intensely pungent vapors of Acrolein, C_2H_3CHO.

Penetrating, sweet taste.

Group B. Alkaloids.

On Platinum they fuse, redden and burn with a bright, sooty flame, leaving a sooty incrustation which burns away easily.

The free Alkaloids are so little soluble in water, that a solution is practically out of the question: nevertheless they are sufficiently soluble to turn red litmus blue.

Solutions of their salts are generally of neutral or acid reaction.

Na_2CO_3 (with brisk stirring in case of Morphia) a white ppt. of the respective alkaloid.

KI_3, gives with all alkaloids and their salts, a brown resinous precipitate. (The test extemporised, by adding to KI a little concentrated HNO_3; then warm till I_2 liberated, and add more KI till the I_2 dissolved to a brown solution.)

HI + I_2 gives also an immediate brown ppt. with the alkaloids and their salts.

Phospho-molybdic acid gives a yellow precipitate.

Phospho-tungstic acid, a white precipitate.

7. **Morphia**, $C_{17}H_{19}NO_3.H_2O$, in short, rectangular prisms, or as a white power, soluble in 1000 parts of cold, and 400 parts of boiling water. Soluble in alcohol. Not soluble in ether or chloroform. KOH in excess, dissolves morphia.

HNO_3, deep orange coloration.

Salts very soluble in water; neutral or acid reaction.

HNO_3, orange coloration.

Fe_2Cl_6, dark blue color.

Mixed with Iodic acid HIO_3, iodine is set free, which (*a*) blues starch-paste, (*b*) dissolves with amethystine color in chloroform. (Avoid excess of test.)

H_2SO_4 and ammonium molybdate give blue-purple color.

8. **Strychnia,** $C_{21}H_{22}N_2O_2$, in brilliant rhombic prisms, soluble in 7000 parts of water. Insoluble in absolute Alcohol, in Ether and in Potash. Very soluble in Chloroform.

$K_2Cr_2O_7$, gives, with solid Strychnia and H_2SO_4, an intense blue-violet color, changing to red and orange.

Solutions of its salts colorless, and may be neutral or acid.

KOH, or NH_4OH, or Na_2CO_3, white ppt. of strychnia; precipitate shaken with chloroform is dissolved. The chloroform solution evaporated in small porcelain capsule, mixed with a little pounded Manganese dioxide, Lead peroxide or Potassium dichromate, and stirred with a rod dipped into H_2SO_4, gives blue purple streaks.

Chlorine water gives a white precipitate.

Very dilute solutions intensely bitter. Taste cautiously, and not until the substance is ascertained.

9. **Quina,** $C_{20}H_{24}N_2O_2$, white powder, soluble in 350 parts of water. Soluble in Alcohol and Ether.

Moistened with Chlorine water, and a drop of NH_3, beautiful green color.

Salts in acid solution, fluorescent, reflect bluish tint.

NH_4OH, or Na_2CO_3, white precipitate of Quina, very soluble in Ether; ethereal solution decanted into watch glass, evaporated spontaneously, leaves a white film; which, with Chlorine water and Ammonia, gives an emerald-green coloration.

$Cl_2 + K_4FeCy_6 + NH_4OH$, deep red tint, changing to dirty brown.

Solutions bitter.

10. **Cinchonia,** $C_{20}H_{24}N_2O$. Large, quadrilateral prisms. Less soluble in Alcohol than Quina. Insoluble in Ether.

Moistened with Chlorine water, and a drop of Ammonia, white.

Turns plane of polarization to the right.

Salts of Cinchonia more soluble than those of Quina.

Not fluorescent.

KOH or NH_4OH, or Na_2CO_3, white precipitate of Cinchonia, insoluble in Ether.

K_4FeCy_6, white, flocculent Ferrocyanide, soluble in excess and after gentle heat, on cooling separates in golden scales (requires skill).

Chlorine water and then NH_3, a yellowish-white precipitate.

Solutions bitter.

Group C. Acids and their salts.

a. Ferric chloride does not precipitate either free **Oxalic, Tar-**

taric, Citric, or **Malic acids,** or their **Salts.** Lime water immediately precipitates **Oxalic acid; Tartaric acid** when the test is in excess; **Citric acid** when the lime is in excess, and the liquid boiled; **Malic acid** under no conditions. Calcium chloride immediately precipitates even free oxalic acid; Tartrates at once, Citrates on boiling, and Malates only after addition of Alcohol. Heated with Sulphuric acid, Oxalic acid dissolves and gives off CO and CO_2 without change of color; Citric acid dissolves with yellow color, and evolves CO; Tartaric and Malic acids dissolve and blacken, with evolution of CO, CO_2 and SO_2. The CO is combustible with blue flame.

β. *Ferric chloride* does not precipitate **Succinic, Benzoic** or **Hippuric acids,** but **Succinates,** cinnamon-colored, **Benzoates,** salmon-colored, and **Hippurates** flesh-colored, respectively as Ferric Succinate, Benzoate or Hippurate. On addition of HCl to the Succinate, the Succinic acid remains in solution; but on its addition to the Benzoate or Hippurate, Benzoic acid separates in scales, and Hippuric acid in needles.

γ. *Ferric chloride* strikes a deep red color with **Acetates,** easily removed by HCl; a blood-red color with **Sulphocyanates,** not altered by HCl, but bleached by Mercuric chloride, or by Zinc with separation of H_2S; a rich cherry-red color with **Meconates,** or with Meconic acid, only removed by much HCl; a blue-black color with **Tannic** or **Gallic acid,** or their soluble salts, bleached by HCl without or with a precipitate: further, Tannic acid is precipitated by Gelatin, and Gallic acid is readily soluble in Ether; a precipitate of Prussian blue with soluble **Ferrocyanides,** insoluble in HCl; an olive-brown coloration with **Ferricyanides,** further distinguished by Ferrous sulphate, which produces Turnbull's blue in a portion of the original solution.

With **Cyanides,** Ferric chloride produces no reaction. They are generally recognizable by the fact that HCl immediately decomposes them, and CNH should be recognizable by its odor, &c.

For particulars of each substance see Index, and apply all the tests given under each substance.

THE CHEMICAL PORTION OF THE PRACTICAL EXAMINATION IN FORENSIC MEDICINE AT THE UNIVERSITY OF LONDON.

Class A comprises simple solutions of Phenol or Carbolic acid, Chloroform, Chloral, Nitro-Benzene, Anilin, Alcohol, Morphia and Meconic acid, Strychnia and Brucia.

Class B comprises in admixture with foreign substances: Caustic alkalies. Mineral acids. Oxalic acid. Phenol. Prussic acid and other Cyanides. Phosphorus. Compounds of Arsenic, Antimony, Mercury, Lead, Copper, Silver, Zinc and Barium.

CLASS A. SIMPLE SOLUTIONS.

Phenol or Carbolic acid, C_6H_5OH, is recognised by its peculiar odor. Aqueous Bromine should give a white ppt. of Tri-brom-phenol, $C_6H_2Br_3OH$. Dilute Ferric chloride is colored violet. It precipitates Albumen.

When in admixture as in Class B, the smell is sufficient to suggest its presence; the liquid should be distilled and the Distillate tested as above.

Long, colorless needles, when pure Melts at 41° C. Boils at 181·5° C. Requires about 15 parts of water for solution. It has a strong burning taste. With very dilute solution of Bromine, it gives a white ppt. With H_2SO_4, forms Phenol-sulphonic acid. On adding Phenol to a mixture of KNO_2 and H_2SO_4, a brown color is produced, changing to green and blue.

Chloroform, $CHCl_3$, has a sweetish, ethereal odor, immediately distinguishable. By distillation, it may be had in a concentrated form. Boiled with pure Potash, the Chlorine may be detected by Silver nitrate, after acidulation with Nitric acid. To a further small portion add a few drops of aqueous Anilin, and a little alcoholic Potash (solid KHO pounded and shaken with rectified spirit) to prevent the separation of free hydrochloric acid; on heating, Phenyl isocyanide, C_6H_5NC, will be formed, the intolerable smell of which will at once prove the presence of Chloroform.

Chloroform is a thin, colorless liquid, of sp. gr. 1·525. Boils at 61°. As it is nearly insoluble in water, look for milkiness or drops at the bottom of the containing vessel.

Chloroform reduces Fehling's solution: $CHCl_3 + 5KHO + 2CuO = Cu_2O + K_2CO_3 + 3KCl + 3H_2O$.

Chloral, $CCl_3,CHO = C_2Cl_3HO$, is a colorless liquid, of sp. gr. 1·5, boiling at 94° C. Its odor is pungent and peculiar, exciting to tears. With water it forms a white, crystalline hydrate, easily soluble in water and in alcohol. It is a true aldehyde, reduces Silver oxide to the metallic state, and gives a bright mirror when heated in a test tube with Nitrate of Silver to which a drop of Ammonia has been added: $CCl_3,COH + Ag_2O = CCl_3.COOH + Ag_2$. With aqueous Potash, Chloral gives a ppt. of Chloroform, and formate of Potassium in solution: $CCl_3,CHO + KHO = H,COOK + CHCl_3$. The Chloroform in the reaction is discovered by aqueous Anilin and alcoholic Potash. Chloral, like Chloroform, reduces Fehling's solution.

Anilin or **phenylamin**, $C_6H_5NH_2$, has a faint odor reminding of tobacco. As it rapidly browns on exposure to air, its solution is more or less tinted from yellowish to brown. Chloride of lime produces a purple color. Mixed with oil of vitriol, on addition of a few drops of di-chromate of potassium, the solution becomes first red and then blue. A deal shaving is colored yellow, on drying. Heated with the merest drop of Chloroform and with alcoholic Potash, Phenyl isocyanide, C_6H_5NC, is produced, the odor of which is most offensive.

Anilin is a colorless, oily liquid, of sp. gr. 1·036. Boils at 184·5°. Requires 31 times its weight of water for solution. Browns on exposure to air.

Nitro-benzene, $C_6H_5NO_2$, resembles oil of bitter almonds as to smell. Boiled with pure potash, the absence of chlorine can be ascertained by the usual test (see Chloroform). With zinc and dilute sulphuric acid, it is slowly changed into Anilin: $C_6H_5NO_2 + 3H_2 = C_6H_5NH_2 + 2H_2O$. Neutralized with sodium carbonate, zinc carbonate removed by filtration, tests for anilin may be employed.

Nitro-benzene is a light yellow liquid, of sp. gr. 1·2. Boils at 200°. Almost insoluble in water: soluble in Alcohol.

Alcohol, CH_3CH_2OH, is recognised by its spirituous odor. The vapor inflammable. If very dilute, distil and examine the first 15 or 20 drops which come over. Reduces Di-chromate of potassium strongly acidulated with sulphuric acid; solution green or blue-green Chrome-alum, and with pleasant odor of free Aldehyde, CH_3CHO.

Alcohol is a colorless, limpid liquid, of sp. gr. 0·793. Boils at 78·4°. Miscible with water in all proportions. With sulphuric acid and an acetate, when heated, a pleasant odor as of apples, from Ethyl acetate, $CH_3COOC_2H_5$. Dissolve a little Iodine in it, then add KHO solution till colorless: on standing, light yellow scales of Iodoform CHI_3, separate.

Morphia, Strychnia, and **Brucia** can only be in solution as salts, as they approach insolubility in water. The solutions would be either neutral or more generally acid.

Potassium ter-iodide would give a brown resinous precipitate, conclusive of their presence.

Sodium carbonate, either at once, or on stirring, will give a precipitate of the alkaloid.

Morphia, $C_{17}H_{19}NO_3$, in solutions of its salts, is also precipitated by Ammonia; the precipitated Alkaloid is scarcely at all soluble in Chloroform, or in Ether, but easily in hot alcohol. Nitric acid gives a rich orange color, with nitrous fumes. Iodic acid is decomposed and Iodine set free with brown tint and distinctive odor; to one part add Chloroform and shake, the Chloroform will be tinted rose or amethyst; to the other part, add starch-paste, which will be blued. Ferric chloride strikes a blue color turning to green. If the Morphia is present as a *Meconate,* the Morphia will behave in the same manner to the various tests, except that with Ferric chloride it will give a cherry-red color, with difficulty removed by Hydrochloric acid, and also will give a white ppt. with Acetate of Lead and with Chloride of calcium. The Ferric chloride test is decisive (p. 52). Sulphuric acid gives scarcely any change of appearance with a Morphia-salt in solution; but on addition of solution of Di-chromate of potassium the mixture passes from brown to green, owing to formation of a salt of Chromic oxide.

Morphia crystallizes in six-sided prisms, of bitter taste, soluble in 500 parts of water, with alkaline reaction. Insoluble in Chloroform and in Benzene. Soluble in excess of Potash. On platinum it melts, burns like a resin with sooty flame, leaving very little carbon in the form of a soot easily combusted. Its *Hydrochlorate,* $C_{17}H_{19}NO_3,HCl,3H_2O$, in tufts of needles, very soluble in water. *Acetate,* in needles. Ferric chloride, a port-wine colour in an Acetate of morphia, the color removed by a few drops of Hydrochloric acid. In an Acetate, Lead acetate gives no precipitate as it does in a meconate.

Strychnia, $C_{21}H_{22}N_2O_2$, in solutions of its salts is at once precipitated by potash, ammonia or carbonate of sodium; it is almost insoluble in absolute alcohol, but very soluble in chloroform. If therefore the white ppt. be shaken with chloroform, the liquid becomes clear, and the chloroform on evaporation leaves the strychnia. No change of color with H_2SO_4, but on stirring a mere speck of Manganese di-oxide or Lead peroxide with this acid mixture, a deep rich blue color is produced, changing to purple, crimson, and red-brown. The same colors with $K_2Cr_2O_7$ and K_3FeCy_6. Curarine gives similar reactions, but is insoluble in Chloroform.

Strychnia requires 7000 parts of water for solution; blues red litmus. Crystallizes in octahedra, or in short six-sided prisms. Intensely bitter. Soluble in Chloroform, Amylic alcohol and hot Benzene. It is as insoluble in ether as in absolute alcohol. Salts quite neutral, or acid. Heated on Platinum, it melts into a dark brown liquid, combusts with resinous flame, gives out an agreeable odor, and leaves Carbon, which burns away.

Brucia, $C_{23}H_{26}N_2O_4$, in solution of its salts is precipitated by Potash, Ammonia or Carbonate of sodium: very soluble in Ethyl or Amylic alcohol. Strong Nitric acid imparts a rich scarlet color; if warmed, orange and then yellow. Stannous chloride changes the red to purple, bleached by excess. Sulphuric acid no change of color, but with H_2SO_4 and Potassium di-chromate a red-brown color, changing through green to yellow.

Brucia crystallizes in needles, or four-sided prisms. Insoluble in ether; easily soluble in chloroform. On platinum, when heated, it melts into a pale liquid, darkens, vaporizes in part, and leaves abundant carbon, which burns away without residue.

CLASS B. IN ADMIXTURE WITH FOREIGN SUBSTANCES.

It is better to save time by at once distilling a portion of all solutions, whether simple or mixed, for which purpose a retort and flask are supplied. Cool the condensing flask in a basin of cold water, covering the flask with wet blotting-paper, or a wet cloth. If the mixture is very thick, it must be diluted with water and the distillation watched in case of frothing. In cases of spurting, re-distillation must take place.

Carbolic acid or **Phenol,** C_6H_5OH, has been already described. Should be recognized by the odor. If necessary, distil and examine the colorless distillate in small part with Ferric chloride; a violet color. Confirm.

Hydrocyanic acid. HNC. Odor of itself. Constriction of throat. Solution faintly acid, or if present as cyanide of potassium, strongly alkaline, yet odorous of peach-blossoms. Place a small portion in a beaker, if solution alkaline add Tartaric acid, and place a watch-glass, dotted over with Nitrate of Silver on the underside, on the beaker. In a few minutes opalescent drops from covering of Silver cyanide, soluble in strong Nitric acid and in Ammonia, will have indicated either the acid or the soluble cyanide. Distil a small quantity, acidulating if necessary. Tests. (*a*) Silver nitrate. (*b*) Ferrous sulphate, Potash, warm, and Hydrochloric acid in excess; Prussian blue.

