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NOTES ON ANALYTICAL CHEMISTRY

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NOTES

ON

ANALYTICAL CHEMISTRY

FOR STUDENTS IN MEDICINE

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

BY

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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 ANALYSIS."

In May, 1879, I published them in a separate form, and now re-issue a second edition considerably extended.

I have again to express my sincere thanks to my assistants, Messrs. C. G. Stewart and A. P. Hoskins, for the help afforded in passing the sheets through the Press.

At the School of St. Thomas's Hospital we take our stand upon the syllabus of the University of London, and I trust and believe that these Analytical Notes will be suitable for students at all ordinary examinations.

In conclusion, I may mention that all the Tables commonly employed are modifications of those of WILL and FRESENIUS: with various improvements, I have also embodied these in this edition.

To save space, a few abbreviations have been employed, such as pr. for precipitate, &c.

ALBERT J. BERNAYS.

Chemical Laboratory,
St. Thomas's Hospital,
April, 1886.

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BERNAYS'S NOTES
ON
ANALYTICAL CHEMISTRY.

PRELIMINARY.

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. It leaves no residue on evaporation. The addition of sodium carbonate to a small portion, and of silver nitrate to another, produces no change in appearance. Acidulated with hydrochloric acid, HCl, no coloration takes place when hydrogen sulphide, H_2S, is added to a further portion of the water. If quite pure, it is not rendered turbid by lime-water (absence of carbonic acid), nor coloured even faintly yellow by Nessler's test (absence of ammonia).

Distilled water is our great solvent, and a substance may be in solution.

Try the reactions with test-papers, especially with red and blue paper stained with litmus.

A. *It is alkaline:* red litmus is turned blue.

α. To a portion in a test-tube, say 15 drops, add solution of sodium carbonate, Na_2CO_3, and boil, if no result. i. No precipitate, and no smell of ammonia, NH_3, would indicate either potassium hydroxide, or sodium hydroxide, or salts of potassium or sodium with alkaline reaction. ii. No precipitate, but a smell of ammonia, would indicate either free ammonia, or a salt of ammonium with alkaline reaction. iii. A white precipitate points to the hydroxides of barium, strontium, or calcium, the carbonates of which metals are insoluble in water.

If an alkaline solution contains free ammonia or ammonium carbonate, the smell of ammonia may be observed. If an alkaline solution contains a sulphide, a smell as of rotten eggs, H_2S, will be noticeable. If, again, the alkaline solution contains a cyanide, the smell of prussic acid, HCN, will announce itself.

β. To a further portion add silver nitrate, $AgNO_3$. The precipitate is grey-brown: divided into two portions, the one is soluble without effervescence in nitric acid, HNO_3, and the other in ammonia, NH_3. Then a hydroxide of the above metals, potassium, K_2, sodium, Na_2, ammonium $(NH_4)_2$, barium, Ba, strontium, Sr, or calcium, Ca, must be present, as these alone are soluble in water.

Potassium hydroxide	KOH	Carbonates soluble in water.
Sodium hydroxide .	$NaOH$	
Ammonium hydroxide	NH_4OH	
Barium hydroxide .	BaO_2H_2	Carbonates insoluble in water.
Strontium hydroxide	SrO_2H_2	
Calcium hydroxide .	CaO_2H_2	

The precipitate is liver-brown: an arsenate of potassium, sodium, or ammonium is present.

The precipitate is yellow: a phosphate, or an arsenite of potassium, sodium, or ammonium is present. The precipitate should be easily soluble in ammonia and in nitric acid.

The precipitate is paler yellow: an iodide or a bromide of potassium, sodium, or ammonium is present. The precipitate should be insoluble in nitric acid, and, in the case of the iodide, insoluble also in ammonia.

The precipitate is white: insoluble in dilute, but soluble in boiling nitric acid and in ammonia, cyanides. Insoluble in HNO_3, but soluble in NH_4OH, chlorides.

The precipitate is white, changing quickly to yellow, orange, red, and black; a thiosulphate of potassium or sodium probably.

The precipitate is white, soluble with effervescence in HNO_3, and equally readily in NH_3: it is a carbonate of K_2, Na_2, or $(NH_4)_2$. Soluble without effervescence in nitric acid, readily in ammonia; probably a borate (oxalate, &c.) of K_2, Na_2, or $(NH_4)_2$.

The precipitate is black: a sulphide of K_2, Na_2, $(NH_4)_2$, Ba, Sr, or Ca. The sulphide is soluble in HNO_3, and the original solution smells of H_2S.

The student will notice that the carbonates, the hydroxides, chlorides, cyanides, sulphides, arsenites, phosphates, arsenates, thiosulphates, bromides, and iodides of K_2, Na_2 and $(NH_4)_2$ are soluble in water.

Although the hydroxides of barium, strontium, and calcium are soluble in water, the carbonates (phosphates, borates, arsenites, arsenates, &c.) of these metals are not soluble.

Carbonate of sodium serves to distinguish solution of one group from the other.

B. *The solution is acid:* blue litmus is reddened.

aa. To a portion in a test-tube, about 15 drops, add sodium carbonate carefully. Effervescence without a precipitate: it is either a free acid, or an acid salt of K_2, Na_2, or $(NH_4)_2$.

Further boil: if ammonium is present, carbonate of ammonium will be recognised by its smell, by its vapours bluing red litmus, and forming white fumes with a glass rod dipped into HCl.

Now heat some of the original solution on platinum: 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 indicates an acid salt of potassium (violet color to flame), or sodium (bright yellow color to flame).

$\beta\beta$. No effervescence, but a precipitate at once: then the reddening of the litmus is due only to the nature of the salt, as many salts, neutral theoretically, have yet an acid reaction on test-paper. The precipitate consists of a carbonate, or of carbonates of metals other than of K_2, Na_2 or $(NH_4)_2$.

$\gamma\gamma$. No effervescence and no precipitate. Possibly mercuric cyanide, or a feeble acid such as arsenious acid, boric acid, carbonic acid or hydrocyanic acid.

$\delta\delta$. No effervescence, but a precipitate on standing, or heating: possibly tartar emetic.

Confirm in each case by further tests, ascertaining the page from the index.

C. *The solution is neutral to test-papers.*

Add sodium carbonate to a few drops of the original solution. No precipitate, even on boiling, would show the absence of all salts except those of K_2, Na_2, or $(NH_4)_2$. Boil; the odour will indicate an ammonium salt, owing to the formation of ammonium carbonate. Evaporate a drop on clean platinum: a violet color to flame, potassium salt; a yellow color, salt of sodium. Try the reactions for radicles.

As already stated (p. 1) with distilled water, all the reactions are negative, inasmuch as we only dilute the various tests. Test-papers are unaltered, and there is no residue on platinum.

The colors communicated to flame are very helpful, but as a rule it is better not to heat upon platinum foil, until we have ascertained something of the character of the unknown body by means of test-papers, sodium carbonate and silver nitrate. Salts of K_2 communicate a violet color to flame, and red as seen through blue glass. Sodium, Na_2, bright yellow. Lithium salts, purple-crimson. Strontium, crimson. Calcium, yellow-red. Copper, green or blue. Thallium, green. Barium, yellowish-green. Boracic acid, green. Antimony, bluish-green. Arsenic, lavender. Phosphorus, green, &c.

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

Beware of adding concentrated acids to hot solutions, to strong ammonia, or sulphide of ammonium to acid solutions before neutralizing with ammonia.

The tests should be employed almost drop-wise 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 must 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 and bismuth chloride, or nitrate, may be indicated, as they are only soluble in much free acid.

When filtration is required, do not allow the washings to pass into the original fluid. Whenever it is possible, decant, or pour off the clear liquid from the precipitate.

I. TESTS FOR BASES IN SALTS SOLUBLE IN WATER.

Look to color: smell. Whether neutral, alkaline, or acid, to test-papers. If alkaline, the nature of the precipitate with silver nitrate, $AgNO_3$.

DIVISION A.