If a Cyanide, evaporate with a few drops of Hydrochloric acid, and test the ash for Potassium by re-solution and Platinic chloride.

If Cyanide of mercury, solution is neutral, and Hydrochloric acid will set free Hydrocyanic acid (p. 42). On addition of H_2S, white Mercuric Chloro-sulphide, changing through yellow, orange, and black to Mercuric sulphide, insoluble in Nitric acid, soluble in

Aqua regia as Mercuric chloride. Evaporate to dryness, and use tests for Mercuric (p. 23).

Phosphorus, P_4, should be recognized by the odor when solution stirred or shaken up. Distil, and look for signs of Phosphorus vapor, white fumes and odor of Ozone, and, in the dark, for luminosity. Silver nitrate should give a brownish ppt. in distillate, or silver nitrate paper held in the vapors should be darkened. A little of the distillate added to a Marsh's apparatus in full activity, should tinge the Hydrogen flame green in the centre. A further portion of the Distillate should be boiled for some time with strong HNO_3, till the Phosphorus is oxydized to Phosphoric acid; then warm with acid Molybdate solution: yellow ppt.

Caustic alkalies. Solution strongly alkaline. If **Ammonic hydrate** present, the odor will be more pronounced on heating, and the usual tests will probably be sufficient: if not, distil a portion and examine for Ammonia (p. 34). No reaction with Sodium carbonate. Sulphate of Copper a precipitate which may or not, be recognizable by color. Evaporate to dryness, incinerate, dissolve in water, acidulate with Hydrochloric acid and test by Flame, and by Platinic chloride, for **Potassium** or **Sodium** (p. 35).

Mineral acids. Solution odorless. Strongly acid. Effervescence with Carbonate of Sodium. On distillation of a portion, **Hydrochloric acid** or **Nitric acid** would be found in the receiver. The tests will be found at pp. 49, 57. Either of these acids will probably be discoverable in the mixture. **Sulphuric acid** will precipitate Barium chloride, and the ppt. will be insoluble in acids. A drop of the liquid upon filtering paper will char the spot when carefully heated.

Oxalic acid, $C_2O_2(OH)_2,2H_2O$, even in admixture, odorless, strongly acid, effervescence with Sodium carbonate. Calcium chloride will give a ppt. even in very dilute solutions, insoluble in Acetic acid: collect on a filter, wash, and prove Oxalate of calcium (p. 111). Silver nitrate a ppt. soluble in dilute nitric acid: if a chloride also present, the precipitated Silver chloride is insoluble and separable by filtration from the Oxalate of Silver. For further tests, p. 48.

In testing for the **Metals,** it should be remembered that several of the Metals, especially **Lead** and **Silver,** may be precipitated by the foreign substances contained in the Admixture.

It is well to shake up the Admixture, to acidulate a portion with dilute Sulphuric acid, and boil in a wide test-tube with a piece of a knitting-needle, or some other form of steel. **Copper** will be deposited with or without metallic lustre, but with characteristic color (p. 23).

A further portion should be warmed with dilute Sulphuric acid, and scraps of pure Zinc. If any **Arsenical** or **Antimonial** compound is present, Arsine AsH_3 or Stibine SbH_3 will be evolved and detected by the deposit of black Silver in the case of Arsine, or of black Antimonide of Silver Ag_3Sb in the case of Stibine, on a filter paper dotted with Nitrate of Silver solution held in the tube in which the experiment is performed. If **Mercury** is present, the Zinc will be beautifully lustrous. **Lead** and **Silver** will also be precipitated as grey coatings, or as metallic crystals, if in large quantity. If desired, the excess of Zinc may be dissolved and leave the other metal, Cu, Pb, Hg, Sn or Sb. (See respective metals.)

A further portion, similarly shaken up and made acid by Hydrochloric acid, may be boiled with strips of Copper. Thus may Reinsch's test be used in the case of Silver and Mercury, as well as of Arsenicum and Antimony. In the case of Silver, the deposit is lustrous, silver-white, and not removed by heat.

Mercury is also silver-white and lustrous, but on removing the copper, drying on blotting-paper, and heating in an arsenical tube, the Mercury volatilizes as a mirror, which, on stirring with a match or wire, gives round globules of Mercury.

Another method may be employed. Evaporate a large portion of the shaken-up Admixture in a porcelain dish, calcine as completely as possible, dissolve the Ash in a few drops of Nitric acid, evaporate to dryness, re-dissolve in water, filter if necessary and test the filtrate with Hydric Sulphide for **Lead, Copper** and **Silver.** The black or brown precipitate collect, decant or filter, wash, dissolve by heat in dilute Nitric acid, evaporate to remove excess of acid, and test for Lead, Copper and Silver in the ordinary way.

Potassium iodide gives with **Lead,** bright yellow Lead iodide PbI_2, with **Copper,** grey Cuprous iodide Cu_2I_2 and free Iodine, with **Silver,** light yellow Silver iodide AgI, insoluble in HNO_3 and in NH_3.

Potassium dichromate gives with Lead, yellow $PbCrO_4$, with Silver, crimson-red Ag_2CrO_4, with Copper, orange-brown $CuCrO_4$.

If the ppt. considerable, a portion of the sulphide may be ignited on charcoal with Na_2CO_3 in the reducing flame of the blowpipe, the mass cut out, pounded, washed to remove charcoal; **Lead** in flattened spangles so soft as to mark paper, **Copper** in red globules, and **Silver** in brilliant white rather hard beads.

Arsenic and Mercury will not be found in the ash.

If the ash has been yellow while hot, and white on cooling, moisten a portion on platinum-foil with dilute Cobalt nitrate: ignite strongly in the outer blowpipe-flame: **Zinc** will give a green mass. Other tests for Zinc at p. 28.

Barium may be present as: 1. Soluble salt. Dilute Sulphuric acid will give a white ppt. of $BaSO_4$, insoluble in HCl. 2. As insoluble Carbonate and Phosphate of Barium, precipitated by the foreign substances in the Admixture: these dissolved in Hydrochloric acid will give the Barium-flame and the ppt. of $BaSO_4$ with H_2SO_4 insoluble in HCl. 3. As insoluble Barium sulphate, a white or discolored sediment, insoluble in HCl. Collect on a filter, or calcine, fuse with pure Na_2CO_3: Sodium sulphate and Barium carbonate will be formed. Dissolve in water, filter and test the filtrate for Sulphate (p. 44): the Barium carbonate on the filter should be well washed with distilled water, dissolved in Acetic acid and tested for Barium. On clean Platinum wire, a yellowish-green color to flame. Calcium sulphate an immediate white ppt. of $BaSO_4$, insoluble in HCl.

FURTHER DIRECTIONS FOR THE DETECTION OF THE COMMON INSOLUBLE BODIES.

Notice color and appearance.

I. IF BLACK. Possibly cupric oxide, antimonous sulphide, manganese peroxide, ferrous sulphide, nickel, or cobalt sulphide, mercuric sulphide, bismuth sulphide, lead sulphide, cupric sulphide, silver sulphide, carbon as graphite, carbon as charcoal. Boil at once the finely-pounded substance with HCl.

Cupric oxide, CuO dissolves as green Cupric chloride $CuCl_2 + H_2O$ in HCl; precipitated black by H_2S, and the Sulphide insoluble in NH_4OH and in $(NH_4)_2S$, (p. 22). Heated with HCl, a green and blue flame. Unchanged on heating.

Antimonous sulphide, Sb_2S_3 dissolves as $SbCl_3$, with evolution of H_2S. Thus: $Sb_2S_3 + 6\ HCl = 2\ SbCl_3 + 3\ H_2S$. Orange-red sulphide precipitated by H_2S, soluble, when neutralized, in $(NH_4)_2S$ (p. 18). Confirm H_2S by lead-paper, which is blackened.

Manganese peroxide, MnO_2 dissolves in HCl as manganous chloride, with evolution of chlorine. $MnO_2 + 4\ HCl = MnCl_2 + 2\ H_2O + Cl_2$. Ignited on platinum changes to red-brown. Manganous manganic oxide Mn_3O_4. Thus: $3\ MnO_2 = Mn_3O_4 + O_2$. Further heated with Na_2CO_3 gives a fused blue-green mass of manganate of sodium Na_2MnO_4. $3\ MnO_2 + 2\ NaHO = Na_2MnO_2 + Mn_2O_3 + H_2O$.

Ferrous sulphide, FeS soluble as Ferrous chloride with evolution of H_2S. $FeS + 2\ HCl = FeCl_2 + H_2S$. No ppt. with H_2S, nor with NH_4OH after addition of NH_4Cl. Black ppt. with Ammonium sulphide. Confirm Ferrous by K_3FeCy_6, and H_2S by Lead-paper (p. 39).

Nickel and **cobalt sulphides.** Soluble in strong HCl, or in HNO_3. Color of respective solutions green or pink (pp. 30 and 31).

Mercuric sulphide, HgS. Insoluble in HCl and in dilute HNO_3. Boiled with Aqua regia, gives Mercuric sulphate and chloride, with Sulphur. Then $HCl + H_2S$, characteristic ppt. of Mercuric (p. 23). Volatile on Platinum. Heated in dry glass tube, sublimes.

Bismuth sulphide, Bi_2S_3 almost insoluble in HCl: readily in HNO_3. Solution gives a brown ppt. with H_2S, insoluble in NH_4HO and in $(NH_4)_2S$. $K_2Cr_2O_7$, orange ppt. insoluble in KOH (p. 24).

Lead sulphide, PbS. Native galena has lustre and appearance of lead: but is brittle. Slowly soluble in HCl, with evolution of H_2S; filtered, H_2S, gives a slate-colored ppt. insoluble in NH_4OH and $(NH_4)_2S$.

Boil a further portion with HNO_3, yellow sulphur is separated together with lead sulphate, and lead nitrate in solution. $K_2Cr_2O_7$, yellow ppt., soluble in KOH (p. 16).

Cupric sulphide, CuS almost insoluble in HCl. Dissolves readily in HNO_3 to blue solution, with deposit of sulphur. H_2S to solution gives black ppt. Steel deposits red copper (p. 22).

Silver sulphide, Ag_2S but little affected by HCl. Boiling nitric acid would dissolve it as nitrate, with some sulphate, and sulphur would separate. HCl, a white curd-like ppt. soluble in NH_4OH (p. 109).

Carbon as Graphite, a soft powder, of semi-metallic lustre: Marks paper: " black lead." Insoluble in acids. Combustible with difficulty, usually leaving reddish-colored residue of ferric oxide. Deflagrates with nitrate of potassium.

Carbon as Charcoal is insoluble in HCl or in HNO_3. Burns away on Platinum, leaving a little white ash, alkaline from Carbonate of Potassium. Heated with H_2SO_4, gives off SO_2 and CO_2. Deflagrates when fused with KNO_3.

II. IF RED. Possibly, mercuric oxide, mercuric sulphide as vermilion, red lead, or basic chromate of lead.

Heat in a porcelain capsule, and boil a further sample with HCl.

Mercuric oxide turns black when heated, and volatilizes as 2Hg and O_2. Soluble in HCl as Mercuric chloride $HgO + 2HCl = HgCl_2 + H_2O$ (p. 23).

Vermilion, HgS. Volatile when heated. Dissolves in Aqua regia. Its volatility and color refer to Mercuric (p. 104).

Red lead. Pb_3O_4. Strongly heated evolves O. Heated on platinum, fuses to yellow oxide of lead. Dissolves in HCl, evolving Cl_2, to colorless Lead chloride, giving crystals on cooling. The solution with H_2S gives slate-colored ppt. insoluble, when neutralized, in NH_4OH and $(NH_4)_2S$. Red Lead warmed with dilute Nitric acid, is decomposed into Oxide of Lead which dissolves as Lead nitrate and insoluble puce-colored Peroxide PbO_2. $Pb_3O_4 + 4\ HNO_3 = 2(Pb2NO_3) + PbO_2$. For lead, p. 15.

Basic chromate of lead. Heated on platinum, darkens.

Boiled with HCl, Chlorine is evolved, white Chloride of Lead is precipitated, and green Chromic chloride is found in solution. For Chromic oxide see p. 107.

III. IF SOME SHADE OF PURPLE-BROWN, OR RED-BROWN. Possibly, amorphous phosphorus, lead peroxide, or cupric ferrocyanide, ferric hydroxide or ferric oxide.

Heat in a porcelain capsule, and boil a further portion with HCl.

Amorphous phosphorus. When heated to 260°, it burns like ordinary Phosphorus with white suffocating vapors of Phosphorus pentoxide. Forms a fusible alloy with Platinum. Untouched by HCl. Slowly dissolved as Ortho-phosphoric acid in boiling nitric acid (p. 44).

Lead peroxide, PbO_2. Heated on porcelain fuses as yellow Oxide of lead. See Red lead (p. 105).

Cupric ferrocyanide, $Cu_2FeC_6N_6$. Heated, it burns and blackens. Dissolves in dilute HCl, and then gives Prussian Blue with Fe_2Cl_6.

Boiled with HCl, evolves Hydrocyanic acid (p. 42), and gives green solution of Cupric chloride (p. 22).

Ferric oxide, Fe_2O_3, various tints of red-brown. Heated on platinum, a deeper brown. With difficulty soluble in HCl as ferric chloride, with yellow or yellow-red colour. Easily soluble in $HNO_3 + HCl$. H_2S reduces the solution to Ferrous salt, with deposit of yellow sulphur. K_4FeCy_6, added to the solution gives Prussian blue (p. 26).

Ferric hydroxide, $Fe_2O_3, Fe_2(OH)_6$, dissolves easily in boiling HCl to yellow or yellow-red Ferric chloride Fe_2Cl_6 (p. 26). Heated in a tube, it gives off water, proving a Hydroxide, and turns to red-brown Ferric oxide.

IV. IF A SHADE OF ORANGE, OR YELLOW. Possibly Antimonous sulphide, Arsenious sulphide, Mercuric oxide, a basic Mercuric salt, Stannic sulphide, Cadmium sulphide, Lead chromate, Sulphur, or Lead oxide.

Heat in a porcelain capsule; test with Ammonium sulphide, and a further portion with HCl.

Antimonous sulphide Sb_2S_3, precipitated orange colored, fuses to black glass, evolves SO_2, gives flame of Antimony, and alloys with platinum. Soluble in Ammonium sulphide, and separates as orange-red Sulphide on evaporation of the solution. Dissolves as Antimonous chloride in HCl, with evolution of H_2S (p. 39).

Arsenious sulphide As_2S_3, darkens in color, and fuses to a black mass when heated: sulphur burns with arsenical flame, and the Arsenicum forms a fusible alloy with platinum. Soluble to colorless solution in ammonium sulphide, separating on evaporation as yellow sulphide. Insoluble in HCl. Gives a mirror of arsenicum, when heated in a narrow tube closed at one end, with Na_2CO_3 and charcoal.

Mercuric oxide HgO, precipitated, is yellow. Black when heated, and volatilized as $2Hg + O_2$. Dissolves in 2HCl, as mercuric chloride. Blackened by ammonium sulphide (p. 23).

Basic Mercuric salts are yellow. Dissolve in dilute HCl, and examine for Mercuric, for Nitric and Sulphuric acids.

Cadmium sulphide CdS, yellow. Heated in porcelain capsule, brown oxide remains, and sulphur dioxide is evolved with smell as of burning brimstone. Insoluble in sulphide of ammonium. Soluble in hot HCl, as chloride, with evolution of H_2S. $HCl + H_2S$, yellow ppt. (p. 20). On charcoal with Na_2CO_3 a brown incrustation.

Lead chromate, yellow. When heated, it melts, and becomes dark brown. Evolves oxygen and becomes partly Chromic oxide, and basic Chromate of lead. Blackened by Ammonium sulphide. Boiled with HCl, it evolves Chlorine, and we obtain a green solution of Chromic chloride, together with white crystals of Lead chloride. Lead chromate is soluble in KOH (p. 16). Fused with Na_2CO_3, on charcoal, globules of Lead with yellow incrustation, and yellow Chromate.

Sulphur, pale yellow. Fusible to red-brown liquid, burning with violet flame to sulphur dioxide: no residue. Soluble in Ammonium sulphide. Insoluble in HCl. Boiled with H_2SO_4, SO_2 is evolved. Boiled with concentrated nitric acid, orange fumes are evolved owing to the oxydation of Sulphur to sulphuric acid (p. 44), and the consequent reduction of nitric acid.

Lead oxide PbO, or Litharge, is deep yellow. Fuses to deep orange liquid. Blackened by Ammonium sulphide. Slowly dissolved in boiling HCl, with separation of lead chloride. More readily dissolved in boiling HNO_3, to lead nitrate. Solution with H_2S, slate colored PbS; with $K_2Cr_2O_7$, yellow Lead chromate, soluble in KOH (p. 16).

V. IF GREEN. Probably chromic hydroxide, chromic oxide, emerald-green, or cupric salts.

Chromic hydroxide, bluish-green, soluble in HCl to green chromic chloride. Heated on platinum with Na_2CO_3, a yellow, fused mass of chromate. Heated in a tube, much water evolved (p. 106), and darker Cr_2O_3 formed.

Chromic oxide, green. With difficulty soluble in HCl. No water evolved on heating, but merely moisture. Ignited, it is almost insoluble in acids; must be fused with $Na_2CO_3 + KNO_3$; yellow mass dissolve in Acetic acid, and test for Chromate (p. 47).

Emerald Green. Cupric aceto-arsenite. Blackened by Ammonium sulphide. Dissolves in Ammonic hydrate with blue color, in which Copper detectible by a knife-blade. Distilled with HCl, Arsenious chloride is found in the distillate, and detectible by H_2S. On addition of Sulphuric acid and ethyl alcohol to a portion, Ethyl acetate evolved. Cupric, p. 22; Arsenicum, p. 45; Acetates, p. 51. If a little of the solution of the salt be spread on a white plate, and a fragment of solid Silver nitrate placed in the middle, a ring of yellow Silver arsenite will form round the silver nitrate. Distillation with HCl, and Silver nitrate, as given above, are the two best tests for Scheele's green, **Cupric arsenite**, in wall papers.

Malachite would dissolve with effervescence as cupric chloride in HCl, as it is a Basic carbonate.

VI. IF BLUE. Probably indigo, Prussian blue, ultramarine, cobalt-blue and many insoluble cupric salts.

Indigo has a dark blue tint with coppery lustre. It is unchanged by H_2SO_4, or by cold potassium hydroxide. On platinum, when heated, purple vapors of the pure substance are evolved, and it burns leaving but little ash.

Prussian blue is turned white by H_2SO_4, evolving Prussic acid CNH, (p. 42). Heated with Potassium hydroxide into brown Ferric hydroxide (p. 106), and solution of Potassium ferrocyanide (p. 51). On platinum, heated, a copious ash of Ferric oxide.

Ultramarine, bright-blue; unchanged by alkalies; turned white by HCl, evolving H_2S.

Cobalt (Thénard's blue) is unchanged by dilute acids and alkalies. Borax bead, blue. **Smalt** similar, but no Alumina.

Insoluble **Cupric salts** dissolve easily in HCl, with blue or green color. Azurite $2CuH_2O_2$, $CuCO_3$, dissolves in HCl with effervescence.

VII. IF WHITE, OR NEARLY WHITE. Names are legion.

SECTION A. *Blackened by ammonium sulphide.* Compounds of Mercury, Lead, Silver, Bismuth, Cuprous and Stannous. *Orange* or yellow, soluble in excess, Antimonous and Stannic.

Calomel, Hg_2Cl_2, completely volatile. Blackened by Ammonic hydrate; the solution decanted, gives, with Nitric acid and Silver nitrate, the characteristic reaction of a Chloride (p. 49). Boiled with copper and dilute Nitric acid, silvery coating of mercury. Aqua regia dissolves Mercurous as Mercuric chloride. (Absence of Mercuric chloride in Mercurous: boil with water, decant and add Lime-water: if a yellow ppt. mercuric present.)

Lead hydroxide, PbH_2O_2, unchanged by Ammonia. Dissolves as Lead chloride in HCl to $PbCl_2$, which may crystallize out in shining needles. On Platinum fuses to yellow oxide. Gives beads of Lead, with yellow incrustation, heated on charcoal (p. 15).

Lead hydrocarbonate, $PbCO_3$, PbH_2O_2; "White lead." Dissolves with effervescence in HCl, or better in HNO_3, as a salt of lead. Other tests at p. 15.

Lead sulphate, $PbSO_4$, also unchanged by Ammonia. Strong HCl dissolves sufficient to give white ppt. with Barium nitrate, proving Sulphate (p. 44). Fused on Charcoal with Na_2CO_3, beads of

Lead, with yellow incrustation; the beads, washed and dissolved in HNO_3, give the reactions of Lead nitrate; the mass moistened on a Silver coin, gives the browning or blackening of a Sulphide (p. 39), and the odor of H_2S.

Silver chloride, AgCl. Dissolved by Ammonia, and re-precipitated by Nitric acid. Insoluble in acids. Fuses on charcoal; "Horn-silver." Fused on charcoal with Na_2CO_3: beads of Silver and a mass containing Sodium chloride. Dissolve the washed beads in Nitric acid, and confirm Silver (p. 16), and test for Chloride in the dissolved Sodium carbonate and Chloride (p. 49).

Silver cyanide, AgCN. Dissolved by Ammonia. With concentrated HCl, yields Hydrocyanic acid (p. 42). Heated on Charcoal, Cyanogen burns with peach-blossom colored flame, and metallic Silver remains: the metal tested as at p. 17, dissolved as a Nitrate in nitric acid.

Bismuth sub-nitrate, $BiNO_4,H_2O$. Unchanged by Ammonia. Soluble in HNO_3, solution precipitated by water, and ppt. increased by tartaric acid; solution gives reactions for Bismuth (p. 23). Heated on charcoal, metallic beads, brittle, with scanty yellow incrustation. The powder in a test-tube with Ferrous sulphate, gives with H_2SO_4 the reaction of a Nitrate (p. 57).

Bismuth oxy-chloride, BiOCl; similar to the above, but the solution in Nitric acid gives the reaction of a Chloride (p. 49).

Ferric phosphate, blackened by Ammonium sulphide. Unchanged by Ammonia. In HCl soluble with yellow color, re-precipitated by NH_4OH, not re-dissolved by Acetic acid. The solution in HCl gives, when warmed with Nitric acid solution of molybdate, a yellow ppt. (p. 44), and with K_4FeCy_6, Prussian blue. For Ferric, p. 26.

Antimonous oxide. Orange-red by Ammonium sulphide, soluble in excess, and depositing Sb_2S_3 on evaporation. No change with Ammonia. Dissolves in HCl as Antimonous chloride, $SbCl_3$ precipitated by water as white Oxy-chloride, dissolved by Tartaric acid, and precipitated by H_2S as orange-red Antimonous sulphide (p. 19).

Antimonous oxy-chloride, SbOCl, like the former, but when fused with Na_2CO_3 on charcoal and treated with water, Chloride of Sodium dissolves and may be tested by $AgNO_3$ (p. 49). The remaining globules of Metallic Antimony are brittle, soluble in HCl, and detected as at p. 19.

Stannic oxide, SnO_2, yellow with Ammonium sulphide and dissolved slowly, then re-precipitated by HCl as yellow hydrated sulphide. On charcoal, with Na_2CO_3, gives beads of lustrous, malleable tin, with white incrustation; the metal dissolved in hot HCl gives the reactions of stannous (p. 20). When ignited, stannic oxide is insoluble in HCl; may be fused with Na_2CO_3, and then dissolved in HCl as $SnCl_4$.

SECTION B. Not discolored by Ammonium sulphide beyond the yellow color of the test.

Boil a portion of the unknown substance with Hydrochloric acid.

a. **It dissolves.** Compounds of Aluminum, Zinc, Magnesium, Barium, Strontium or Calcium.

Heat on Platinum, moistening with HCl; **Zinc** gives a bluish flame, and the mass is yellow only whilst hot; **Barium** gives a yellowish-green, **Strontium** a crimson, **Calcium** a yellowish-red color to the flame.

Among the radicles, Nitrates, Chlorates, Acetates, and Chlorides need not be looked for in this Section, as the only insoluble Subnitrate is that of Bismuth, and the only insoluble Chlorides are of Silver and mercurous, all decomposed and turned into black Sulphides by Sulphide of ammonium.

On heating with HCl, effervescence, without odor, denotes **Carbonates** (p. 39); a smell as of a burning brimstone match, **Sulphites** (p. 39).

Test the solution for an **Arsenite,** or **Arsenate,** by addition of H_2S, and look for both of these acids as directed at pp. 45, 46, and for a **Phosphate,** after proving the absence of an Arsenate, by means of acid Molybdate and heat (p. 44).

A portion must be heated on Platinum with H_2SO_4, when a green mantle to the flame will indicate a **Borate.**

Some **Silicates** gelatinize with HCl; after evaporation, ignition, and re-solution in HCl, **Silicon dioxide,** SiO_2, will be left as an insoluble white powder (p. 42), and Chlorides of the basyls will be found in solution.

After ignition, if with only slight darkening, it is turned into a Carbonate, then effervescence with HCl, and solution of Chlorides of basyls, **Oxalates** will be indicated.

Charring, with odor of burnt sugar, leaving a Carbonate or Oxide, a **Tartrate.** Dissolve in HCl, and test for basyl in the Chloride.

Charring, with pungent odor, leaving a Carbonate or an Oxide, probably a **Citrate.** Dissolve in HCl, and test for basyl in the chloride.

If no radicle has been found, an **Oxide** or **Hydroxide** is probably present: the latter gives off water when heated in a test-tube.

A few examples may suffice:

Zinc oxide, ZnO, white when cold, yellow when hot. Moistened with Nitrate of Cobalt and re-heated strongly Rinman's green (p. 28). Dissolved in HCl, no other acid but the solvent HCl discoverable.

Magnesia, MgO, white very light powder. Unchanged by heat, Ignited with Cobalt nitrate, pink. Solution in HCl, gives the reactions of magnesium (p. 23). When moistened, magnesia blues red litmus paper.

Calcium Oxide, CaO, white, unchanged by heat. Sufficiently soluble in water to be detectible as Lime-water, or Calcium hydroxide in water. The powder boiled with water, and filtered, is alkaline to test-paper, and gives a white ppt. with Na_2CO_3. Silver nitrate will indicate a Hydroxide, and further tests will prove Lime (p. 33).

The Student can always ascertain for himself as to solubility or otherwise, by placing a drop on the inside of a dry test-tube near to the open end, and evaporating over the gas. A stain more or less distinct will prove one way or the other.

Aluminum Oxide, Al_2O_3, is white, unchangeable by heat. Moistened with nitrate of cobalt, and re-ignited, Thénard's blue. When fully ignited it is not soluble in HCl, and must be fused with Na_2CO_3 (p. 27).

Aluminum phosphate, $AlPO_4$, is white, unchangeable. The solution in HCl gives Phosphate reaction with acid molybdate (p. 44), and on Platinum, when ignited with Cobalt nitrate, Thénard's blue (p. 27). Insoluble in Acetic acid.

Barium, Strontium, Calcium and **Magnesium phosphates** dissolve in HCl with ease; also in Acetic acid. Unchanged by heat. Moistened with HCl and heated, Ba gives yellowish-green color to flame, Sr crimson, Ca yellowish-red, Mg no reaction. To remove the Phosphate, so as to obtain only Chlorides of the respective metals in solution, add to the HCl solution Acetate of Sodium, then Ferric chloride till a distinct red color appears in the supernatant fluid: **Ferric phosphate**, $FePO_4$, is thrown down. Boil, filter, precipitate by Ammonia any Ferric in solution, filter, and examine the filtrate for Ba, Sr, Ca, and Mg. The phosphate will be discovered by the acid molybdate in the HCl solution (p. 44).

Calcium oxalate, CaC_2O_4, white. Heated on platinum, becomes grey in color, and is converted into Carbonate, insoluble in water, alkaline from presence of some Calcium oxide, soluble, with effervescence, in HCl, and only gives reactions of Calcium (p. 33). The powder, boiled with Sodium carbonate, gives Sodium oxalate in solution (p. 48), and insoluble Calcium carbonate.

Carbonates of Barium, Strontium, Calcium, and **Magnesium** are white and infusible. Moistened with HCl, effervescence, and on re-heating the characteristic colors of Ba, Sr and Ca to flame, as just given.

[**Cream of Tartar**, or **Hydro-tartrate of potassium**, $KHC_4H_4O_6$. is often passed over as insoluble. Acid reaction. Effervescence from H_2S when sulphide of ammonium added. Easily soluble in KHO, and gives ppt. of $KHC_4H_4O_6$ on careful addition of HCl. On Platinum violet color to flame, smell of burnt sugar as the Tartaric acid is decomposed, and Carbon which burns away, leaving fused Carbonate of potassium. The latter dissolves in little water, is alkaline, effervesces with HCl, and gives yellow ppt. with $2HCl,PtCl_4$.]

b. **The white substance does not dissolve.**

When hydrochloric acid or nitric acid have failed in effecting solution, it is as well to look at once for several common white powders.

Barium sulphate, $BaSO_4$ white, insoluble. Moistened with HCl on platinum, it gives yellowish green flame of Barium. On Charcoal, heated with Na_2CO_3, the mass boiled with water and filtered, the insoluble part can be tested after solution in HCl for Ba (p. 32), and the soluble, containing Sulphide and Sulphate, indicates the former by blackening silver-coin on which it is laid, by the smell of H_2S, &c.

Strontium sulphate, $SrSO_4$, requires same treatment as $BaSO_4$, but is sufficiently soluble in HCl to give a reaction with $CaSO_4$ (p. 32). and the crimson color to flame.

Calcium sulphate, $CaSO_4$, is sufficiently soluble in water to be a test for Ba and Sr (pp. 31, and 32), although it is often passed over by the student as insoluble. Test for Ca (p. 33), and for sulphate (p. 44).

Calcium fluoride, CaF_2, is at once decomposed by H_2SO_4. Hydrofluoric acid, which etches, or corrodes glass, is then easily detected, and the Calcium in the Calcium sulphate.

Silica, SiO_2, white, insoluble, infusible. Easily dissolved by HF, as Silicon fluoride, SiF_4. Fused on Platinum with Na_2CO_3, effervescence from escape of CO_2, and dissolves to a clear glass, soluble on boiling with water, and the Silica discoverable as at p. 42. Many Silicates are insoluble in all acids, except Hydrofluoric acid.

As a rule, if a **substance is insoluble in acids. and is not acted upon by Ammonic sulphide, fuse with Na_2CO_3, in a Platinum crucible.** Silicates are thus unlocked, and such basyls as Ba, Sr, Ca, Mg, Al_2, Fe_2, &c., will be found in solution as chlorides, if the fused mass be boiled with water and HCl, evaporated to dryness, ignited and re-dissolved in HCl. All the **Silica** will remain undissolved. If no Silica is present, there will be no residue, and such Oxides as Alumina and others which are, when strongly ignited, scarcely attacked by acids, will be found in solution as Chlorides of the respective metals. Of course, if Sulphates are present, these will be easily detected.

When the metals **Potassium** and **Sodium** are to be looked for in insoluble Silicates, the very finely-pounded mineral must be unlocked with Barium hydrate instead of Sodium carbonate.

ANALYSIS OF MIXTURES.

The foregoing methods, slightly modified, enable us to separate the metals.

Preliminary tests as before (pp. 1–4), but the Na_2CO_3 test is not so decisive as in a simple salt.

Alkaline solutions may contain bases such as Lead hydroxide, Stannic or Stannous hydroxide dissolved in Alkalies. Add HNO_3, or HCl, till moderately acid, and warm till clear.

Acid solutions may contain salts, such as Phosphate of Calcium, dissolved in an acid. These will mostly be precipitated by Ammonia in the Aluminum group.

A solid must be boiled first with water, filtered, and a portion of the filtrate evaporated on platinum to see if anything has dissolved. Place a drop in the upper part of a clean test-tube held horizontally, and evaporate gently. Thus the residue is more easily seen. If any, test the solution separately.

The portion insoluble in water should be boiled with HCl. Notice evolution of gas or odor, and, if anything has dissolved, proceed to test.