Sodium carbonate produces a precipitate, for the most part white, but may be colored. Shows the presence of metals, the carbonates (or in a few cases the hydroxides) of which are insoluble in water.

The carbonates, sulphites, phosphates, borates, oxalates, silicates, arsenites and arsenates of these metals are insoluble in water. Hence, if the solution is neutral, or faintly acid, and sodium carbonate has given a precipitate, the above-named salts need not be looked for.

In testing for the metals, the latter are divided into six groups, according to precipitation, or otherwise.

GROUP I.

Add **hydrochloric acid**, HCl, to a fresh portion in a test-tube. Salts of lead, silver, and mercurous are precipitated, respectively, as lead chloride, silver chloride, and mercurous chloride; e.g.: $AgNO_3 + HCl = AgCl + HNO_3$.

Lead Chloride, $PbCl_2$, is white, crystalline, soluble in boiling water. It is unchanged by ammonia, and precipitated from its solution by ammonia. Confirmed by dilute sulphuric acid, in a fresh portion: white lead sulphate. Also by potassium dichromate, yellow lead chromate, soluble in potassium hydroxide.

Silver Chloride, AgCl, is white, curdlike, insoluble in boiling water and in nitric acid, soluble in ammonia. Potassium dichromate, a cherry-red precipitate of silver chromate.

Mercurous chloride, Hg_2Cl_2, calomel, is tawny-white, insoluble in boiling water, and turned black by ammonia. Potassium dichromate, brickdust-coloured mercurous chromate. Metallic copper, in strip, has mercury deposited when boiled with further portion.

The chief soluble salts of lead are the nitrate and acetate; of silver, the nitrate and sulphate; of mercurous, the nitrate, strongly acid. They form colourless solutions.

Pb. Ag. Hg_2.

GROUP II.

Hydrochloric acid, HCl, has no visible reaction; boil, and add **hydrogen sulphide,** H_2S, to the acid solution. Salts of antimonous, stannous and stannic, gold and platinum; of lead, mercuric, bismuth, cupric, and cadmium, are decomposed and precipitated as sulphides; e.g.:—

$$2\,Sb_2Cl_3 + HCl + 3H_2S = Sb_2S_3 + 6\,HCl + HCl.$$
$$Cd\,2\,NO_3 + HCl + H_2S = CdS + 2HNO_3 + HCl.$$

The sulphides of antimony, Sb_2S_3, stannous, SnS, and stannic, SnS_2 (gold and platinum), are soluble in ammonium sulphide, after neutralizing with ammonia; the other sulphides are not soluble.

Antimonous sulphide, Sb_2S_3, is orange-red and soluble in ammonium sulphide, after neutralizing the free hydrochloric acid with ammonia, NH_4OH; it is also soluble, as chloride, in concentrated hydrochloric acid. The probable salt, antimonous chloride, $SbCl_3$, is very acid, and precipitated on addition of water as white oxychloride, SbOCl, soluble in tartaric acid, and discovered by H_2S.

A solution of tartar emetic is slightly acid, slowly precipitated by sodium carbonate, by HCl as white oxy-chloride of antimony, soluble in excess, and precipitated as orange sulphide by H_2S.

Stannic sulphide, SnS_2, yellow, soluble in ammonium sulphide after neutralizing with ammonia.

Stannous sulphide, SnS, brown, and readily soluble in ammonium bi-sulphide after neutralizing with NH_4OH; on addition of dilute HCl, yellow stannic sulphide is precipitated. Confirm stannous by adding mercuric chloride to excess of the original solution; mercurous chloride, Hg_2Cl_2 is first precipitated, and, on warming, changed into grey metallic mercury.

N.B. *If sodium carbonate has produced a precipitate, arsenites and arsenates need not be looked for, as only those of Group VI. can be present in solution in water. The present scheme is for the detection of bases. In the search for acids, in a solution acidulated with* HCl, H_2S *distinguishes arsenious from phosphoric acid by the formation of a bright yellow precipitate of arsenious sulphide,* As_2S_3, *soluble in ammonia, in ammonium carbonate, and in ammonium sulphide.*

Lead sulphide, PbS, slate-coloured, insoluble in NH_4OH and ammonium sulphide. As lead chloride, $PbCl_2$, is soluble in much water, it is possible to have a solution in water, not precipitated in Group I. but in Group II. Confirmation of lead, by dilute sulphuric acid, and by potassium dichromate.

Mercuric sulphide, HgS, black and insoluble in NH_4OH and NH_4HS. The precipitate by sodium carbonate is red-brown. If H_2S is slowly added, white chloro-sulphide is first precipitated, becoming yellow, orange, and black, when excess of H_2S. Confirmed by potassium iodide to fresh portion: a scarlet precipitate, soluble without colour in the test.

Bismuth sulphide, Bi_2S_3, is dark brown, insoluble. Salts of bismuth, unless very strongly acidulated, are precipitated white by water, and the precipitate is much increased by tartaric acid. Potassium dichromate to a fresh portion: orange precipitate of bismuth chromate.

Cupric sulphide, CuS, is black, insoluble. The salts are blue or green: if blue, HCl will change the colour to green. Carbonate of sodium will have given a pale greenish-blue precipitate of copper carbonate. Potassium ferro-cyanide, a red-brown precipitate. Ammonia in excess, a dark blue solution. Steel deposits copper, with characteristic red colour.

Cadmium sulphide, CdS, is light yellow, insoluble. Ammonia gives a white precipitate of the hydroxide, so soluble in slight excess that, if solution acid, no precipitate is formed.

The salts of antimonous are the chloride, and potassium tartrate; of stannous and stannic, the chloride; of lead, the chloride, nitrate and acetate; of mercuric and bismuth, the chloride and nitrate; of cupric and cadmium, the sulphate, nitrate and chloride.

Sb. Sn. Sn. Pb. Hg. Bi. Cu. Cd.

Sb_2S_3 is orange-red. SnS_2 is yellow. SnS, brown. Soluble in ammonium sulphide, after neutralizing with ammonia.

PbS is slate-coloured. HgS is black. Bi_2S_3 is dark brown. CuS is black. CdS is light yellow. Insoluble in ammonium sulphide.

N.B. *A ferric salt, yellow or red in colour, has an acid reaction, and is reduced, in acid solutions, on addition of* H_2S *to a ferrous salt, with deposition of yellow sulphur (blackened by ammonia). Sodium carbonate, first added, will have given, with effervescence, a red-brown gelatinous precipitate, very different from that with mercuric. Ferric salts discovered in Group III., but indicated in present Group II. For chromates, or salts of chromic acid, see p 44. If a solution is yellow-red, the colour is deepened by* HCl, *and* H_2S *changes it to a dingy green, mixed with yellow sulphur. Practically, only a chromate of the metals under Group VI. will be met with.*

GROUP III.

The tests, I. HCl, and II. HCl + H_2S, having produced no results, except as indicated in the last paragraph, add **ammonic hydrate** carefully, without shaking, so as to float it on the surface of the liquid in the test-tube; if there be no precipitate at the junction of liquids, metals of Groups III. and IV. are absent. If there is a precipitate, add to another portion of the original solution **ammonium chloride**, NH_4Cl, and **ammonia**, NH_4OH.

The metals of this group, ferric, aluminic, and chromic, will be precipitated as hydroxides:—

Ferric hydroxide . .	$Fe_2H_6O_6$, red-brown.
Aluminic hydroxide .	$Al_2H_6O_6$, white.
Chromic hydroxide .	$Cr_2H_6O_6$, bluish-green.

N.B. *Unless a ferrous salt is quite free from a ferric salt, there will be a dirty green precipitate, browning on exposure. Always confirm by ferricyanide of potassium.*

The ferric salts are yellowish-red or yellow, very acid. Aluminum salts, colourless and acid. Chromic salts are violet or green.

Ferric hydroxide, $Fe_2H_6O_6$, is red-brown, and insoluble in ammonia and in potash. Ammonium sulphide, a black precipitate of ferrous sulphide, mixed with sulphur. Potassium ferro-cyanide, Prussian blue. Sodium carbonate, with effervescence, will have given a bulky brown precipitate.