When insoluble in HCl, boil a fresh portion with HNO_3; if it dissolves, boil off most of the acid, dilute, and apply the following process.

The portion insoluble in acids should be treated as at p. 65.

N.B. In separations, the reagent must always be added till all the substance has been precipitated. It is necessary to pass H_2S in the form of gas.

GROUP I., Ag, Pb, Hg_2 (ous).

Add to the solution **Hydrochloric acid**: if no ppt. Group I. is absent; if a ppt., continue the addition till all is thrown down. Collect on a filter, wash with water, collecting the first washings in the filtrate and preserve the Filtrate for the other Groups.

Treat the ppt. with boiling water, **Lead chloride** will dissolve, and the filtrate will give with dilute H_2SO_4 a white ppt. of $PbSO_4$, with KI yellow PbI_2, with $K_2Cr_2O_7$ yellow $PbCrO_4$, soluble in KHO. **Lead.**

Remove $PbCl_2$ by washing with hot water, and add NH_4OH. **Silver chloride** will dissolve, and will be reprecipitated on adding HNO_3 in excess to the filtrate. Collect AgCl, and confirm by fusing with Na_2CO_3 on charcoal; beads of Silver (p. 17). **Silver.**

Mercurous chloride will not dissolve, but will turn black. Confirm Mercurous by p. 17. **Mercurous.**

If Lead is present, as $PbCl_2$ is somewhat soluble in water, it will always be found also in Group II.

GROUP II.

Sub-group A. Sulphides soluble in $(NH_4)_2S$. As, Sb, Sn.

Sub-group B. Sulphides insoluble in $(NH_4)_2S$. Hg(ic), Pb, Bi, Cu, Cd.

Through the Filtrate from Group I., diluted with water if very acid, pass H_2S in excess, and boil for some time.

[N.B. Arsenic acid is very slowly precipitated by H_2S, requiring excess and much boiling. It may be reduced to Arsenious acid by Sulphurous acid and heat, boiling till SO_2 is expelled.]

No precipitate, or only a whitish ppt. of Sulphur, shows absence of Group II.; a *yellow* ppt. proves absence of Hg, Pb, Bi, Cu, and presence of Stannic, As or Cd, or it may be only Sulphur.

The ppt. is *black*: all the members may be present.

Filter. Keep the filtrate for remaining groups. Wash the ppt. digest it with $(NH_4)_2S$ (or better, with hot dilute KOH), and filter.

Sub-group A., soluble. To the filtrate add HCl: if a white ppt. is produced, it is Sulphur, and As, Sb, Sn, need not be looked for. Otherwise, wash the ppt., treat with $(NH_4)_2CO_3$ solution, and filter. Arsenic will dissolve, re-precipitated yellow by HCl; collect As_2S_3, and confirm by drying and heating with black flux, p. 46. **Arsenic.**

The portion insoluble in $(NH_4)_2CO_3$ should be fused with **Ammonium** or **Potassium nitrate,** whereby the Sulphides of Antimony and Tin are converted into Oxides: boil with Tartaric acid solution, and filter. Sb will dissolve: on adding to the filtrate HCl and H_2S, orange Sb_2S_3 will precipitate. **Antimony** (p. 19).

Sn will not dissolve in Tartaric acid: wash, dry, and fuse on charcoal with Na_2CO_3; beads of Sn, soluble in hot HCl to $SnCl_2$, and then giving a white to grey ppt. with $HgCl_2$, of metallic Mercury and a dark brown ppt. with H_2S. **Tin** (p. 20).

Sub-group B., insoluble. Wash well, and boil with dilute HNO_3. HgS alone is insoluble, any black remainder must be examined for **Mercuric** (p. 22).

Evaporate the solution nearly to dryness, dilute moderately, and add dilute H_2SO_4: Lead sulphate, white, will be precipitated. Collect and confirm **Lead** (p. 15).

To the filtrate add NH_4OH; white ppt. denotes **Bismuth** (p. 23).

If the ammoniacal solution is blue; **Cupric** (p. 21).

1. If copper is absent, add $(NH_4)_2S$: a yellow ppt. proves **Cadmium** (p. 24).

2. If **Copper** is present, re-precipitate the ammonia solution by HCl and H_2S, digest the sulphides with potassium cyanide solution: CuS will dissolve, and yellow CdS will be left behind.

Boil off H_2S, then add Nitric acid to change any Ferrous into Ferric salts: evaporate down to a few drops to get rid of excess of acid. Dilute with water, add NH_4Cl together with NH_3 in slight excess, collect on a filter and wash rapidly. [If NH_4Cl were not previously added, Ammonic hydrate would precipitate Magnesium hydrate, but, being soluble in NH_4Cl, it is prevented from separation in this its wrong Group. It is only precipitated here if Phosphoric acid is present, inasmuch as Ammonium Magnesium phosphate is insoluble in NH_4Cl.

GROUP III.

Ammonium chloride and Ammonia precipitate:

Ferric hydroxide.	Ferric phosphate.
Aluminic hydroxide.	Aluminic phosphate.
Chromic hydroxide.	Chromic phosphate.
Barium oxalate.	Barium phosphate.
Strontium oxalate.	Strontium phosphate.
Calcium oxalate.	Calcium phosphate.
	Magnesium phosphate,

and some Manganese.

N.B. Magnesium oxalate is not precipitated in presence of sufficient NH_4Cl. Chromic salts may re-dissolve with pink color in NH_4Cl and NH_3, but are precipitated dull green on boiling: therefore boil a short time. If Manganese is present, the solution may turn brown from oxydizing: all may precipitate, or some may be found in Group IV.

Wash the ppt. Heat a portion on Platinum: oxalates are changed into carbonates. Try the ash with HCl: if effervescence, **Oxalates** are present.

Dissolve another small portion in HCl, add acid Ammonic molybdate and warm: a yellow ppt. indicates **Phosphates.**

Proceed to ascertain the base.

1. Dissolve a portion of ppt. in HCl, dilute, add Potassic ferrocyanide: immediate dark-blue ppt. indicates **Iron.** Test original solution with both Potassic ferrocyanide and Potassic ferricyanide, to see whether Ferrous or Ferric (p. 25) present.

2. Fuse a larger portion of the group-precipitate on Platinum

with Na_2CO_3, and a little KNO_3. **Chromium** gives yellow Chromate: **Manganese** gives blue-green manganate: **Ferric oxide** remains undissolved as a red-brown powder. Aluminum dissolves without color. Dissolve in water, filter, add a drop of alcohol to the filtrate and boil: manganese will be reduced to brown Oxide and precipitated. Filter and again test residue on filter for Manganese. Filtrate is yellow if Chromium present: confirm by acidulating with Acetic acid and adding Lead acetate: yellow ppt. of Lead chromate. Also by reducing with alcohol and H_2SO_4 (p. 48).

To another portion of Filtrate add HCl till acid, then NH_4OH till alkaline and boil; a gelatinous ppt. indicates **Aluminum**: collect on Filter, wash and confirm by blow-pipe test, p. 27.

3. If an **oxalate** present, treat the ash, now converted into Carbonate, with Acetic acid and filter. Add to a portion of the filtrate Potassic chromate. **Barium** will yield a yellow ppt.: confirm by adding to another portion dilute Sulphuric acid. If an immediate ppt. **Barium oxalate** was in the original substance: filter and boil, and **Strontium** will be separated as sulphate. Again filter: **Calcium** remains and can be proved by neutralizing with NH_3, and addition of Ammonic oxalate, which precipitates CaC_2O_4.

4. If a **phosphate** is present. Dissolve the group-precipitate in HCl, add NH_3 in slight excess, and then excess of Acetic acid. Aluminic, Ferric and Chromic phosphates will remain undissolved. Filter: add Ferric chloride till on standing the supernatant liquid shows a red color from excess of Ferric acetate, boil till color removed from the solution properly diluted. Ferric phosphate, and basic Ferric, Aluminic and Chromic acetates will be precipitated, while **Ba, Sr, Ca** and **Mg** will remain in solution. Filter, and test filtrate for these latter by the Group V. method (p. 31).

N.B. The precipitated Sulphates of Barium and Strontium do not give the Flame-tests easily. Fuse each separately with Na_2CO_3 on Platinum: dissolve in little water, filter, wash well with water the residue of carbonate on the filter, dissolve in HCl, and apply the flame-tests (Ba, yellow-green, Sr, Crimson). Again: $SrCl_2$, soluble in absolute alcohol, $BaCl_2$, is insoluble.

Note. Borates and Fluorides of Ba, Sr, Ca, are also precipitated by ammonia, but not in NH_4Cl solution, unless much of them be present. They are best looked for in the original by H_2SO_4. Borate green flame. Fluoride corrodes glass.

GROUP IV., Zn, Mn, Ni, Co.

To the filtrate from the last group add $(NH_4)_2S$. Wash the ppt.; if it is white, only Zn is present, if black, Ni or Co must be present. Add cold dilute HCl, sulphides of Zn and Mn will dissolve, those of Ni and Co will remain insoluble. Filter rapidly.

a. Solution. Add KOH in excess; **Manganous** will be precipitated; **Zinc** will remain in solution. Filter and confirm each by blowpipe tests, reprecipitating the Zn by $(NH_4)_2S$.

b. Insoluble part. Test a portion with borax bead; Cobalt, dark blue; Nickel, brown-purple. If cobalt be present, nickel must be sought for as follows.

Dissolve the ppt. in aqua regia, evaporate nearly to dryness, add KCN solution in excess, boil, filter and add HCl in slight excess; **Nickel** will fall as cyanide, **Cobalt** will remain in solution as cobalticyanide.

GROUP V., Ba, Sr, Ca, Mg.

To the Filtrate from the preceding groups add $(NH_4)_2CO_3$, and warm. Ba, Sr and Ca will precipitate as carbonates. Wash the ppt., dissolve it in Acetic acid, and add K_2CrO_4 (neutral or yellow chromate), till **Barium** is precipitated. Filter; add K_2SO_4 and warm; **Strontium** sulphate will fall. Filter; add ammonia in excess and ammonium oxalate; **Calcium** will be thrown down as oxalate. Confirm each ppt. by flame test (p. 33).

To a portion of the filtrate from $(NH_4)_2CO_3$, add Na_2HPO_4 solution, stir and allow to stand. **Magnesium** will go down as phosphate. Confirm as at p. 34.

GROUP VI., K_2, Na_2, $(NH_4)_2$.

The remaining portion of the Filtrate must be ignited to drive off Ammonium salts, dissolved, and HCl and $PtCl_4$ added *in the cold.* A yellow crystalline ppt. indicates **Potassium.**

A strong yellow flame in the original will prove **Sodium.**

To test for Ammonia, the original must be warmed with KOH. The vapor blues litmus, and gives white fumes with HCl.

For separation of **Ca, Mg, Na_2** and **K_2**, see WATER-ANALYSIS, p. 139.

DETECTION OF ACIDS IN MIXTURES.

The student should be previously quite familiar with the reactions for acids and bases in simple salts, otherwise he cannot attempt mixtures. The following remarks only indicate the modifications involved when the radicles occur together. The same Grouping is employed as in the tables for simple salts (p. 14). The basyls and some of the acids will have been already discovered. In mixtures, the Na_2CO_3, test is not so definite, as many compounds insoluble in water may be present in solution in excess of acids or alkalies. For the detection of many acids it is necessary to have them in a neutral solution containing no base but the alkalies. There are two methods of doing this.

1. *For Basyls of Groups I. and II.* Dissolve in HCl, pass H_2S gas, boil, filter, evaporate off the H_2S, neutralize carefully with KOH.

2. *For other Groups.* Dissolve in HCl, boil the solution with Na_2CO_3 in *very slight* excess, filter, neutralize the filtrate with HCl or HNO_3. (*Do not test afterwards for the acid employed.*)

These, in the subsequent paragraphs, are called the *prepared solutions.*

N.B. Volatile acids (Group A) will be evolved on first treating with HCl. To test for Chloride in the original, a separate portion must be dissolved in HNO_3, $AgNO_3$ added, and the silver ppt. washed and tested as usual.

Group-test A. HCl, added to the original and warmed, will liberate the volatile acids. Test the evolved vapors as follows:

1. Effervescence with no marked odor; **Carbonate.** Close the tube with the thumb to collect the gas, and decant it into lime-water in another test-tube. A white ppt. is $CaCO_3$, possibly with some $CaSO_3$. Add HNO_3 in excess, boil, add $Ba(NO_3)_2$; if sulphite, a white ppt. of $BaSO_4$.

2. Odor of burning brimstone, besides the above test; **Sulphite.**

3. Odor of rotten eggs, blackening lead paper; the gas decanted into lime-water gives no ppt., but the solution, boiled with HNO_3, on addition of $BaCl_2$ yields by oxydation a white ppt. of $BaSO_4$. With HCl there may be a deposit of whitish Sulphur. **Sulphide.**

4. Red fumes *in the cold,* bluing paper dipped in KI and starch paste. **Nitrite.**

5. A glass rod dipped in $AgNO_3$ is clouded white, and a smell of HCN may be noticed. **Cyanide** (also many ferro- ferri- and sulpho-cyanides). If sulphide be also present, apply the sulpho-cyanate test (p. 51).

6. Smell of SO_2, and deposit of S. **Thiosulphate.**

The other tests (p. 40) give indications also in mixtures.

[These acids may be isolated if necessary by distilling with dilute sulphuric acid, collecting the vapor in water, and neutralizing with KOH. In this case HF will also pass over, and will corrode the glass; acetic acid will be detected by odor and by Fe_2Cl_6 in the neutralized distillate; ferro- and ferri-cyanides will give HCN. Many organic compounds will decompose the H_2SO_4, and give SO_2 if the distillation be carried too far.]

7. Chloric and hypochlorous acids will give off chlorinous vapors as in a simple salt.

8. **Urates,** and some others, will give with HCl a ppt. of the acid, which can be filtered off and specially tested. Uric acid chars on platinum with odor of burnt feathers; gives the Murexide test, p. 54.

See also page 73.

For Arsenious, Arsenic and Chromic acids, see pages 46 and 47. Silicic acid, p. 42.

Group-test B. $BaCl_2$ or $Ba(NO_3)_2$. Yellow ppt. indicates **Chromate**; a white one, soluble in HNO_3, points to Phosphate, Arsenite, Arsenate, Oxalate, Borate, Silicate, Fluoride, Tartrate, Citrate: a white ppt. insoluble in HNO_3 proves **Sulphate.** Sulphites and Thiosulphates will partially dissolve in HNO_3, but will be oxydized to $BaSO_4$, with red fumes, on warming.

[Group B can be removed if necessary by boiling the prepared solution with $Ba(NO_3)_2$, filtering, precipitating the excess of Ba by Na_2CO_3, filtering again, and neutralizing the filtrate with HNO_3. The $Ba(NO_3)_2$ ppt., treated cautiously with dilute Sulphuric acid, gives the acids of this group in solution. N.B. Fluorides and Silicofluorides are with difficulty dissolved in HNO_3. Therefore look for Fluoride in original by H_2SO_4 and etching glass, p. 45.]

Group-test C. $AgNO_3$. Notice the characters of the precipitate as given in the preliminary tests, p. 2.

Digest the ppt. with dilute HNO_3, everything will dissolve except Sulphide (black), Chloride (white curdy), Bromide (yellowish white), Iodide (pale yellow), Cyanide (white), Ferrocyanide (white), Sulphocyanate (white), Ferricyanide (orange). Wash the insoluble portion, treat with Ammonia, and filter: only Iodide and Sulphide will remain undissolved. Filter again and wash.

1. The portion insoluble in NH_4OH is treated cautiously with Chlorine water; from AgI, Iodine is liberated with violet vapor, bluing starch; Ag_2S is oxydized, yielding AgCl, and H_2SO_4 in solution; test for Sulphate.

2. The ammoniacal solution is re-precipitated by HNO_3; AgCl, AgBr, and AgCy are thrown down. Ignite the ppt. gently in porcelain, AgCy is decomposed to Ag and Cy_2, the latter giving the odor of Cyanogen and peach-blossom flame. Digest in HNO_3; Ag from the cyanide dissolves, AgCl and AgBr are left. Divide into two portions; test one for Bromide by adding Cl_2 water cautiously; red vapors of Bromine will be liberated (p. 50); in the other look for Chloride by digesting with a drop of KBr solution, the AgCl will be turned into AgBr, KCl will go into the solution and will give a *white, curdy* ppt. with $AgNO_3$.

Ferro- Ferri- and Sulphocyanides must be looked for in the Fe_2Cl_6 group.

Group-test D. $CaCl_2$. Applied to the prepared and neutralized solution. White ppt. indicates Carbonate, Sulphite, Thiosulphate, Arsenite, Arsenate, Chromate, Phosphate, Borate, Oxalate, Tartrate, Fluoride, Silicate. Most of these have been already found.

Wash the ppt. Ignite a portion on Platinum. If it chars, a vegetable acid is present *Tartrate,* burnt-sugar odor, etc. Burn white, dissolve in HCl, and test for inorganic acids.

If it does not char; Tartrate, etc., are absent.

Digest the ppt. in acetic acid; all the Calcium salts will dissolve except Oxalate and Fluoride. Heat the original with H_2SO_4; glass etched; **Fluoride.**

Ignite the ppt. on platinum; a carbonate formed, effervescing with HNO_3, indicates **Oxalate.** The ash can be dissolved in HCl and tested for inorganic acids of this group.

Ignite some of the prepared solution on platinum with H_2SO_4. Green mantle flame indicates **Borate.** Confirm by turmeric test, p. 47.

Warm a few drops of the original solution, acidified with HNO_3, with Ammonium molybdate; yellow ppt. indicates Phosphate, or **Arsenate.** Test for Arsenicum by Marsh's and Reinsch's test, p. 47. If not present, it must be **Phosphate.**

When Arsenate is present, boil down nearly to dryness with H_2SO_3, dilute, add HCl and precipitate Arsenicum by H_2S; the filtrate will contain the Phosphate; boil off H_2S and try molybdate again.

[To separate tartaric and citric acids, saturate with milk of lime; calcium tartrate precipitates. The filtrate, on boiling, throws down calcium citrate.]

Group-test E. Fe_2Cl_6 (free from Ferrous).

Use the " prepared solution."

1. **A precipitate.** Test it with Acetic acid and with HCl.

(*a*) *Soluble in Acetic acid and in HCl;* **Borate,** yellowish ppt.; **Benzoate,** buff colored, with HCl gives scales of Benzoic acid; **Succinate,** red-brown, with HCl no crystals; **Hippurate,** flesh-colored, with HCl gives needles of hippuric acid; **Urate,** red-brown, with HCl a white minutely crystalline ppt. of Uric acid (Group A).

(*b*) *Soluble in HCl, but not in Acetic acid;* Phosphate, Arsenate, already found; **Tannate,** blue-black very finely divided ppt.; **Gallate,** black ppt.; with HCl yellow color, with ppt. of Gallic acid; **Pyrogallate,** brown-red ppt. Salts uncommon. HCl, yellow color. With KOH, dark brown.

(*c*) *Insoluble in HCl;* **Ferrocyanide,** dark blue.

[To separate Hippurate, Benzoate and Succinate, add to the Fe_2Cl_6 ppt. Hydrochloric acid and ether; Benzoic acid is very soluble in ether and must be removed in the ethereal layer; to the filtrate add Ammonia, alcohol and $BaCl_2$; Barium succinate precipitates; the filtrate treated with Na_2CO_3, to remove the Barium, and filtered, on evaporation and addition of HCl gives needles of Hippuric acid. When Tannic and Gallic acids occur together, the cautious addition of gelatin solution will precipitate Tannic and leave Gallic acid. The separation of acids in this group is very difficult, but they are rarely given together.]

2. **A coloration.**

(*a*) *Not removed by HCl*; **Ferricyanides,** brown color unbleached by $HgCl_2$; **Sulphocyanates,** blood-red, bleached by addition of $HgCl_2$. The former give with Ferrous sulphate a dark blue ppt.; the latter yield no reaction, if free from Ferric.

(*b*) *Removed by HCl.* It can readily be seen in mixtures whether a reduction of color is effected.

Boil the solution of the salt with Ferric chloride. Acetate and Formate are thrown down as basic Ferric salts; heat with Ammonia, filter, add $AgNO_3$ and boil, **Formate** reduces the $AgNO_3$ to grey metallic Silver and is thereby broken up; filter, neutralize, and add again Fe_2Cl_6, a second red coloration shows **Acetate** not decomposed.

Meconic acid is not precipitated on boiling with Fe_2Cl_6, the filtrate still remains red; a portion with HCl is bleached with difficulty. The prepared solution gives with Lead acetate a white ppt. from which Meconic acid can be recovered by passing H_2S.

Salicylic acid furnishes a purple color, from the original solution the acid is thrown down by HCl in minute needles.

Phenol, a blue-purple color. It will be found in the distillate, and will give a precipitate with bromine water of Tribromophenol $6H_2Br_3OH$, nearly insoluble.

Sulphites give red-brown with Fe_2Cl_6; Thiosulphates a purple, but the colors are fugitive.

[For the acids of this section it may be often necessary to isolate by precipitation with Lead acetate, filtering, washing the ppt. and decomposing it by H_2S, when the acids are found in solution.]

Group F, not precipitated by reagents, includes Nitrates, Chlorates and Perchlorates. The detection of these in presence of other salts is generally easy, by the $FeSO_4 + H_2SO_4$ test, deflagration on charcoal, etc. (p. 57).

A further test for **Nitrate** would be: boil with KOH till all ammonia originally present is expelled, then add a little Zn and boil again; nitrate is reduced to NH_3, which is evolved.

After removal of Chloride by just enough $AgNO_3$ and filtration, if the filtrate, evaporated and ignited, is again turned into a Chloride, **Chlorate** (or Perchlorate) has been present (p. 41).

Quantitative determination is often the only possible means of making certain of difficult mixtures of organic acids. When a solid mixture is dissolved, the substances frequently react on one another to give fresh compounds and unexpected reactions.

VOLUMETRIC ANALYSIS.

In all chemical reactions, substances combine or replace one another in fixed numerical proportions.

The Unit taken is the atom of Hydrogen, = 1, and the *Equivalent* of any substance is the amount of it that corresponds with one atom of hydrogen, or the amount that contains one atom of replaceable hydrogen. *Example.* Sulphuric acid, H_2SO_4, when completely saturated by Sodium, forms the normal Salt Na_2SO_4. Therefore H_2SO_4 contains two atoms of replaceable hydrogen. Hence half of it is equivalent to one of hydrogen.

Adding up the Atomic weights, $H_2 = 2$, $S = 32$, $O_4 = 64$: total $= 98$.

The *Equivalent* of Sulphuric acid is 98 divided by 2, = 49.

Orthophosphoric acid, H_3PO_4, has three atoms of replaceable hydrogen; its equivalent therefore is $(3 + 31 + 64) \div 3 = 32{\cdot}7$.

Nitric and Hydrochloric acids have each one atom of replaceable hydrogen, hence their Equivalents are the same as their molecular weights, i.e. 63 and 36·5 respectively.

(A Salt in which all the replaceable hydrogen of the acid is replaced by a Metal or basylous radicle is called a *Normal salt*, e.g. KNO_3, Na_2SO_4, $CaCO_3$, Ag_3PO_4.)

It follows that if solutions are prepared, each containing, in the same volume, *equivalent weights* of different substances, they will accurately correspond to one another in combining power. For instance, if one solution contain an Equivalent, 49 grammes, of H_2SO_4 in a Litre, and another solution contain also an equivalent, 40 grammes, of Sodium Hydrate, NaOH, then the two solutions will correspond measure for measure in combining power, 10 cubic centimetres of one will saturate 10 cubic centimetres of the other, and so on.

The Weights and Measures preferably used are those of the decimal system.

1 cubic Centimetre of water at 4° C. weighs 1 Gramme. 1000 cubic Centimetres = 1 litre = 1000 grammes = 1 kilogramme. The cubic Centimetre is written abbreviated as 1 c.c. The Gramme is written Grm.

The apparatus required is as follows:—

1. *A. Burette.* A glass tube graduated in c.c. and tenths of c.c. having at the bottom a pinchcock, or stopcock, so as to let out the standard solution in small measured quantities.

2. *Several Pipettes,* marked to deliver 1 c.c., 5 c.c., 10 c.c., 20 c.c. and 25 c.c. respectively.

4. *Several measuring flasks,* marked on the neck to hold, respectively, 50, 100, 250, 500 and 1000 c.c.

5. White porcelain dishes, beakers, glass rods, funnels, &c.
6. Balance and set of Gramme weights.
7. Standard solutions. The most usually useful are "deci-equivalent," or contain one-tenth of an Equivalent of the reagent dissolved in a litre of water.
8. Solutions of indicators, such as Potassium chromate, Tincture of litmus, Tincture of cochineal, &c.

ACIDIMETRY AND ALKALIMETRY.

The measure of the amount of free acid or alkali in a solution, is founded on the changes, which certain vegetal coloring matters undergo, under the action of Acids, or Alkalies.

Litmus, the pigment usually chosen, is an extract from certain Lichens (Rocella, Lecanora, &c.) growing on rocks. When neutral it is lilac, when acid red, when alkaline blue.

The soluble Bases, therefore, turn litmus blue; the soluble Acids turn it red. When equivalent quantities of an acid and base combine, the result is a *Normal salt.* But this normal salt is frequently not neutral to test paper. If the base is stronger than the acid, the normal salt will have an *alkaline* reaction, e.g. Sodium carbonate: if the acid is stronger, the reaction will be acid, e.g. Sulphate of copper. Only when a strong acid meets an equally strong base is the resulting Normal salt neutral to litmus, e.g. Sodium sulphate, or Calcium cloride. Acidimetry and alkalimetry, therefore, are used mainly for such Acids and Bases as produce salts mainly neutral to litmus.

In the case of a free acid we place a small known quantity in a white porcelain dish, and add from a burette a "standard solution"—one of known strength—of an alkali such as Potash, Soda, or Ammonia, until the liquid shows a neutral reaction to litmus. If the liquid be colorless, we can add at the beginning a few drops of *Tincture of Litmus*; if it be colored, we must test it with Litmus paper.

The number of measures of standard solution required, indicates the *Acidity* of the substance. Similarly for *Alkalinity*, using a standard solution of Sulphuric, Hydrochloric, or Oxalic acid. The last is convenient because it can be easily weighed, but the solution does not keep.

Since Oxalic acid is dibasic, one equivalent, = one of displaceable hydrogen, will be half the molecular weight.

Crystallized Oxalic Acid, $H_2C_2O_4,2H_2O = 126$: one half is 63; therefore to make an equivalent solution we must take 63 grammes of Oxalic acid per Litre of distilled water. It is generally more convenient to use one-tenth of this strength—a Deci-equivalent solution, made by dissolving 6·3 grammes of pure crystallized

Oxalic acid in a Litre of distilled water. Then one Litre of this solution (representing one tenth of an equivalent of Oxalic acid), represents also one tenth of an equivalent of other substances.

Therefore 1 cubic centimetre = $\frac{1}{1000}$ of this quantity. The equivalent of Sodium hydroxide, NaOH, being 40, 1 c.c. of the Oxalic solution = $\frac{4}{1000}$ = ·004 gramme of NaOH. (See Table, p. 125.)

Potassium hydroxide KOH, having an Equivalent = 56, 1 c.c. of the Oxalic solution = ·0056 gramme of KOH.

In the same way 1 c.c. = ·0017 gramme of Ammonia NH_3, or ·0035 grm. of Ammonic hydrate NH_4OH.

These numbers, ·004, ·0056, &c., are called the **co-efficients** of the Alkali, or Acid.

To determine the amount of **free Alkali** in a substance. Take a small weighed quantity, dissolve it in water in a white porcelain dish, add sufficient tincture of Litmus to color it light blue, then drop in the standard Oxalic acid solution from the burette, until the litmus just becomes neutral or rose-violet in tint. Then the number of c.c. of acid required, multiplied by the co-efficient of the alkali, gives the amount of Alkali present. From this, the percentage is readily calculated.

For example, if 0·1 gramme of an impure Soda has been weighed out, and we find that it requires 20 c.c. of the standard Acid for neutralization, then as 1 c.c. of the standard is equal to ·004 grm. NaOH, 20 c.c. will equal 20 × ·004 = 0·08 grm. NaOH. Therefore 0·1 grm. of the substance contains 0·08 grm. NaOH, corresponding to 80 per cent. of Sodium hydrate.

To measure Acidity, we require a standard solution of Alkali of the same strength as the Oxalic acid solution, i.e. "Deci-equivalent," or containing 4 grammes of NaOH per litre. The nearest approach to this is the *Liquor sodæ* of the British Pharmacopœia, 1867, diluted to ten times its volume. It may be purchased, or prepared as follows:

Take 27 grammes of pure crystallized (not effloresced) Sodium carbonate, $Na_2CO_3,10H_2O$, dissolve in a Litre of water, add 12 grammes of slaked Lime, boil for some time, with constant stirring, in a clean iron vessel, cover close, allow to stand, and decant the clear liquid. This will be a little too strong, so must be "titrated," or its strength determined, by means of the Oxalic solution above. Pour the Soda solution into a burette. In a white porcelain dish, place 100 cubic centimetres of the Deci-equivalent Oxalic solution, color it with tincture of Litmus, then run in the Soda solution till just faintly alkaline. The number of c.c. used will be the amount equal to 100 c.c. of Oxalic solution. Now take *ten times* this quantity of Soda solution and dilute with water till it measures exactly *one Litre.* The Acid and Alkali solutions should now be precisely equal in strength, that is, 10 c.c. of Oxalic solution should exactly neutralize 10 c.c. of the Soda, and vice versâ. Hence if a free Acidity has to be determined, take a convenient quantity of the substance, or liquid, color with a few drops of Litmus, and run in the Soda from a burette till neutrality is attained. Each c.c. of the Soda solution is equal to ·004 gramme of NaOH, to ·00365 grm. HCl, to ·0049 of H_2SO_4, to ·006 grm. acetic acid, or ·0063 grm. of Oxalic acid. Calculate the percentage.

TABLE OF EQUIVALENTS.

1 c.c. of Standard Acid (deci-equivalent) requires for neutralization.		1 c.c. of Standard Alkali (deci-equivalent) requires for neutralization.	
Name.	Grammes.	Name of Acid.	Grammes.
Potassium hydroxide, KOH	·0056	Hydrochloric	·00365
„ oxide, K_2O	·0047	Nitric	·0063
„ carbonate, K_2CO_3	·0069	Sulphuric	·0049
„ hydrocarbonate, $KHCO_3$	·0100	Acetic	·0060
Sodium hydroxide, NaOH	·0040	Tartaric	·0075
„ oxide, Na_2O	·0031	Citric	·0064
„ carbonate, Na_2CO_3	·0053	Oxalic	·0063
„ hydrocarbonate, $NaHCO_3$	·0084	Malic	·0067
Ammonia, NH_3	·0017	Lactic	·0090
Ammonium hydroxide, NH_4OH	·0035	Hydrobromic	·0081
„ carbonate, $(NH_4)_2CO_3$	·0048	Hydriodic	·0128
„ hydrocarbonate, NH_4HCO_3	·0079	Phosphoric	·00327
Calcium oxide, CaO	·0028	Carbonic	·0022
„ hydroxide, $Ca(OH)_2$	·0037		
„ carbonate, $CaCO_3$	·0050		
Barium oxide, BaO	·0076		
„ hydroxide, $Ba(OH)_2$	·0085		

If we are titrating (estimating the strength of) an alkaline carbonate, it is better to use a few drops of *Tincture of Cochineal* as an indicator. This is yellowish-red when acid, purple when alkaline: the transition is very sharp and hardly affected by the presence of Carbonic acid.

ESTIMATION OF HYDROCYANIC ACID.

When silver nitrate is added to an alkaline cyanide, at first a soluble double cyanide of silver and the alkali is formed. With potassium this is $KAg(CN)_2$. As long as the cyanide is not more than half saturated with silver, this soluble compound is obtained; after we pass this point, the excess of silver cyanide begins to precipitate.