Aluminum hydroxide, $Al_2H_6O_6$, is white, gelatinous, insoluble in ammonia, but soluble in potassium hydroxide to a colourless solution. To original solution add KOH; white hydroxide, soluble in excess.

Chromic hydroxide, $Cr_2H_6O_6$, is bluish-green, soluble on heating with large excess of ammonia, with peach-blossom tint. KOH, bluish-green hydroxide, readily soluble in excess to an emerald green solution.

The chief soluble salts are: Of ferric, the chloride, sulphate, and nitrate. Of aluminum, the sulphate, and alumina alums. Of chromic, the sulphate and chrome-alum.

Fe_2. Al_2. Cr_2.

GROUP IV.

Ammonium sulphide in presence of ammonium chloride.

Proceed as directed under Group III. If there is a precipitate on floating ammonia on to the liquid containing both HCl and H_2S, and proof has been obtained that neither ferric, aluminum, or chromic, are present in Group III., add ammonium sulphide to the NH_4Cl solution.

The metals of this Group IV., ferrous, cobalt, and nickel, zinc, d manganous, are precipitated as hydrated sulphides.

Ferrous sulphide .	FeS, black.
Cobalt sulphide .	CoS, black.
Nickel sulphide .	NiS, black.
Zinc sulphide . .	ZnS, white.
Manganous sulphide	MnS, flesh-tinted.

The ferrous salts are sea-green, changing naturally to dingy yellowish-green. Cobalt salts, pink, red, or even blue. Nickel salts, green. Zinc salts, colourless. Manganous salts, colourless or pink.

Ferrous sulphide, FeS, black, readily soluble in dilute HCl. Ferri-cyanide of potassium to a fresh portion, Turnbull's blue.

Cobalt sulphide, CoS, black, insoluble in dilute HCl. Ferri-cyanide of potassium, in a fresh portion, a reddish-brown precipitate.

Nickel sulphide, NiS, is black, and insoluble in dilute HCl. Potassium ferri-cyanide, a yellowish-brown precipitate. Under Group-test III., ammonium chloride and ammonia will have detected nickel by the beautiful plum-coloured solution.

Zinc sulphide, ZnS, is white, and insoluble in potash. Salts colourless. Potassium ferri-cyanide, a brownish-yellow precipitate. Ammonia gives a white, gelatinous precipitate, very soluble in excess.

Manganous sulphide, MnS, is flesh-tinted, darkening on exposure to air. Potassium ferri-cyanide, a brown precipitate.

The chief soluble salts of Fe, Co, Ni, Zn, and Mn, are the sulphates, chlorides, and nitrates.

Fe. Co. Ni. Zn. Mn.

GROUP V.

If no precipitates by Group-tests I., II., III., and IV., add **ammonium chloride, ammonia and ammonium carbonate** to a fresh portion, and boil if necessary. The metals of this Group V., barium, strontium, and calcium, are precipitated as white carbonates. Soluble salts, colourless.

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

Barium carbonate, $BaCO_3$, white. Solution of calcium sulphate, to a fresh portion, an immediate white precipitate of barium sulphate, $BaSO_4$. Ammonia, no reaction. Yellowish-green colour to flame.

Strontium carbonate, $SrCO_3$, white. Calcium sulphate to a fresh portion, no immediate precipitate, but one of $SrSO_4$ on warming. Ammonia, no reaction. Crimson flame.

Calcium carbonate, $CaCO_3$, white. Calcium sulphate, of course no precipitate. Ammonium oxalate, an immediate precipitate of calcium oxalate, insoluble in acetic acid. Ammonia, no reaction. Yellow-red colour to flame.

Inasmuch as Division-test A has given a white precipitate, although ammonium carbonate in presence of the chloride of ammonium has given no precipitate, magnesium must be present in form of a salt of magnesium.

Magnesium carbonate, $MgCO_3$, white, by sodium carbonate. Ammonia, white precipitate of magnesium hydroxide MgH_2O_2. Ammonium chloride first added to a further portion, then NH_4OH, and sodium phosphate, a white crystalline precipitate of magnesium-ammonium-phosphate.

The chief soluble salts of barium and strontium are the chloride, and the nitrate; of calcium and magnesium, the chloride, sulphate, and nitrate.

Ba. Sr. Ca. Mg.

DIVISION B.

Sodium carbonate produces no precipitate.

GROUP VI.

Boil a small portion of the original solution with **sodium carbonate**:—

Ammonium, $(NH_4)_2$, is recognised as ammonium carbonate, NH_4HCO_3, by the odour of hartshorn, by the bluing of red litmus held in the tube, and by the white fumes of ammonium chloride, when a glass rod, dipped into hydrochloric acid, is held in the vapours. Salts colourless and volatile. Platinic chloride, $PtCl_4$, to fresh portion: yellow precipitate of ammonium platinic chloride $2NH_4Cl, PtCl_4$.

If ammonium not present, look for potassium and sodium.

Potassium salt, on a loop of platinum wire, a violet colour to flame, made red by viewing through blue glass. Platinic chloride, a yellow precipitate of potassium platinic chloride $2KCl, PtCl_4$.

Sodium salt, on a loop of platinum wire, bright yellow colour to flame. No precipitate with $PtCl_4$.

Ammonium, as hydrate, NH_4OH, strongly alkaline, smells of hartshorn, fumes on addition of HCl. $AgNO_3$, grey-brown precipitate, very soluble in free ammonia, and in nitric acid.

Potassium, as hydroxide, KOH, strongly alkaline; no reaction with Na_2CO_3; evolves NH_3 from ammonium chloride on heating. Precipitates grey-brown AgOH, soluble in ammonia, and in nitric acid. Confirmed by flame-test, and by platinic chloride.

Sodium, as hydroxide, NaOH, like KOH, but yellow color to flame, and no reaction with platinic chloride, $PtCl_4$.

The salts of potassium, sodium, and ammonium, are legion. They are nearly all soluble in water, and all are colourless except those with coloured acids.

K_2. Na_2. $(NH_4)_2$.

RECAPITULATION OF METALS PRECIPITATED IN EACH GROUP.

Division A. *Sodium carbonate a precipitate in first five groups.*

Group I. By hydrochloric acid, HCl, as chlorides. Lead, silver, and mercurous: $PbCl_2$, AgCl, and Hg_2Cl_2.

Group II. By H_2S added to HCl solution, as sulphides. Antimony, (arsenic), stannic, stannous, gold, and platinum, as sulphides, Sb_2S_3, (As_2S_3), SnS_2, SnS, (Au_2S_2 and PtS_2); soluble in ammonium sulphide. And lead, mercuric, bismuth, copper, and cadmium, as sulphides, PbS, HgS, Bi_2S_3, CuS, and CdS, insoluble in ammonia and ammonium sulphide.

Group III. By NH_4OH added to NH_4Cl. Ferric, aluminum, and chromic, precipitated as hydroxides: $Fe_2H_6O_6$, red-brown; $Al_2H_6O_6$, white; $Cr_2H_6O_6$, bluish-green.

Group IV. By $(NH_4)_2S$ added to NH_4Cl. Ferrous, cobalt, nickel, zinc, and manganous, precipitated as sulphides: FeS, CoS, and NiS, black; ZnS, white; MnS, flesh-tinted.

Group V. By $(NH_4)_2CO_3$ added to NH_4Cl. Barium, strontium, and calcium, precipitated as carbonates: $BaCO_3$, $SrCO_3$, and $CaCO_3$.

Magnesium must be present, if Na_2CO_3 has produced a precipitate of MgH_2O_2, $MgCO_3$.

Division B. *No precipitate with* Na_2CO_3.

Group VI. Includes ammonium, potassium and sodium.
Boil the solution with Na_2CO_3. Ammonium is evolved as $(NH_4)_2CO_3$. 2 NH_4Cl, $PtCl_4$.
Potassium and salts, violet colour to flame. 2 KCl, $PtCl_4$.
Sodium and salts, yellow colour to flame.