Place the hydrocyanic acid in a beaker, add soda solution till alkaline, run in from a burette the deci-equivalent silver nitrate solution (the same as used for chlorine), until a slight permanent turbidity is noticed. Then the amount of silver solution added is equivalent to *half* the hydrocyanic acid present, or

1 c.c. of silver nitrate = ·0054 grm. HCN.
= ·0130 grm. KCN.

TITRATION OF ARSENIOUS OXIDE, As_2O_3.

When Iodine is added to a solution of an alkaline arsenite, the latter is oxidized to Arsenate, with production of Hydriodic acid. Leaving the Alkali out of consideration:

$$As_2O_3 + 2I_2 + 5H_2O = 2H_3AsO_4 + 4HI.$$

Free Iodine blues starch, Hydriodic acid does not. Hence the appearance of the blue iodide of starch shows when we have added just more than enough Iodine to oxidize the Arsenious oxide.

Standard solution of Iodine. 12·7 grammes (one tenth of an equivalent) of recrystallized Iodine, and 18 grammes of pure Potassium iodide, are dissolved in water, and the volume made up with distilled water to 1 Litre. The Potassium iodide takes no part in the reaction, and is only added to dissolve the Iodine.

1 c.c. of this solution = ·0127 grm. of Iodine = 00495 grm. of As_2O_3.

The solution under examination is mixed with a slight excess of Sodium hydrocarbonate, $NaHCO_3$, a few drops of starch paste added, and the standard Iodine solution run in from a burette till the blue color is just permanent. Then the number of c.c. used multiplied by ·00495 gives the amount of Arsenious oxide As_2O_3 present.

Of course the solution must not contain other substances capable of acting upon Iodine.

ESTIMATION OF ALCOHOL IN WINE.

The specific gravity of **Absolute alcohol** is ·794 at 15·5° C.

Mixtures of alcohol and Water have higher gravities, which have been determined by experiment, whereby tables have been made stating the percentage of Alcohol corresponding to a certain gravity.

Hence to determine the amount of Alcohol present in a certain liquid, if nothing but Alcohol and Water are present, we simply ascertain the specific gravity, and look in the table for the amount of Alcohol corresponding to that gravity. But if, as in the case of Wines and Beers, we have Sugar and other solid matters present which increase the gravity, and would interfere with the result, we must get rid of them by distillation, thereby obtaining a liquid, the distillate, which contains Alcohol and Water only.

Making up this to the same volume as the original liquid, we obtain a fluid of exactly the same strength in Alcohol as the original, but separated from the Sugar and other matters.

By taking the gravity of this, and referring to the tables, we obtain the alcoholic strength of the original liquid.

If the original liquid contain a volatile acid such as Acetic, to prevent it coming over, we add a slight excess of Potash or Soda solution before distilling. If Volatile Oils be present, they would usually lower the gravity, and must be removed by diluting with water and separating, or by agitation with fresh Charcoal and filtering.

The general process is as follows:—

Measure out 50 cubic centimetres of the liquid, distil with good condensation until at least two thirds, or say 35 c.c. has passed over. Make up the Distillate to the original bulk, 50 cubic centimetres, with Distilled Water, bring it by cooling or warming to a temperature of 15·5° C., transfer to a "specific gravity bottle" and weigh. Calculate the gravity, and refer to tables for the amount of alcohol corresponding.

A specific gravity bottle is a small vessel provided with a perforated stopper. We must first ascertain what weight of water it will hold. Fill it with pure water at 15·5° C., insert the stopper, seeing that no air-bubbles are enclosed, wipe the outside dry, and weigh without delay. This gives the *water contents*. In the same manner it is filled with the Distillate, or Liquid to be tested, and this also weighed. Then the latter weight divided by the *Water contents* gives the specific gravity, taking water at 15·5° C. as unity.

In all cases, the Gravity is determined at the standard temperature of 15·5° C. If we were to determine it at a higher temperature, owing to the expansion by heat, the liquid would be lighter, and there would appear by the tables to be more Alcohol. On the contrary, at a lower temperature the Gravity would be greater, and there would appear to be more Water and less Alcohol. To avoid the error we must carefully bring the Liquid to the temperature of 15·5° C. before weighing.

The gravity can also be taken by a Hydrometer, but this is less correct.

By the same process the specific gravity of other liquids, either heavier or lighter than water, can be taken.

ESTIMATION OF THE HARDNESS OF WATER.

A water which does not lather freely when shaken with a solution of soap, or when soap is dissolved in it, is said to be "**hard.**" This hardness is due to the presence in the water of certain salts, mainly those of Calcium and Magnesium.

Two kinds of hardness are recognised, viz.: **temporary hardness,** which is removable by simply boiling the water, and **permanent hardness,** which cannot be thus got rid of.

Temporary hardness is caused by the presence of the Bi carbonates of Calcium and Magnesium. The normal Carbonates are nearly insoluble in pure water, but are far more soluble in water containing Carbonic acid gas in solution, in which they dissolve as the Bi-carbonates. By boiling, these are decomposed into the Carbonates, which are precipitated, and free Carbon dioxide which is expelled:—

$$CaH_2 2CO_3 = CaCO_3 + H_2O + CO_2.$$

The "boiler-crust," which forms in boilers and kettles, is a mass of the Carbonates of Calcium and Magnesium thus precipitated.

Another method of softening temporarily hard waters, is to add Calcium Hydroxide, or Slaked Lime, in quantity just sufficient to form, with the Bi-carbonates present, the insoluble normal Carbonates. Thus:—

$$CaH_2 2CO_3 + CaH_2O_2 = 2CaCO_3 + 2H_2O.$$

Permanent hardness is a consequence of the presence, in the water, of soluble salts of Calcium and Magnesium, which are not decomposed, or precipitated, on boiling, and which cannot therefore be removed by this method. These salts are mainly the Sulphates, Chlorides, and Nitrates of Calcium and Magnesium.

Permanent hardness may be removed by precipitation with an alkaline carbonate, which throws down the insoluble Carbonates, leaving, in solution, a salt of the alkaline metal, which does not render water hard. Thus:—

$$CaSO_4 + Na_2CO_3 = Na_2SO_4 + CaCO_3.$$

Hardness of both kinds is removed by **Distillation.**

Soap, which may be looked upon as consisting mainly of Sodium stearate, has a softening action upon water similar to that of the alkaline Carbonates, save that, in this case insoluble Calcium and Magnesium stearates are precipitated, while the Sodium goes into solution combined with the acid previously in combination with the Calcium and Magnesium. This reaction explains the phenomenon of the hardness of water, since the water will not lather with soap, until the whole of the Calcium and Magnesium are thrown out of solution as insoluble Stearates.

Upon this fact the method for the determination of the amount of hardness in a water is based.

To determine the hardness of a water, a **standard soap solution** is required. For this dissolve a small quantity of a good curd Soap in methylated spirit, and dilute somewhat, with a mixture of two parts of methylated spirit, to one of water. Now make a solution of Calcium chloride of known strength, so that the Calcium, calculated as $CaCO_3$, shall be equal to (say) 7 grains per Gallon. Pour the filtered solution of soap into a burette, and 100 c.c. of the standard Calcium chloride solution into a bottle of about 250 c.c. capacity; add the Soap Solution from the burette in small quantities at a time, stopper and shake vigorously after each addition, until a permanent lather is formed. The amount of Soap solution required to effect this is then read off from the burette, and the Soap solution is diluted with the mixture of two parts methylated spirit, and one of water, until 100 c.c. of the standard Calcium chloride solution require exactly 15·2 c.c. of the Soap solution. Now, since the standard Calcium chloride solution is equivalent to 7 grains per gallon of $CaCO_3$, and 100 c.c. of Distilled Water require 1·2 c.c. of Soap solution to form a permanent lather, the remaining 14 c.c. of the Soap Solution are equivalent to 7 grains per gallon of $CaCO_3$; that is, 1 c.c. of the Soap solution, in 100 c.c. of water, is equivalent to half a grain per Gallon of hardness calculated as $CaCO_3$. With this standard soap solution, the hardness of any water may be determined.

Waters, which require more than 25 c.c. of the Soap Solution per 100 c.c. of the water, should be diluted, and a correction made accordingly.

The **total hardness** of a water is first determined by direct titration with the standard soap solution; then the **permanent hardness** by boiling 100 c.c., for half an hour, to remove the temporary hardness, filtering off the precipitated carbonates, making up the filtrate to 100 c.c., and titrating by the above-mentioned method.

The **difference** between the Total and Permanent hardness gives the Temporary.

For example:—

Total Hardness. 50 c.c. of a water made up to 100 c.c., required 19·5 c.c. of standard soap solution, equal to (19·5 − 1·2) 18·2 grs. per gallon.

Permanent Hardness. 100 c.c. of the water, boiled for half an hour, filtered, and the filtrate made up to 100 c.c. required 12·8 c.c. standard Soap Solution equal to 5·8 grs. per gallon.

Temporary Hardness is therefore 18·2 − 5·8 = 12·4 grs. per gallon.

ESTIMATION OF CHLORINE IN NEUTRAL SOLUTIONS.

Solution of Silver nitrate when added to a solution of a Chloride gives a *white* precipitate of Silver chloride, $AgCl$. Silver nitrate added to a solution of a Chromate gives a *crimson* ppt. of Silver chromate, Ag_2CrO_4. But silver has a greater affinity for Chlorine than it has for Chromic acid, therefore, if Silver nitrate be added to a mixture of Chloride and Chromate, it will not touch the chromate until it has saturated all the Chloride; as soon as this happens, the Chromate will immediately give its crimson ppt. Taking Sodium chloride as an example, the reaction is: $NaCl + AgNO_3 = AgCl + NaNO_3$.

To prepare the standard deci-equivalent solution of Silver. Dissolve 17 grammes of pure Silver nitrate (crystals are preferable, as the fused sticks are sometimes impure) in 1 Litre of pure Distilled Water. Each cubic centimetre of this solution equals of:

NaCl	·00585	Coefficients.
KCl	·00745	
Cl	·00355	
HCl	·00365	

To perform the analysis. Take a weighed quantity of the solid, about 0·1 gramme, or a measured volume of the liquid to be tested, place in a white porcelain dish, add one or two drops of a solution of normal Potassium chromate, K_2CrO_4, and run in the standard Silver solution from a Burette until the red color produced by every drop of the Silver solution does not disappear, but remains just slightly marked on stirring. Then the Chloride is saturated by Silver. Read off the number of c.c. required, multiply by the proper coefficient, and the result is the amount of Chlorine or Chloride present. Solutions which are alkaline or acid, must be first neutralized by dilute Nitric acid, or by Ammonia, before testing, as free acid or alkali prevents the proper formation of the red Silver chromate at the end of the reaction.

In testing Drinking Waters, a weaker Silver solution is used, prepared by dissolving 2·906 grammes of Silver nitrate in a litre of pure water. 1 c c. of this = ·001 grm. of NaCl = ·000607 grm. of Cl. 100 c.c. of the Drinking Water are evaporated nearly to dryness in a white porcelain dish, a drop of Potassium chromate added, and the Silver solution dropped in till a permanent red tinge is produced. Multiplying the number of c.c. by the proper coefficient gives the amount of Chlorine or of Chloride of Sodium in 100 c.c.; this multiplied by 10 gives *Grammes per Litre*, the latter multiplied by 70 gives *Grains per Gallon*. The same Solution and processes are used for testing the amount of Chloride in the ash of milks, &c. For the estimation of the Chlorides in Beers, &c., see p. 133.

MILK.

Consists of an emulsion of fat (3·5%) in minute globules, suspended in a slightly alkaline solution of Casein (4%) and Albumen (0·7%), with Lactose (4%) and Salts (0·7%). The amounts found in a very good Cow's milk.

In an analysis, the first thing to ascertain is the total Solid matter present.

Weigh out about 5 grammes in a flat-bottomed platinum dish, add a drop of Acetic acid, mix by movement till coagulated, then dry for three hours on the water-bath. Thus we obtain the weight of the **total solids.** Burn these at as low a temperature as possible, and weigh the **ash.** Moisten the ash with a drop of Potassium chromate, and titrate with Silver nitrate, p. 130. Calculate as Sodium chloride.

In the meantime weigh out, in a porcelain dish, about 7 Grammes for determination of the **Fat.** Add about 1 Grm. of precipitated Calcium sulphate, then a drop of Acetic acid, stir and warm till coagulated and mixed. By drying on the water-bath, and stirring with a glass rod, reduce the residue to a granular powder. On this pour enough pure Benzene to cover it, allow it to stand for half-an-hour, pour off the clear Benzene carefully, without loss, into a previously-weighed wide-mouthed flask, add to residue some more Benzene, and, after standing as before, pour off into the flask again. Repeat this operation six to eight times, taking care that the benzene poured off does not occupy more than half the capacity of the flask (about 40 c.c. of benzene). Then distil off and retain the solvent, dry the residue of fat carefully, by heating in a current of air, and weigh the fat. Subtract the fat from the total Solids, the result is "**solids not fat,**" consisting mainly of Casein, Albumen, Lactose, and Ash, and averaging 9·3 per cent. If below 9, the milk has been watered. The standard often taken is 8·7 per cent. as that of solids not fat.

If it be necessary to determine the **Lactose,** measure out 10 c.c. into a 100 c.c. flask, add a drop of Acetic acid, warm till coagulated, add distilled water till the liquid measures 100 c.c., filter from the Casein, transfer a portion to a burette, and titrate with Fehling's solution.

Measure 10 c.c. of Fehling into a flask, add 40 c.c. of water, heat to boiling, and add the milk-filtrate from a burette, keeping the flask boiling until the blue color of the Fehling's solution is discharged, and merely a red precipitate of Cuprous oxide in a colorless liquid remains. Then the quantity of milk-filtrate used = 10 c.c. of Fehling = 0·065 grm. Lactose. From this, calculate the percentage of Lactose.

E.g. 10 c.c. of milk taken, coagulated, filtered and made up to 100 c.c. Titrated with Fehling, 16 c.c. of the milk-filtrate decolorized 10 c.c. of Fehling's solution = 0·065 grm. of Lactose. Therefore 16 c.c. of the filtrate, = 1·6 c.c. of the original milk, contained 0·065 grm. of Lactose.

To calculate the percentage:—

$$1{\cdot}6 : 100 :: {\cdot}065 : x = 4{\cdot}06.$$

Hence the original milk contained 4·06 per cent. of **Lactose.**

To determine the **Casein**, the precipitate by Acetic acid, left on the filter in the preparation for Lactose-determination, should be washed off, partially dried till pasty, extracted with Water, Absolute alcohol and Ether,—to remove Salts and Fat,—then dried and weighed in a platinum dish, ignited, and the **ash** deducted.

BREAD.

1. Notice physical characters, odor, color, cleanness, whether well-baked and of even porosity.

2. A portion about the size of a walnut should be covered with distilled water, allowed to soak, the liquid poured off and filtered if necessary. Test filtrate by HCl and $BaCl_2$ for *Sulphate*. Any considerable ppt. may be due to *Alum*, or to impurity in the Salt used in the making. The remaining moist bread should be mixed, squeezed, and a drop of the liquid examined under the microscope for extraneous starches, potato, rice, bean, &c., and for fungus.

3. Break off, not cut, a piece of the crumb that has not been touched with a knife, place in a porcelain dish, and pour over it the following solution: two small and fresh logwood chips are warmed with about 10 c.c. methylated spirit, diluted with water and Ammonic carbonate added in excess. After soaking in this for a short time, the solution is poured away, and the bread left covered in a dark place till next day. A permanent purple color indicates **Alum**, a dull blue tint may be due to **Iron.**

4. From a fresh surface a small thin slice is cut so as to include an average of crust and crumb, from outside to centre. Weighed at once in a platinum dish, dried at 110° C: weighed again, loss of weight is **Water.** Burn and weigh the **Ash.** Determine the chloride volumetrically, p. 130, and calculate as Sodium chloride. Average water = 36 per cent.: Ash, 1·2 per cent.: Salt, 0·5 per cent. Deducting Salt from Ash, since flour contains a mere trace of Chlorides, we get the approximate "*Ash of Flour*," averaging 0·7 per cent. A slight excess usually means a coarse flour. The utterly improbable adulterations, chalk, plaster, bone-earth, &c., would make a flagrant difference in the ash.