II. TESTS FOR SUBSTANCES INSOLUBLE IN WATER.

(See index.)

TESTS FOR SOME ACIDS IN SOLUBLE SALTS.

Acids may be grouped upon certain principles. With the exception of certain hydroxides soluble in water, as those of potassium, sodium, ammonium, barium, strontium and calcium (KOH, $NaOH$, NH_4OH, $Ba(OH)_2$, $Sr(OH)_2$ and $Mg(OH)_2$), each metal must be in combination with some radicle, or acid principle, in a salt.

Organic acids may generally be distinguished from inorganic acids by the fact, that the former are carbon compounds, and are nearly all carbonized by heat.

Sodium carbonate, Na_2CO_3, will have already revealed the absence of many acids, as not only are the carbonates of the metals nearly all insoluble in neutral or alkaline solutions, but also the phosphates, borates, chromates, sulphites, thiosulphates, arsenites, arsenates, silicates, oxalates and others. So that, if sodium carbonate gives a precipitate in a solution of a metallic salt, we need not look for a carbonate, a phosphate, a borate, a chromate, a sulphite, a thiosulphate, an arsenite, an arsenate, a silicate, an oxalate and others.

A colorless solution will reveal the absence of a chromate as the latter must be yellow, if only a trace is present.

Hydrochloric acid, HCl, as a group-test, will discover many acids, in salts. It thus acts, because the radicle chlorine exchanges hydrogen for another metal, and separates a different acid. As illustrations may serve:

A *carbonate* is decomposed with effervescence:

$$Na_2CO_3 + 2HCl = 2NaCl + H_2O + CO_2.$$

A *sulphite* is decomposed, and on heating, the smell of the burning brimstone match reveals sulphur dioxide.

$$Na_2SO_3 + 2HCl = 2NaCl + H_2O + SO_2.$$

A *thiosulphate* is decomposed, and, on heating, sulphur is deposited, and sulphur dioxide evolved.

$$Na_2S_2O_3 + 2HCl = 2NaCl + H_2O + S + SO_2.$$

A *chlorate* is decomposed, and on warming becomes yellowish-green, evolving chlorine and the peroxide of chlorine, as a yellowish-green gas.

A *sulphide* is alkaline, smelling of hydrogen sulphide, H_2S, which is evolved.

A *cyanide* is alkaline, smelling of prussic acid, HCN, which is evolved.

An *acetate* gives off acetic acid, on addition of HCl.

A *nitrite* gives off nitrous fumes at once, and the liquid becomes deep yellow.

Barium chloride, $BaCl_2$, or barium nitrate, $Ba\,2NO_3$, is a group test, as so many barium salts are insoluble in water. From solutions of neutral salts, it precipitates insoluble carbonates, sulphates, sulphites, thiosulphates, phosphates, borates, chromates, arsenites, arsenates, oxalates, tartrates, citrates (silicates, iodates, silicofluorides), and others. Barium sulphate is insoluble in HCl, and in HNO_3.

The action of $BaCl_2$ may be given in symbols:—

$$\begin{aligned} BaCl_2 + Na_2CO_3 &= 2NaCl + BaCO_3. \\ BaCl_2 + Na_2SO_4 &= 2NaCl + BaSO_4. \\ BaCl_2 + Na_2HPO_4 &= 2NaCl + BaHPO_4. \\ BaCl_2 + Na_2HAsO_3 &= 2NaCl + BaHAsO_3. \end{aligned}$$

Silver nitrate, $AgNO_3$, is a very important group-test. It not only precipitates many radicles which the barium chloride test precipitates, but also others. Thus chlorides, bromides, iodides, cyanides, soluble sulphides, etc., are precipitated by $AgNO_3$. Thus:—

$$\begin{aligned} AgNO_3 + NaCl &= NaNO_3 + AgCl. \\ AgNO_3 + KI &= KNO_3 + AgI. \\ AgNO_3 + KBr &= KNO_3 + AgBr. \\ 3AgNO_3 + Na_2HPO_4 &= 2NaNO_3 + Ag_3PO_4 + HNO_3. \end{aligned}$$

The value of silver nitrate as a preliminary test, when a solution is alkaline to test-paper, has been shown in the case of the hydroxides soluble in water (p. 2), the grey-brown color of the insoluble silver hydroxide, AgOH, soluble both in NH_4OH, and in HNO_3, being decisive. Then again, silver arsenite, Ag_3AsO_3, and phosphate, Ag_3PO_4, are bright yellow: silver arsenate, Ag_3AsO_4, liver-brown. Silver chromate is crimson.

Before entering upon a more careful study of the acids, we will suppose one metal to be in combination either as a carbonate, chlorate, sulphate, phosphate, arsenite, chloride, bromide, iodide or nitrate.

a. Carbonates. Alkaline to test-paper. Only the carbonates of K_2, Na_2 and $(NH_4)_2$ soluble in pure water. Na_2CO_3, no reaction. Add HCl to a fresh portion: effervescence without disagreeable smell; carbon dioxide, CO_2. With $BaCl_2$ to a further portion, white pr. of $BaCO_3$, soluble with effervescence in HCl. With $AgNO_3$ to a fresh portion, a tawny pr. of Ag_2CO_3, soluble in NH_4OH, and with effervescence in HNO_3.

b. Chlorates. All chlorates are soluble in water; Na_2CO_3 may or may not give a precipitate. HCl, no effervescence; absence of carbonates. Heat: solution with HCl becomes yellowish green, and gives off chlorine, and chlorine peroxide as yellow-green gases. In fresh portions, neither $BaCl_2$ nor $AgNO_3$ give any reaction, as barium and silver chlorates are soluble in water; shows absence of phosphates, sulphates, arsenites, chlorides, bromides, iodides and cyanides.

A chlorate, heated on platinum strongly, becomes a chloride; proved by solution in water, addition of $AgNO_3$, and insolubility of $AgCl$ in HNO_3.

c. Sulphates. All are soluble in water, except the sulphates of barium, strontium, or lead. Na_2CO_3 may or may not give a precipitate. Add HCl to a fresh portion: no reaction, even on heating (absence of carbonate and chlorate); but on addition of $BaCl_2$ to the heated HCl solution, a white precipitate of $BaSO_4$. A sulphate.

d. Phosphates. Only those of K_2, Na_2 and $(NH_4)_2$ are soluble in water. If therefore Na_2CO_3 gives a pr., absence of carbonates, phosphates and arsenites. Add HCl to a fresh portion: no effervescence and no yellow-green coloration (absence of carbonates and chlorates). $BaCl_2$ added to the heated HCl solution, no reaction: absence of sulphates. $BaCl_2$, white pr. soluble in HCl (absence of chlorides, bromides, iodides and cyanides); probably a phosphate or arsenite. $AgNO_3$, bright yellow pr., soluble in HNO_3, and in NH_4OH, a phosphate or arsenite. $CuSO_4$, a whitish-blue pr. of $CuHPO_4$. Ammonium chloride, ammonia and magnesium sulphate, a white crystalline pr. of $MgNH_4PO_4, 6H_2O$. A phosphate.

e. Arsenites. Only those of K_2, Na_2 and $(NH_4)_2$ soluble in water. If therefore with Na_2CO_3 a pr., we need not look for an arsenite (or phosphate). $BaCl_2$ and $AgNO_3$, like a phosphate. $HCl + H_2S$, a bright yellow pr. of arsenious sulphide, As_2S_3, soluble in NH_4OH, in $(NH_4)_2CO_3$, and in $(NH_4)_2S$. An arsenite thus distinguished from a phosphate. $CuSO_4$, a green pr., confirms an arsenite.

f. Chlorides. Silver chloride, $AgCl$, and mercurous chloride, Hg_2Cl_2, alone insoluble in water. Na_2CO_3 may, or may not, give a precipitate. HCl, no reaction, even on heating (absence of carbonates and chlorates). Add $BaCl_2$ to same HCl solution: no reaction (absence of sulphates). Neutralize the HCl solution, to which $BaCl_2$ has been added: no reaction (absence of phosphates and arsenites). $AgNO_3$ to a fresh portion: white pr. curd-like, insoluble in nitric acid, soluble in ammonia (absence of iodides). Chlorine water, no reaction; a chloride (not a bromide).

g. Bromides resemble the chlorides as to solubility. Na_2CO_3 may or may not give a pr. HCl, no reaction, even on heating: no precipitate on addition of $BaCl_2$ to the heated acid solution, and no pr. on neutralizing with NH_4OH. Absence of carbonates, chlorates, sulphates, phosphates, and arsenites. $AgNO_3$, yellowish pr. insoluble in HNO_3, and with difficulty in NH_4OH. Probably a bromide. Add chlorine water; solution becomes sherry-coloured, and the color imparted to chloroform, which may be yellow, to orange-red, when shaken with the liquid. HNO_3 to a fresh portion, and heat: if concentrated, bromine is set free, and condenses in blood-red drops, from the suffocating red-brown vapors; if dilute an orange color to the liquid, and orange vapours. Starch-paste in the vapors, yellow, or orange.

h. Iodides.—More insoluble iodides than chlorides, or bromides. Na_2CO_3 may, or may not, give a pr. HCl, no reaction, even on heating: absence of carbonates and chlorates. $BaCl_2$, no reaction: absence of sulphates, phosphates and arsenites. $AgNO_3$, yellow pr. insoluble both in NH_4OH, and in HNO_3. Probably an iodide. Chlorine water colors the original solution deep sherry-brown, from which chloroform extracts the iodine, on shaking, with violet colour: starch-paste blued by free iodine. HNO_3, separates solid iodine, vaporised by heat as violet vapor, condensing to solid iodine.

i. Nitrates.—All soluble in water, except the basic nitrate of bismuth. Na_2CO_3 may or may not give a pr. HCl, no reaction: absence of carbonates and chlorates. $BaCl_2$, no reaction: absence of phosphates, sulphates and arsenites. $AgNO_3$, no reaction: absence of chlorides, bromides, and iodides. Mix a further portion with solution of ferrous sulphate, and pour a thin stream of H_2SO_4 to the bottom of the test-tube; there will be a line of olive-brown colour separating the aqueous liquid from the acid, and, on shaking, the whole becomes first brown, then rich yellow, with orange-red nitrous fumes. A nitrate. H_2SO_4 separates HNO_3, and copper turnings give the reaction: $3Cu+8HNO_3=3(Cu2NO_3)+2NO+4H_2O$. Nitric oxide, NO, with the air gives nitrogen peroxide, N_2O_4, orange-fumes.

For more complete instruction, the student is referred to the "Studies on the Acids and Salts," pp. 35–48.

Studies on the Metals, Oxides, Hydroxides, Sulphides.

Division A.—Solutions of such metallic salts, soluble in water, as are precipitated by a solution of sodium carbonate, either as carbonates or hydroxides.

This division comprises Groups I., II., III., IV., and V. See pp. 4–8.

Group I.—From soluble salts of lead, thallium, silver, and mercurous, HCl precipitates the chlorides of lead, thallium, silver, and mercurous. Their sulphides are black or brown-black, and insoluble in ammonium sulphide, after neutralizing the acid liquid with ammonia.

1. Lead, Plumbum, Pb = 207.

Bluish-white metal, lustrous, malleable. Sp. gr. 11·37. Melts at 326° C. Blow-pipe bead on charcoal flattens under the pestle, and marks paper like black-lead. Melts, and gives a yellow incrustation of yellow oxide, when heated on charcoal in outer blowpipe flame. Dilute HCl, and dilute sulphuric acid, scarcely a reaction. HNO_3 dissolves lead, as lead nitrate: $3Pb+8HNO_3=3(Pb2NO_3)+2NO+4H_2O$. Boiling H_2SO_4 produces some lead sulphate, $PbSO_4$, sulphur dioxide, SO_2 and water, H_2O.

Lead oxide, PbO, is yellow, fusible; alkaline to test-papers. Dissolved by nitric acid as lead nitrate: $PbO+2HNO_3=Pb2NO_3+H_2O$. On charcoal, easily reduced to metallic state, with yellow incrustation. Hydroxide of lead, PbH_2O_2, white, soluble in potassium hydroxide. Lead carbonate PbH_2O_2, $PbCO_3$ is white, insoluble in water, and therefore precipitated by solutions of potassium or sodium carbonates. Dissolves with effervescence in nitric acid, as nitrate, $Pb2NO_3$. Chief soluble salts of lead: acetate, $Pb2C_2H_3O_2, 3H_2O$. Nitrate, $Pb2NO_3$. Chloride, $PbCl_2$. Solutions neutral, or faintly acid. Goulard's extract, Liquor plumbi sub-acetatis, is alkaline, blues red litmus.

Tests for lead in soluble salts.

I. HCl, the group-test, a white precipitate of lead chloride, $PbCl_2$, soluble in large excess, especially on heating: not in ammonia.

$HCl+H_2S$, slate-colored sulphide, PbS, insoluble in NH_4OH, and in NH_4HS. The precipitate may be red at first, as chloro-sulphide, $2PbCl_2, 3PbS$, changing by excess of H_2S into sulphide, PbS.

KOH, white hydroxide, PbH_2O_2, soluble in excess of KOH.

H_2SO_4, white $PbSO_4$, soluble in ammonium acetate.

$K_2Cr_2O_7$, yellow $PbCrO_4$, soluble in excess of KOH.

KI, yellow lead iodide, PbI_2, soluble in much boiling water, and crystallizing on cooling in gold-coloured scales.

Before the blowpipe flame, on charcoal, bluish, lustrous beads of metal, with incrustation of yellow oxide.

Galena, or lead sulphide, PbS, is the chief ore of lead. When roasted in the reverberatory furnace, oxydized in part into lead oxide, and lead sulphate. $2PbS+3O_2=2PbO+2SO_2$. $PbS+2O_2=PbSO_4$. When unchanged PbS is heated with PbO and with $PbSO_4$, we obtain lead and sulphur dioxide,

$PbS+PbSO_4=2Pb+2SO_2$. $PbS+2PbO=3Pb+SO_2$. Galena resembles lead; it is not malleable, but brittle. Hot 2HCl dissolves PbS as $PbCl_2$ with evolution of H_2S. Nitric acid forms a nitrate, with separation of S and $PbSO_4$: nitrous fumes are evolved.

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. 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 colourless 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. Sp. gr. 10·57. Melts at 1040° C. Blowpipe bead lustrous, malleable; no incrustation. Absorbs oxygen when melted, and gives it out again; "spits" on cooling. Tarnished by H_2S in presence of air. 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 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.

I. 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.

H_2S, brown-black Ag_2S, soluble in boiling nitric acid.

KOH, grey-brown oxide, Ag_2O, or hydroxide, AgOH, soluble both in NH_4OH and in HNO_3; insoluble in KOH.

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

$K_2Cr_2O_7$, crimson Ag_2CrO_4, soluble in HNO_3.

KI, pale-yellow 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. Sp. gr. 13·56. 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; $3Hg_2+8HNO_3=3(Hg_2 2NO_3)+4H_2O+2NO$. 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. Hg_2O 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. Division-test A, sodium carbonate, gives a precipitate in soluble mercurous salts, first yellowish-white, then, through yellow, to dingy green.

Chief soluble salt, mercurous nitrate, $Hg_2 2NO_3$, very acid. (Calomel, Hg_2Cl_2, is white, and quite insoluble in water. By boiling with HCl into $HgCl_2+Hg$. Volatilized by heat. 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 in aqua regia as mercuric chloride).

KOH, black Hg_2O, insoluble.

NH_4OH, black Hg_2O, insoluble.

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

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

$SnCl_2$, a white precipitate of Hg_2Cl_2, calomel, changing to grey metallic mercury. $Hg_2Cl_2+SnCl_2=SnCl_4+Hg_2$.