5. The **Nitrogen** may be determined by combustion with soda lime. Multiplied by 6·33 this roughly gives the *Gluten.*

6. Exhaust a weighed portion with cold water, filter, divide filtrate into two portions. Titrate one with Fehling's solution for **Sugar,** p. 131. Evaporate the other to dryness, weigh, burn and deduct the ash. Then subtract the sugar, remainder = **Dextrine** and **Extractives.**

7. The residue, insoluble in cold water, may be boiled for some hours with dilute (5 per cent.) H_2SO_4 in a flask (avoiding concentration) so as to turn the starch into sugar, neutralized with KOH,

made up to a convenient volume, say 200 c.c., and titrated with Fehling, p. 131. 1 c.c. Fehling's solution = 045 grm. *Starch.*

8. *If Alum is indicated.* 100 grammes of *crumb* are burnt to a black ash in a platinum dish, moistened with H_2SO_4 and burnt to a white ash by adding small quantities of HNO_3. Heated some time with H_2SO_4 and HCl, diluted, filtered, and the silica on the filter ignited and weighed. Add a slight excess of Ammonia and stir, then excess of Acetic acid, and allow to stand. Phosphates of Calcium and Magnesium dissolve, those of Aluminum and Ferric do not dissolve. Filter, wash, ignite and weigh the Ferric and Aluminum phosphate. Dissolve in HCl, titrate the iron, p. 139, calculate as $FePO_4$, subtract this from the mixed ppt., the remainder is $AlPO_4$. If 100 *Grammes* of Bread are taken, the weight in *Grammes* of $AlPO_4$ found, multiplied by 1036, will equal the number of *Grains* of crystallized Ammonia alum, $(NH_4)_2SO_4,Al_23SO_4,\ 24H_2O$, in the 4lb. loaf. Deduct 8 grains for Alumina which may be derived "from accidental traces of clay, or from rubbing down of the mill-stone." If the mixed $AlPO_4+FePO_4$ do not exceed ·013 gramme, the bread is unalumed, and the iron need not be determined. Always prove that the ppt. contains Aluminum, by igniting it on platinum with Cobalt nitrate; it should show a decided blue color.

Copper and **Zinc** have been occasionally found in bread, and may be detected by the toxicological methods, p. 103.

For further details consult Wanklyn and Cooper's "Bread Analysis."

BEER AND PORTER.

1. Notice clearness, whether much gas, odor, taste.

2. 10 c.c. are evaporated, and weighed for *total solids*, then burnt for *Ash*. Ash should be white, partially soluble in water, alkaline.

3. 50 c.c. are distilled for Alcohol according to p. 126.

4. 20 c.c. titrated with decinormal KOH solution, p. 124, using Litmus paper as an indicator. The number of c.c. of KOH solution multiplied by ·006, the coefficient of Acetic acid, and by 5 (because 20 c.c. were taken) gives *total acidity* calculated as *Acetic acid.*

5. 25 c.c. treated with pure Baryta water in slight excess, evaporated and carefully charred, then extracted with successive quantities of hot water and filtered. The filtrate, concentrated by evaporation, and titrated with $AgNO_3$, p. 129, gives the Chlorine. The highest limit of salt allowed is 60 grains of NaCl per gallon, supposing the source not to be the brewing water. Beer is frequently brewed from impure sugar containing Potassium chloride, hence a determination of K and Na, p. 139, is required before an addition of common salt can be asserted.

6. 25 c.c. evaporated to a syrup, stirred well with 10 c.c. rectified spirit, the latter filtered and gently evaporated gives *alcoholic extract.* Notice its color, whether soluble in water (separation of resin), its taste—bitter, nauseous, salty, &c. The taste of licorice comes out strongly. Hop gives a strong and pleasant bitterness, with a good deal of resin.

7. Examine sediment under microscope.

[For further details, see Blyth's "Food Analysis."]

DIALYSIS.

Liquid diffusion is the property which many substances, when dissolved, possess of passing through membrane. The majority of inorganic soluble substances, and a large number of the simpler organic compounds, are crystallizable and diffusible, and are called **crystalloids.** But viscous and albuminous bodies do not diffuse: they are called **colloid** (or glue-like) substances. Silicic acid gives a fair idea of a colloid.

A **dialyser** is a cylinder, open above, and closed below by a diaphragm of vegetal parchment or bladder, suspended so that the diaphragm just dips into a large basin of distilled water. The mixture to be examined is poured into the cylinder: on standing, the crystalloids diffuse through into the water, while the colloids remain above the membrane. In this way arsenic, strychnia, and other crystalline poisons may be separated from an animal liquid such as blood, or a stomach contents. On evaporating the distilled water, the crystalloid may be recovered almost pure. Arsenious acid must be neutralized before evaporation, to avoid volatilization with the steam.

ANALYSIS OF POTABLE WATERS.

A Winchester quart (half a gallon), in a perfectly clean bottle, should be collected.

Color. Place in a tall cylinder of colorless glass, and look down on to a sheet of white paper. Pure water has a bluish tint; marsh waters are brown: contamination with sewage gives a yellow coloration; algæ give a greenish tinge. Chalk waters often have a white turbidity, clay waters a brown, ferruginous waters a reddish brown, or a brown, flocculent sediment.

Sediment. Allow to stand in a large conical glass, pour off the water, and examine the deposit under the microscope.

Odor. Half fill a flask with the water, warm, shake vigorously and smell. A marshy, or even a fetid or urinous, odor may be detected.

Residue. 500 c.c. are evaporated in a weighed platinum dish, the residue weighed and put down as **total solids.** It should be white. Notice whether crystalline or granular. Ignite gently: waters containing much nitrate will give acid fumes: if much organic matter, the residue will blacken or brown: notice whether the odor is like animal matter. Weigh the ash if necessary; examine it for iron. On first warming up, record whether much gas is evolved.

Chlorine. Evaporate 100 c.c., or less, in a white porcelain dish, and titrate as directed page 130.

Hardness. See page 129.

Free and Albuminoid Ammonia. At the present time this process, introduced by Wanklyn and Chapman, is the readiest means of discovering contamination in waters.

500 c.c. (or a less quantity if the water is very bad) are distilled in a retort until 50 c.c. have passed over. The distillate is transferred to a glass cylinder and 1½ c.c. of Nessler test (see below) added. The brown coloration produced is imitated in another cylinder by mixing pure water with the requisite number of cubic centimetres of a standard Ammonium chloride solution (·0315 grm. of NH_4Cl dissolved in one Litre of pure distilled water: 1 c.c. of this = ·01 milligrm. of NH_3); and adding 1½ c.c. of Nessler test; trials are made till the same tint of color is obtained. Then the number of c.c. of standard solution used indicates the amount of **free Ammonia** in the first Distillate. The Distillation must be continued until 50 c.c. of Distillate give no color with Nessler; the amounts added up will give the free Ammonia present in 500 c.c. of the water.

To the remainder in the retort, 50 c.c. of Alkaline Permanganate solution (see below) are added, and the distillation continued. The Permanganate oxidizes the organic nitrogenous matters, and evolves the Nitrogen as Ammonia. This is collected in the Distillate in successive quantities of 50 c.c., and titrated by Nessler test as above. The result is put down as **Albuminoid Ammonia.**

Ferruginous waters often contain much free Ammonia, otherwise an excess points to urinous contamination. Albuminoid Ammonia should not exceed 0·08 milligramme per Litre, = ·0056 grains per Gallon.

The Alkaline permanganate solution is made by dissolving 8 grammes of Potassium permanganate and 200 grammes of Potash in about 800 c.c. of water, boiling for about two hours till all Ammonia is expelled, and then making up with *pure* water to one Litre.

Pure water for the purpose may be obtained by distilling ordinary good distilled water, rejecting the first distillate, and collecting the middle third. It should give no coloration with Nessler test (p. 1).

Nessler test is made by dissolving together 35 grms. of KI and 13 Grms. of $HgCl_2$ in 800 c.c. of warm water, adding $HgCl_2$ solution until the red ppt. of iodide just fails to redissolve, then adding 160 Grms. of KOH dissolved in water, making up with Distilled water to one Litre, and dropping in $HgCl_2$ solution until 1½ c.c. of the supernatant liquid gives a proper brown coloration when added as in testing a water distillate. Allow to settle and decant for use. This is a solution of Potassio-mercuric iodide in excess of potash : with a small amount of Ammonia it gives a brown ppt. (NHg_2IOH_2) ; with minute traces, it gives a brown coloration.

Extraordinary care must be taken that all utensils used in this process are chemically clean.

Examples :—

1 *A bad water.*—Half the quantity, 250 c.c., was taken, as the Nessler tints with the whole quantity were too intense for easy comparison.

Free NH_3.

Amount of distillates.	Milligrammes of NH_3.
70 c.c.	·030
50 c.c.	·005
	·035
	4
Per litre	·140

$=\begin{cases}\cdot000140 \text{ grammes per litre.}\\ .0098 \text{ grains per gallon.}\end{cases}$

Albuminoid NH_3.

Amount of distillates.	Milligrammes of NH_3.
50 c.c.	·035
50 c.c.	·015
70 c.c.	·004
	·054
	4
Per litre	·216

$=\begin{cases}000216 \text{ grammes per litre.}\\ \cdot01512 \text{ grains per gallon.}\end{cases}$

[Highest passable amount of albuminoid $NH_3 = 0\cdot08$ milligram per litre = ·0056 grains per gallon.]

2. *A passable water.*—500 c.c. distilled.

Free NH_3.

80 c.c.	·025
50 c.c.	·003
	·028
	2
Per litre	·056

$=\begin{cases}\cdot000056 \text{ grammes per litre.}\\ \cdot00392 \text{ grains per gallon.}\end{cases}$

Albuminoid NH_3.

60 c.c.	·022
55 c.c.	·010
50 c.c.	·002
	·034
	2
Per litre	·068

$=\begin{cases}\cdot000068 \text{ grammes per litre.}\\ \cdot00476 \text{ grains per gallon.}\end{cases}$

3. *A good water.*—500 c.c. distilled.

Free NH_3.

50 c.c.	·007
	2
Per litre . .	·014

$=\begin{cases}\cdot000014 \text{ grammes per litre.}\\ \cdot00098 \text{ grains per gallon.}\end{cases}$

Albuminoid NH_3.

90 c.c.	·010
60 c.c.	·002
	·012
	2
Per litre . .	·024

$=\begin{cases}\cdot000024 \text{ grammes per litre.}\\ \cdot00168 \text{ grains per gallon.}\end{cases}$

Nitrates. The residue of 500 c.c. of the water is extracted with successive small quantities of distilled water, filtered, and evaporated to a few drops. "Frankland's tube" is a glass cylinder open at both ends, with a constriction near the top closed by a glass stopcock. The upper part thus forms a small funnel, the lower is graduated. The tube filled up to the stopper with mercury is supported by a clamp in a deep mercury trough. The extract of the water residue is poured into the funnel, the tube raised and the stopcock opened, when the liquid is drawn into the lower portion of the tube. Take care that air does not enter; if it does, depress the tube in the mercury till the air is just expelled. Then rinse the remainder of the soluble water-residue into the funnel with a few drops of water; and repeat with three successive washings of concentrated H_2SO_4, transferring each washing by opening the stopcock gently. Now grasp the tube in the hand, closing the lower end with the moistened thumb, and shake sharply, but so as to leave an unbroken column of mercury below. The sulphuric acid will liberate Nitric acid, this with the mercury will give **Nitric oxide** and mercurous sulphate. Nitric oxide contains half its volume of nitrogen: therefore, if 500 c.c. of water (half a litre) be taken, the amount of nitric oxide per half Litre = the amount of Nitrogen per Litre; *i.e.* nitrogen existing as nitrates and nitrites, or "Oxidized nitrogen."

Example. 500 c.c. of the water gave 3·0 c.c. of NO at 19° C. and 773 millimetres pressure;

Correcting for temperature and pressure:—

$$\frac{3\cdot0 \text{ c.c} \times 773 \times 1}{760 \times [1 + (19^\circ \times \cdot003665)]}$$
$$= 2\cdot85 \text{ c.c. NO at } 0^\circ\text{C and } 760 \text{ mm.}$$

But NO contains half its volume of N, and we have taken half a litre of water. Hence the number of c.c. of NO found corresponds with the number of c.c. of N *per litre*. Now 1 litre of hydrogen at 0°C and 760 mm weighs ·0896 grm. Nitrogen is 14 times as heavy: 1 litre N $=\cdot0896\times14=1\cdot25$ grm. Therefore 1 c.c. N weighs ·00125 grm. In our example, 2·85 c.c.

(the volume of N found) multiplied by ·00125 grm. (weight of 1 c.c. N) gives ·00356 grm. as the weight of oxidized nitrogen per litre. Multiplied by 70, =0·249 grns. per gallon. This is a moderate amount.

Note.—It is easy to remember that 1 c c. of nitrogen weighs a milligramme and a quarter.

Nitrates are generally produced by oxidation of nitrogenous organic matters. Hence they have been put down as "previous sewage contamination." But they may be geological in origin, as many deep well waters, conspicuously free from organic impurity, contain much Nitrate, such as the Kent waters from Artesian wells, and others. But a water containing much Nitrate requires further examination to ascertain its source.

Phosphates. For these a larger quantity of water is required. Two Litres are acidified with Nitric acid, evaporated to dryness, and the residue ignited till white. Then it is dissolved in a little HNO_3, warmed, diluted slightly, filtered, and the filtrate treated with a moderate amount of acid Ammonium-molybdate solution, and again warmed for some hours on the water bath. Phosphate will be indicated by a yellow color, if very little, or a yellow ppt. if more. In case a precipitate appears, collect it on a small filter, wash thoroughly with water and dissolve it in Ammonium hydrate. To the Ammoniacal solution add a small quantity of a mixture of Ammonium chloride and Magnesium sulphate, and allow to stand. Ammonio-magnesium phosphate, $NH_4MgPO_4,6H_2O$, will precipitate. Collect this on a filter, wash with dilute Ammonia, dry, ignite and weigh as Pyrophosphate of Magnesium $Mg_2P_2O_7$. Multiplied by 0·64 this gives the P_2O_5 in 2 Litres. Inasmuch as Phosphates are present in all sewage, the estimation is of great importance, but it must not be forgotten that Phosphates occur in many rocks, and may come from geological sources. **In a surface water they certainly point to sewage contamination.**

Lead is often present in drinking waters. The purer the water, the more chance there is that lead pipes may introduce this poison. To detect it, one Litre of the water should be evaporated to 100 c.c., placed in a glass cylinder over white paper, a little HCl and H_2S added, and the brown coloration, if any, imitated in another cylinder with a standard (very weak) solution of Lead acetate + HCl + H_2S. The number of c.c. used to produce the same tint gives the amount of lead present. A water containing Lead should be at once condemned.

It should be remembered that the mere darkening by H_2S added to the acidulated water does not prove the presence of Lead.

Copper may be present. Similar treatment with HCl + H_2S will also produce a dark discoloration. The concentrated water will give a more or less red-brown tint with a solution of Potassium ferrocyanide.

If **Iron** alone is present, H_2S gives no darkening in the acidulated water. Ammonic sulphide will indicate the presence of iron. On reducing the bulk of the water to one-tenth, Potassium ferrocyanide will produce more or less of a coloration from Prussian blue which can be imitated with a standard solution of a Ferric salt.

Silica, Lime, and Magnesia. 250 c.c. are acidulated with HCl, evaporated to dryness and ignited, the ash dissolved in dilute HCl and the insoluble Silica filtered off, washed, ignited, and weighed. Silica averages 1 grain per gallon. The filtrate is diluted, pptd. with Ammonium chloride, Ammonia, and Ammonium oxalate, boiled, and the precipitate of Calcium oxalate collected on a filter, washed, ignited (whereby it is turned into Calcium carbonate) and weighed. The weight of $CaCO_3$ multiplied by 0·56 gives the amount of CaO in 250 c.c. To the filtrate add Sodium phosphate and more Ammonia: on standing, Ammonio-magnesium phosphate precipitates: it is collected, washed with dilute Ammonia, ignited, whereby it becomes Pyrophosphate, $Mg_2P_2O_7$: the weight of this multiplied by 0·36 gives the MgO in 250 c.c.