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, $Hg_2 2NO_3$, first white, then yellow, red, black, 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 sulphide .	As_2S_3, bright yellow.
Antimonous sulphide	Sb_2S_3, orange-red.
Stannic sulphide . .	SnS_2, pale yellow.

Stannous sulphide .	SnS,	brown.
Aurous sulphide . .	Au_2S_2,	black.
Platinic sulphide . .	PtS_2,	black.
Lead sulphide . . .	PbS,	slate-colored.
Cupric sulphide . .	CuS,	black.
Mercuric sulphide. .	HgS,	black.
Bismuth sulphide. .	Bi_2S_3,	brown-black.
Cadmium sulphide .	CdS,	yellow.

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 ammonium sulphide $(NH_4)_2S_2$.

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

a. Sulphides soluble in ammonium sulphide after neutralising the free acid with ammonia.

Arsenicum as arsenious oxide, As_2O_3, forms an acid, arsenious acid, H_3AsO_3, and 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_4HS. See p. 13.

Arsenates, as arsenates of potassium, sodium, and ammonium, are alone soluble in water. 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. 43.

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

A bluish-white, lustrous, brittle metal. Sp. gr. 6·7. 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: $Sb_4+12H_2SO_4=2(Sb_23SO_4)+6SO_2+12H_2O$. 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; $Sb_2S_3+6HCl=2SbCl_3+3H_2S$.

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.

II. $HCl+H_2S$, orange-red Sb_2S_3, insoluble in ammonia and in carbonate of ammonium, but then soluble in ammonium sulphide. Sb_2S_3, soluble in strong HCl to antimonous chloride; a source of H_2S.

KOH, white Sb_2O_3, soluble in excess.

NH_4OH, white, insoluble.

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 hydrogen chloride, 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 colourless 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 ammonium 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 blowpipe-flame, lustrous beads of antimony, with white incrustation of Sb_2O_3. Beads brittle.

6. TIN, STANNUM, Sn = 118.

White lustrous metal, malleable. Sp. gr. 7·25. 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.

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 $SnO,SnCl_2$. Stannous oxide, SnO, is a black substance: hydroxide, SnH_2O_2, white, soluble in KOH, as stannate.

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 ammonium 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. 22.

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.

When tin and antimony together, their chlorides decomposed by zinc, the two metals washed, dried, and weighed, re-dissolved as chlorides in weak aqua regia, and the antimony removed by metallic tin.

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.

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. Sp. gr. 19·5. 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.

$$6HCl+2HNO_3=4H_2O+2NOCl+2Cl_2.$$

Auric oxide, Au_2O_3, the chief oxide, is of 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

NH_4OH, olive-brown fulminating gold, $Au_2O_3,4NH_3$

$SnCl_2$, containing a little $SnCl_4$, gives purple of Cassius $SnAu_2$, $Sn_2O_5,4H_2O$.

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

$$6FeSO_4+2AuCl_3=Fe_2Cl_6+2(Fe_2 3\,SO_4)+2Au.$$

Oxalic acid reduces gold salts.

Upon charcoal, all gold compounds reduced to lustrous gold without incrustation.

8. PLATINUM, $Pt = 194 \cdot 5$.

Dull white metal, malleable and ductile. Sp. gr. 21·5. 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 $PtCl_4$, platinous chloride $PtCl_2$, is first obtained; 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 ammonium sulphide.

KHO generally precipitates potassium platinic chloride, $2\,KCl,PtCl_4$, with yellow color, as platinic chloride is $2\,HCl,PtCl_4$. Excess of KHO gives the yellow hydrate when boiled.

NH_4HO, gives yellow precipitate of $2\,NH_4Cl,PtCl_4$, because the ammonia finds the necessary HCl to make it ammonium 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 ammonium sulphide, after neutralising free acid with ammonia.

LEAD, PLUMBUM, $Pb = 207$.

Chief salts: acetate, nitrate, chloride. See p. 15. If a solution of a lead-salt dilute, although Na_2CO_3 will have given a white precipitate, HCl will occasion none: lead oxide must be sought for in Group II., sub-division *b*.

9. COPPER, CUPRUM, $Cu = 63 \cdot 3$.

A lustrous metal of red color, malleable, ductile, and tenacious. Sp. gr. 8·95. Melts at 1300°. Oxydises readily at a red-heat, forming both red cuprous oxide and black cupric oxide. Sometimes native. Insoluble in dilute sulphuric and hydrochloric acids: slowly in HCl in presence of air: $Cu+2HCl=CuCl_2+H_2$. With hot sulphuric acid:

$$Cu+2\,H_2SO_4=CuSO_4+2\,H_2O+SO_2.$$

With dilute nitric acid:

$$3\,Cu+8\,HNO_3=3(Cu2NO_3)+4\,H_2O+2\,NO.$$

A good method of making nitric oxide. Chlorine attacks it immediately, to cupric chloride.

Cupric oxide, CuO, is the chief oxide. Readily prepared by heating cupric nitrate, $Cu\,2\,NO_3$, to redness. It is black and quite insoluble in water. With 2 HCl, into green $CuCl_2$ and H_2O. With nitric acid, into blue $Cu\,2\,NO_3$ and H_2O. With H_2SO_4, into $CuSO_4$ and H_2O. Anhydrous cupric sulphate is white; blue vitriol, $CuSO_4,5\,H_2O$, blue. Cuprous oxide Cu_2O is ruby copper ore: salts colorless. The chief ore of copper is copper pyrites Fe_2S_2,Cu_2S_2. By roasting, the iron oxydised, and slagged off as silicate by further heating with 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 $2\,CuH_2O_2,CuCO_3$.

II. $HCl+H_2S$ brown-black CuS, slightly colouring the solution. Insoluble in ammonium 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 purple color, and precipitated on heating as yellow or red Cu_2O.

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

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

Fe deposits metallic copper, especially recognisable if solution acid. Zn and Pb also precipitate Cu.

On charcoal, with Na_2CO_3 in outer flame, beads of red 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.

Ammonium carbonate in excess re-dissolves cupric hydro-carbonate with deep-blue color, and may be employed for separating copper from bismuth.

10. MERCURIC, Hg = 200.

Mercury and mercurous 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. 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.

$$HgSO_4+2\,NaCl=Na_2SO_4+HgCl_2.$$

Completely volatile. Sodium carbonate gives a heavy red-brown precipitate of $2\,HgO,HgCO_3$ in solutions of mercuric chloride, but no precipitate in solutions of mercuric cyanide: HCl immediately separates hydrocyanic acid.

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 HgS, insoluble in strong nitric acid.

KOH, yellow mercuric oxide, HgO.

NH_4OH, white mercuric chloro-amide, NH_2HgCl.

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

$SnCl_2$, first mercurous chloride, Hg_2Cl_2, and then Hg: in solution stannic chloride.

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

Heated with Na_2CO_3 in glass tube, mercury volatilises.

11. Bismuth, $Bi = 208$.

A lustrous, reddish-white metal: very brittle. Chiefly native. Sp. gr. 9·8. 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 crystallises with $5H_2O$. Bismuth nitrate, $Bi3NO_3$ is decomposed and precipitated white, on addition of water, as $Bi_2O_3,Bi3NO_3,3H_2O$. Dilute sulphuric acid has no action, but H_2SO_4 yields water, sulphur dioxide, and bismuth sulphate $Bi_2 3SO_4$. Aqua regia dissolves it as $BiCl_3$.

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

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 precipitate of Bi_2S_3, insoluble in ammonium sulphide; soluble in HNO_3.

KOH, white hydrate, insoluble: on boiling, yellow.

NH_4OH, white, insoluble.

$K_2Cr_2O_7$, deep-yellow $Bi_2 3CrO_4$, 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. Sp. gr. 8·6, 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. 27.) Cadmium oxide, CdO, is brown, and the base of all salts: insoluble in water, but dissolved as $CdCl_2$, $CdSO_4$ and $Cd2NO_3$, 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 ammonium sulphide, soluble in HNO_3 and in hot dilute sulphuric acid.