Alkalies. One Litre of the water is precipitated with Baryta water, boiled down to a low bulk and filtered; from the Filtrate the remaining Calcium and Barium are removed by boiling with Ammonium carbonate and Oxalate, and this Filtrate evaporated to dryness and ignited till Ammonium salts are expelled. This renders Magnesia insoluble. Extract the residue with small quantities of water, filter, evaporate to dryness, and again ignite: redissolve in water: it should be entirely soluble and should give no reaction with a minute drop of Ammonium carbonate (absence of Lime and Magnesia). The precipitation with Ammonium carbonate may have to be repeated, as sometimes Ca and Mg are not entirely removed the first time. The Filtrate contains the Alkalies, it is acidulated with HCl, evaporated to dryness in a platinum vessel, cautiously ignited (it decrepitates) and weighed as NaCl + KCl. Dissolve in a little water, add Platinic chloride in excess, evaporate again and extract with a mixture of ether and alcohol. Sodio-platinic chloride dissolves, Potassio-platinic chloride, K_2PtCl_6, remains as a yellow crystalline powder, and is weighed and calculated into KCl: this subtracted from the mixed NaCl + KCl gives the weight of the NaCl. Calculate and record as K_2O, and Na_2O in grains per Gallon.

Waters near the sea contain much Sodium.

In sewage, Potassium predominates. Hence the presence of Potassium-salts may be a bad sign.

Sulphates. 250 c.c. of the water are acidulated strongly by HCl, heated to boiling, precipitated by Barium Chloride, boiled till the ppt. settles clear, and the $BaSO_4$ collected, washed, ignited, weighed, and calculated as SO_3 [$BaSO_4 = 233$: $SO_3 = 80$].

Nitrites are an indication that a water is insufficiently aërated or oxidized. Boil 100 c.c. rapidly down to 5 c.c.; make a mixture of KI solution, a little starch paste, and HCl; no reaction should appear: on adding the concentrated water, if a Nitrite be present blue iodide of starch will be produced.

The quantitative determination of the mineral constituents is not often required for a drinking water. A complete analysis of course requires a larger quantity of water, say two gallons.

Characteristics of Sewage. Absence of dissolved Oxygen, high Chlorides, Phosphates, Potassium salts, free and albuminoid Ammonia. Nitrates in recent sewage are almost absent, but after dilution, and oxidation of nitrogenous compounds, the Nitrates become high. Microscopic examination, odor, color, and a careful examination of the source are required before deciding. If the water alters much in composition from time to time, surface contamination may be expected.

BILE.

A syrupy liquid, faintly alkaline, olive- or golden-brown in color; specific gravity 1·009 to 1·020. Human bile contains:—

	Per cent.
Water	86 to 90
Solids	14 to 10
Biliary acids and salts	5·6 to 10
Fats	0·3 to 1·7
Cholesterin	0·4 to 1·0
Mucus	0·14 (varies)
Coloring matters	1·2 to 2·7
Ash	0·6 to 1·0

Pettenkofer's test for bile acids (Glycocholic and Taurocholic acids). Mix in a mortar about 1 part of clean Glucose with 3 parts of concentrated Sulphuric acid: pour this carefully into the middle of the bile spread on a white plate: a rich purple color will indicate bile acids.

Gmelin's test for coloring matters (Bilirubin, Biliverdin, Bilifuscin). Some bile is poured on a white plate, fuming Nitric acid is dropped gradually into the middle; at the point of contact a play of colors, green, blue, violet, red, and finally yellow, indicates bile pigment.

THE URINE.

A clear yellow, acid liquid, depositing more or less of a cloud of mucus on standing.

Normal sp. gr. 1·016 to 1·024.

Average quantity passed by an adult in 24 hours, say, 53 ozs. General composition in 1000 parts:

Water	958 to 940
Solids	42 to 60
	1000 1000
Urea	15 to 31·
Uric acid	0·45
Kreatinin	0·70
Hippuric acid	0·25
Mucus and coloring matters	0·35
Kryptophanic acid	0·4 to 0·10
Ash	25 to 16·00

With traces of Xanthin, Phenol, Indican, an odorous essential Oil, and other matters.

In disease it may also contain Albumen, Fat, Bile, Blood, Dextrose, Cystin, Renal casts, as well as increased quantities of Urates, Phosphates, Oxalates, Coloring matters, and Urea. It often becomes alkaline from the presence of Ammonia, and is then turbid with earthy Phosphates.

In Typhus it contains Leucin and Tyrosin; Chlorides are almost absent, Urea high, and coloring matter low.

In Fevers, Urea is usually higher.

The determination of **Urea** by Russell and West's process depends upon the fact that Urea, $CO(NH_2)_2$, is decomposed by Potassium hypobromite into CO_2, N_2 and $2H_2O$. If Alkali in excess, CO_2 absorbed, and only N_2 free.

$$CO(NH_2)_2+3KBrO+KOH=KHCO_3+2H_2O+N_2+3KBr.$$

If the urine is so concentrated that 5 c.c. gives more Nitrogen than the graduated portion of the tube can hold, less must be taken.

If **Albumen** be present, since it gives N_2 when treated with hypobromite, it must first be removed by faintly acidulating the Urine with acetic acid, boiling, filtering, and taking 5 c.c. of the Filtrate.

10 c.c. are evaporated, dried, and the **Total solids** weighed. Then they are burnt carefully, and the **ash** weighed.

Chlorides are best determined gravimetrically.

20 c.c. of the urine, diluted with water, are acidified strongly with nitric acid, heated to boiling, precipitated with $AgNO_3$, boiled, the AgCl collected on a weighed filter, washed, dried, weighed and calculated into NaCl or Cl.

$AgCl=108+35{\cdot}5=143{\cdot}5.$

$$143{\cdot}5 : 58{\cdot}5 :: \text{weight of AgCl} : \text{weight of NaCl}.$$
$$143{\cdot}5 : 35{\cdot}5 :: \text{weight of AgCl} : \text{weight of Cl}.$$

The weight of NaCl or Cl multiplied by 5 gives their amount in 100 c.c. of Urine.

Uric acid. 200 c.c. of urine, sediment and all, are boiled down to one-tenth, acidulated with HCl, and allowed to stand 12 hours. The Uric acid deposits in granules which may be collected, slightly washed in cold water and weighed.

To test for *Albumen*, a little of the Urine is boiled; a precipitate of earthy Phosphates with albumen, if any, occurs. On addition of a minute drop of Nitric acid, the Phosphates dissolve, and the Albumen remains.

Or the Urine may be carefully poured so as to float on a layer of concentrated Nitric acid; at the junction of the two layers, a cloudy zone will appear if Albumen is present. To determine it, 50 c.c. of Urine are faintly acidified by Acetic acid, boiled, and the coagulated Albumen, collected on a weighed filter, washed, dried and weighed.

Urine containing **Dextrose** is of higher sp. gr. On adding a drop of $CuSO_4$, then KOH in excess, the CuH_2O_2 dissolves to a beautiful blue liquid, and on boiling, red Cuprous oxide Cu_2O deposits. To ascertain the amount, titrate with Fehling's solution, p. 131.

Fermentation-test. 100 c.c. of Urine are measured into a bottle of 200 c.c. capacity, about one gramme of German yeast is added, stirred, loosely covered and set aside for 24 hours in a warm place not above 30°C. Another bottle with 100 c.c. of Urine, without yeast, is set aside. Dextrose is changed by the yeast into Alcohol and Carbon dioxide, hence the quantity is diminished ($C_6H_{12}O_6 = 2CO_2 + 2C_2H_6O$). At the end of the prescribed time, determine the gravities of both by the Hydrometer, brought, if necessary, to the same volume by added water. Every degree per thousand of Sp. gr. lost, equals 0·2196 grm. of Dextrose in 100 c.c. To calculate the total amount per day, multiply by the number of c.c. passed and divide by 100. Of course the whole day's urine must be mixed for the sample, as the quantity of dextrose fluctuates.

For Bile, see p. 140.

Indican is characteristic of intestinal disturbances, but is sometimes met with under other circumstances. Add to the urine its own bulk of Hydrochloric acid, then a drop of Calcium hypochlorite (chloride of lime); Indigo will show itself by a blue coloration and precipitate. If the whole be shaken up with Chloroform, Indigo-blue will deposit, and indigo-red dissolve. (If KI has been administered, the amethystine color of the Chloroform may be due to liberated Iodine: bleached by a little KOH).

The other ingredients require larger quantities of Urine, and longer processes.

Sediments are examined under the microscope.

BLOOD.

Blood has an alkaline reaction; its specific gravity varies from 1·050 to 1·060. Its average composition is as follows:—

Total solids	20·5
Water	79 5
Hæmoglobin	12·0
Fibrin	0·2
Albumen	7 0
Fatty matters	0·2
Ash	0·8
Extractives	0·3
	100·0

The Extractives consist of Sugar, Urea, Kreatin, Leucin, Tyrosin, Xanthin, Hypoxanthin, Uric, Lactic and Hippuric acids; Alcohol, Indican and a yellow Pigment have also been stated to be present. Becquerel gives the Extractives as 0·84 per cent.: no doubt they vary.

Estimation of total Solids, Ash and Iron. A weighed quantity, about 20 grammes, of the Blood is evaporated in a porcelain dish on the water-bath with frequent agitation, dried in the air-bath at 105° C., and the total solids weighed. They are burnt at as low a temperature as possible, the Ash weighed, then dissolved in a little Hydrochloric acid, and the Iron determined by color titration with Potassium ferrocyanide.

Sodium chloride. One Grm. of Blood is mixed with about 2 c.c. of Baryta water, dried, burnt at a low temperature, the Ash boiled with water, filtered, and the Filtrate titrated with standard Silver nitrate (p. 130).

Fibrin. Place in an 8-oz stoppered bottle about 1 oz. of clean shot, weigh the whole, then add about 100 c.c. of freshly drawn blood and weigh again; the difference gives the weight of blood taken. Shake for some time, then decant the liquid from the coagulated Fibrin, wash with water, dry, and weigh again. Subtracting the weight of bottle and shot, we obtain the amount of Fibrin; calculate the percentage.

Corpuscles. The liquid decanted from the Fibrin is mixed with three times its volume of saturated solution of Sodium sulphate, set aside till the Corpuscles deposit, these collected on a weighed filter, washed first with boiling Sodium sulphate solution, then with distilled water, dried, weighed, and the weight of filter deducted. The average quantity is 33 to 35 per cent.

Serum, Albumen, and Extractives. 20 Grms. of fresh blood are allowed to coagulate, the Clot removed, pressed, and the Serum weighed (average about 50 per cent.). The latter is then slightly acidified with Acetic acid, evaporated, dried, and any fat removed by Benzene; the residue is exhausted with hot proof spirit, dried and weighed; this gives the **Albumins.** The alcoholic solution evaporated, dried and weighed, then burnt and the **Ash** deducted give the **Extractives.**

Fat. 50 Grammes of Blood are acidulated with Acetic acid, mixed with half the bulk of Sulphate of Calcium, evaporated, granulated, exhausted with Benzene, the latter poured into a weighed flask, distilled, and the Fat weighed.

Hæmoglobin. This contains 0·42 per cent. of Iron, hence the percentage of Iron found in the ash multiplied by 100 and divided by 0·42 gives approximately the amount of Hæmoglobin. Another method is to compare the color of the diluted defibrinated Blood with a standard solution of Hæmoglobin, or with a standard solution of Picrocarmine (with Gelatin or Glycerin), made to imitate it. A third more exact method is to measure the absorption of the green light by the Spectroscope. For details see Dr. Charles' "Physiological Chemistry," 1884, p. 245.

Sugar. Add to a weighed quantity of Serum an equal bulk of powdered Sodium sulphate crystals, boil, filter and wash, titrate the Filtrate with Fehling's solution, as directed under Milk (p. 131). Average amount 0·05 per cent.

For determination of **Urea** (average 0·02 per cent.), and *Uric acid*, see Dr. Charles' "Physiological Chemistry," p. 267. The other Extractives will be found in the alcoholic Filtrate from the Albumen (see above). Their separation is difficult.

Average composition of the ash of blood (Jarisch): –

Chlorine	30·74
Potash	26·55
Soda	21·11
Phosphoric acid . . .	8·82
Sulphuric acid	7·11
Ferric oxide	8·16
Lime and magnesia . . .	1·33

WEIGHTS AND MEASURES.

METRIC SYSTEM.

The unit of length is the **metre,** of volume the **litre,** of weight the **gramme.**

Multiples of these are denoted by prefixing Greek numerals: **deca** (10 times), **hecto** (100 times), **kilo** (1000 times), **myria** (10,000 times).

Fractions are indicated by the Latin prefixes **deci** (one-tenth), **centi** (one-hundredth), **milli** (one-thousandth).

One cubic centimetre is the volume of a cube one centimetre—one-hundredth of a metre—in side.

One cubic centimetre of water at the temperature of maximum density, 4° C., weighs one gramme. For ordinary purposes, 1 c.c. of water may be taken to weigh 1 grm. at common temperatures.

One litre = 1000 cubic centimetres. One litre of water at 4° C. therefore weighs 1000 grammes or 1 kilogramme.

Abbreviations. Cubic centimetre = cc. or c.c.
Gramme = grm.
Milligramme = mgrm.

EQUIVALENTS.

The following are approximate equivalents for ordinary use:—

1 grm. = 15·432 grains.
1 kilogrm. = 2·2 lbs.
1 metre = 39·37 inches.
1 litre = 1·76 pint.

1 grain = 0·0648 grm.
1 ounce = 28·35 grms.
1 pound = 453·6 grms.
1 minim = 0·059 c.c.

1 c.c. = ·03527 fluid oz.
1 ounce (avoirdupois) = 437·5 grains.
1 pound (ditto) = 16 oz. = 7000 grains.
1 pint = 20 fluid oz. = 1¼ lb. of water.
1 gallon of water = 10 lbs. = 70,000 grains.
1 cubic foot of water weighs 62·5 lbs. = 6¼ gallons.
1 minim of water weighs 0·91 grain.

A *drop* varies with the temperature, nature, and volume of the liquid. With water it is more than a minim, with alcohol it is less.

THERMOMETERS.

Fahrenheit:	freezing point 32°,	boiling point 212°.	F.
Centigrade:	,, ,, 0°,	,, ,, 100°.	C.
Réaumur:	,, ,, 0°,	,, ,, 80°.	R.

To convert Fahrenheit into Centigrade and vice versâ:—

$$\frac{(F^\circ - 32^\circ) \times 5}{9} = C^\circ. \qquad \Big| \qquad \frac{C^\circ \times 9}{5} + 32^\circ = F^\circ.$$

MEASUREMENT OF GASES.

Boyle and Marriott's law, "the volumes of gases are inversely proportional to the pressures." The standard pressure at which gases are measured is 760 millimetres of mercury $= 29 \cdot 92$ inches. (The old standard, 30 inches, $= 761 \cdot 986$ millimetres.) If a gas is measured at any other pressure, a correction must be made, by rule of three, to find what its volume would be at 760 millimetres.

Similarly a correction must be made for temperature. The standard is 0° C. Gases expand $\frac{1}{273}$ of their volume for every 1° C. increase of temperature: $\frac{1}{273} = \cdot 003665$. Hence, if a gas be measured at a temperature t°, to find its volume at 0° C. we must divide by

$$1 + (t^\circ \times \cdot 003665).$$

Example.—100 c.c. of a gas at 770 m.m. and 10° C.: what is the corrected volume at 0° C. and 760 m.m.?

1. *To correct for pressure:* multiply by the observed pressure in millimetres, and divide by 760.

$$100 \times 770 \div 760 = 101 \cdot 32 \text{ c.c.}$$

2. *To correct for temperature:* divide by $1 + \cdot 003665\ t^\circ =$ (in this case $1 \cdot 03665$).

$$101 \cdot 32 \div 1 \cdot 03665 = 97 \cdot 74 \text{ c.c.}$$

The corrected volume is 97·74 c.c. at 0° and 760 m.m.

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