KOH, white hydroxide, insoluble.

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

$(NH_4)_2CO_3$, white carbonate, insoluble.

$K_4FeC_6N_6$, white $Cd_2FeC_6N_6$.

Ferricyanide of potassium, yellow-brown precipitate.

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. Precipitated from palladous chloride by potassium iodide, and 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 precipitate in a solution originally colored reddish-yellow or yellow, add NH_4OH to one portion: this, with the H_2S present, forms ammonium 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. 44. Chromates of the alkaline metals soluble in water. The acid chromates, of red-yellow color, with effervescence, into neutral yellow chromates, by sodium carbonate.*

Group III.—From soluble salts, the metals of this group are not precipitated either as chlorides or as sulphides.

To the tests $HCl+H_2S$ float a few drops of ammonic hydrate: if no precipitate, pass on to Group V.

If a precipitate, 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 **ammonium chloride**, and then **ammonia** has been added. Comprises:

Ferric as hydroxide .	$Fe_2H_6O_6$.
Manganic as hydroxide .	$Mn_2H_6O_6$.
Aluminum as hydroxide	$Al_2H_6O_6$.

14. IRON, FERRUM, Fe = 56.

Beautiful white metal, malleable, ductile, tenacious. Sp. gr. 7·84. 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 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 sulphate, $Fe_23SO_4,9H_2O$, and ferric chloride, $Fe_2Cl_66H_2O$.

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 red-brown ferric hydroxide, insoluble.

KOH, red-brown, $Fe_2H_6O_6$, insoluble.

K_4FeCy_6, precipitates Prussian blue, $Fe_4Fe_3Cy_{18},18H_2O$.

K_3FeCy_6, a brown coloration.

Potassium sulphocyanide gives blood-red solution.

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

Fused with borax, in reducing flame, the bead green; in outer flame, yellowish-red.

15. ALUMINUM, Al = 27.

Bluish-tinted metal, malleable and ductile. Sp. gr. 2·7. 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. Aluminum 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: alum, $K_2Al_24SO_4,24H_2O$. 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.

KOH, white, gelatinous hydroxide, soluble in excess as potassium aluminate, $K_2O,Al_2O_3,3H_2O$.

$(NH_4)_2CO_3$, white precipitate of hydroxide, insoluble.

Na_2HPO_4, white aluminum 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. Almost infusible. 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. 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 = 56.

Manganic oxide, Mn_2O_3, is blackish-brown. Found as the mineral braunite. Salts deep red, and decomposed by heat into salts of manganous (p. 27). In the rare manganese alum, $K_2Mn_24SO_4,24H_2O$.

18. GLUCINUM OR BERYLLIUM, Be = 9.

Silverwhite metal, malleable and ductile. Sp. gr. 2·1. 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. Diluted and boiled, re-precipitated.

$(NH_4)_2CO_3$, white carbonate, easily soluble in excess. ($Al_2H_6O_6$, insoluble).

$(NH_4)_2S$, white hydroxide.

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

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

19. ZINC, Zn = 65·3.

Bluish-white, lustrous metal. Brittle at common temperatures. Malleable and ductile between 100° and 150°. Sp. gr. 7. Melts at 420°. When pure, but little acted upon by dilute sulphuric and hydrochloric acids. With the ordinary, dilute acids give the respective chloride and sulphate, with evolution of H_2. In cold nitric acid:

$$4\,Zn+10\,HNO_3=4(Zn2NO_3)+NH_4NO_3+3\,H_2O.$$

With hot nitric acid, besides an ammonium salt, a nitrate, nitric and nitrous oxides, nitrogen and water. Potassium hydroxide dissolves zinc; $2\,KOH+Zn=ZnO,K_2O+H_2$.

Zinc oxide ZnO is white, and canary-yellow whilst hot. Its hydrate 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 $ZnSO_4,7\,H_2O$; $ZnCl_2,H_2O$. Colorless. Sodium carbonate precipitates white basic carbonate of zinc.

Tests for zinc in soluble salts:—

IV. $NH_4Cl+(NH_4)_2S$, white, gelatinous zinc sulphide, insoluble in KOH.

KOH, white ZnH_2O_2, soluble in excess.

NH_4OH, white ZnH_2O_2, soluble in excess. If free acid, or ammonium salts present, no precipitate.

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

K_4FeCy_6, white, gelatinous Zn_2FeCy_6.

K_3FeCy_6, brownish-yellow precipitate.

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

First heated strongly on charcoal, note the passing yellow colour 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. Dissolved by all three dilute acids. Sp. gr. 8. Melts at white heat. 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 per-chloride, $MnCl_4$, with red color; on warming into manganous chloride, $MnCl_2$, and chlorine, Cl_2. $MnO_2+4\,HCl=MnCl_2+Cl_2+2\,H_2O$. MnO_2 is a test for chlorine.

Manganous oxide, MnO, a greyish-green powder, is the chief base of manganesium. Its hydrate, 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, $MnSO_4,7\,H_2O$; $MnCl_2,4\,H_2O$. Sodium 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

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: browning on exposure.

NH_4OH, white, somewhat soluble. No precipitate 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. 24).

Ferrum as ferrous. Ferrous oxide is black. The hydroxide FeH_2O_2 is white, insoluble in water, oxydizing rapidly into blue-green, and, finally, red ferric hydrate. Its soluble salts are more or less sea-green; faintly or strongly acid. Chief salt: Ferrous sulphate, $FeSO_4,7H_2O$. Sodium carbonate, white pr. 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 present (p. 24). III. $NH_4Cl + NH_4OH$, no immediate pr., but rapidly oxydizing, separating red ferric hydrate. If 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 hydroxide, insoluble. Changing to dirty green and at last to red ferric on the surface.

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

K_4FeCy_6, bluish-white precipitate $K_2Fe_2Cy_6$; 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, $Co = 58{\cdot}6$.

White, reddish-tinted metal. Magnetic, malleable, tenacious. 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 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. Sodium carbonate, a lilac precipitate of $3CoO,2CoCO_3,4H_2O$.

Tests for cobalt in soluble salts.

IV. $NH_4Cl + (NH_4)_2S$, as black CoS,H_2O, insoluble in HCl; soluble in aqua regia.

KOH blue basic 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.]

[CaO2ClO 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.

Silvery, faint yellow tinge. 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, $NiAs_2$, 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, 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 $HCl+H_2S$ no reaction; separation of cupric, &c. NH_4Cl+NH_4OH, a plum-colored liquid, so that nickel is 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 slightly soluble. With difficulty soluble in HCl; easily in HNO_3 and in aqua regia.

KOH, apple-green hydroxide NiH_2O_2; insoluble.

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, readily soluble to greenish-blue fluid.

K_4FeCy_6, greenish-white Ni_2FeCy_6.

K_3FeCy_6, yellowish-brown precipitate.

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 as are iron and cobalt

Borax bead, in outer flame, reddish-yellow while hot; paler 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. 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 carbonates 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 sodium 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.

Barium carbonate, $BaCO_3$, strontium carbonate, $SrCO_3$, calcium carbonate, $CaCO_3$.

Chloride of ammonium to which **ammonium carbonate** has been added, precipitates barium, strontium, and calcium as **carbonates,** but not magnesium.

25. BARIUM, Ba = 137.

Metal of pale yellow color. From the fused chloride by electrolysis. 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 silver oxide, Ag_2O.

Chief soluble salts: $BaCl_2,2H_2O$; $Ba2NO_3$, 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, white hydroxide in concentrated solutions, soluble in boiling water.

NH_4OH, no reaction.

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

All soluble sulphates precipitate barium as $BaSO_4$.

Na_2HPO_4, white $BaHPO_4$.

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

$2HF,SiF_4$, almost colorless 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. Decomposes water: $Sr+2H_2O=SrH_2O_2+H_2$.

Strontia, SrO, is the only basic oxide. By heating the nitrate to redness, forms strontium hydrate, SrH_2O_2, with water, 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 Ag_2O.

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

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

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

NH_4OH, no reaction.

$CaSO_4$, immediate 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 separated from barium chloride.

27. CALCIUM, Ca = 40.

Yellow lustrous metal. From the fused chloride by electrolysis. Decomposes water: $Ca+2H_2O=CaH_2O_2+H_2$.

Calcium oxide, CaO, the only basic oxide. White, infusible; lime-light. Quick-lime 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. Requires 700 parts of cold, and 1280 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 oxide, Ag_2O, 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: $CaCO_3,H_2CO_3+CaH_2O_2=2\,CaCO_3+2H_2O$.]

KOH, white CaH_2O_2, insoluble.

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.

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, a yellowish-red color to flame.

28. MAGNESIUM, Mg = 24.

Silvery lustrous metal. Sp. gr. 1·74. 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: $MgSO_4,7H_2O$ is Epsom salts; $MgCl_2,6H_2O$; $Mg2NO_3,6H_2O$.

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 MgH_2O_2, insoluble.

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

$NaHCO_3$, a precipitate on heating. 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 $MgNH_4PO_4,6\,H_2O$.

Magnesium is precipitated as $MgNH_4PO_4,6\,H_2O$, after the separation of calcium by ammonium oxalate.

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 recognisable by the smell, the carbonate of sodium test, on boiling, liberates carbonate of ammonium, recognizable by the smell, &c. Group VI. includes ammonium, potassium, and sodium (lithium, rubidium, and caesium).

XXIX. Ammonium, $(NH_4)_2 = 36$.

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

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

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 $KHC_4H_4O_6$, 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 NHg_2H_2IO, oxy-di-mercur-ammonium iodide.

A solution of NH_3 in H_2O, or of NH_4OH, is colorless, alkaline, smells of ammonia, leaves no residue on warming. $AgNO_3$, grey-brown precipitate of AgOH, readily soluble in excess. If free from carbonate, no precipitate by lime-water. Fumes more or less with HCl. $PtCl_4,2HCl$, yellow precipitate of ammonium-platinic chloride.

XXX. Potassium, Kalium, $K = 39$. $K_2 = 78$.

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

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 ammonium).

VI. $PtCl_4,2HCl$, yellow crystalline precipitate 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 redissolves 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.

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

Lustrous, reddish-tinted metal. Sp. gr. 0·97. 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.

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

Tests in soluble salts.

Na_2CO_3, no reaction, even on boiling. Not an ammonium salt.

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.

XXXII. LITHIUM, $Li = 7$.

Silvery metal. Sp. gr. 0·6. Decomposes water. 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) $2Li_3PO_4,H_2O$, soluble in HCl, and not re-precipitated by NH_4OH until heated.

Carmine color to flame.

XXXIII. RUBIDIUM, $Rb = 85{\cdot}3$.

Yellowish-white, lustrous. 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.

XXXIV. CAESIUM, $Cs = 133$.

White, lustrous, easily oxydized. 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.

Violet color to flame.

EXAMINATION FOR ACIDS IN A FREE STATE AND IN COMBINATION AS SALTS.

Some description has already been given at pp. 12–14 of certain salts.

It cannot be repeated too often—at least, not until the fact is remembered—that nearly all the salts of potassium, sodium, and ammonium are soluble in water, and that in these sodium carbonate can give no precipitates.

Nitrates, sulphates, chlorates, chlorides, bromides, iodides, cyanides, and acetates are for the most part soluble in water.

It is always advisable to moisten a solid with ammonium sulphide, so as to disclose the presence, or absence, of most metals of the first four groups. If blackened or browned, turned orange-red or yellow, there is reason to believe in the presence of some metal, the carbonate, sulphite, thiosulphate, phosphate, borate, arsenite, arsenate, oxalate, &c., of which need not be looked for. In the case of a white powder, like **ARSENIOUS OXIDE**, yellow sulphide of ammonium dissolves it to a colorless solution, which, when diluted with water, gives, with hydrochloric acid, a bright yellow precipitate of arsenious sulphide, soluble in ammonia. A further test—heat upon platinum—would volatilize it with lavender-colored flame. In the case of **CALOMEL**, sulphide of ammonium would form a black sulphide. Heated on platinum, it would volatilize. Complete volatility, (and the blackening) would suggest calomel or corrosive sublimate; ammonia added to a further portion would confirm mercurous, as the white powder would be blackened, and the clear solution, decanted, and acidulated with nitric acid, would be precipitated as white chloride of silver by silver nitrate.

The condition of a solution as to neutral, alkaline, or acid, is of first importance, and so also is the effect of heat upon platinum.

If a solution is colorless, no chromate need be looked for.

As a group-test, carbonate of sodium retains its value, and tells distinctly what the acidity proceeds from (p. 2). If no precipitate and no effervescence in a neutral solution, salts of all acids may be present. In the analyses of simple solutions containing but one acid and one base, of salts soluble in water, such as satisfy the requirements of most examinations for students of medicine, there is scarcely need for filtration when carbonate of sodium has produced a precipitate; but we may continue the addition till slight excess is present (alkaline, and no further precipitate), warm, filter, neutralize the filtrate carefully with HCl or with HNO_3 (not forgetting which acid employed), and examine the filtrate for the acids. The precipitate 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 best removed by excess of H_2S in an acidulated solution. In a simple solution, if it be neutral, and sodium carbonate has given a precipitate, carbonates, phosphates, borates, arsenites, arsenates, oxalates, tartrates, citrates, *sulphites, thiosulphates*, and *silicates* need not be looked for, as these salts follow the carbonates in their insolubility in water.

A. Salts, visibly or detectibly decomposed by hydrochloric acid, HCl.

Comprises carbonates, sulphides, sulphites, thiosulphates, nitrites, chlorates, hypochlorites, cyanides, silicates, titanates, tungstates, molybdates, chromates, arsenites, sulpharsenites, sulpharsenates, sulphantimonites sulphantimonates, antimonites, antimonates, acetates, urates, hippurates, benzoates, salicylates, gallates, and ferrocyanides.

THOSE SALTS, WITH NO NUMBERS ATTACHED, ARE EITHER UNIMPORTANT, OR TREATED ELSEWHERE. THE LESS IMPORTANT SALTS ARE ALWAYS PRINTED IN SMALLER TYPE.

I. Carbonates. Those of the alkaline metals alone soluble in water. Solutions colorless; alkaline to test-paper. The hydro-carbonates of K_2, Na_2, and $(NH_4)_2$, also alkaline. All bi-carbonates of metals somewhat soluble: they lose CO_2 when heated, and are precipitated as carbonates.

The common 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 pr. of $CaCO_3$.

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

$AgNO_3$, white pr. of Ag_2CO_3, soluble in NH_4OH, and, with effervescence, in HNO_3.

Solution of Na_2CO_3 precipitates $MgCO_3$ at once; but solution of $NaHCO_3$, or of $KHCO_3$, only pr. $MgSO_4$ on standing, or at once on warming.

Solution of *carbonic acid*, H_2CO_3, is inodorous, turns litmus port-wine red, evolves pearly bubbles of CO_2 on heating, precipitates lime-water, and leaves no residue on evaporation.

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.

$SnCl_4$, yellow $SnS_2,2H_2O$, soluble in excess of original solution.

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

Sulphydric acid, or *hydrogen sulphide*, in solution in water, is recognized by its odor of putrid eggs, and acidity to test-paper. Either colorless, or slightly milky from sulphur. No residue on heating.

A. HCl, no reaction. Precipitates many metallic sulphides.

$HCl + H_2S$ is No. II. Group-test (pp. 17–24).

Cl_2 precipitates S, with formation of 2 HCl.

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

HNO_3 oxydizes the H_2 of H_2S, and deposits S. When heated, sulphuric acid 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.

$$2\,K_2Cr_2O_7 + 8\,H_2SO_4 + 6\,H_2S = 2(K_2Cr_2 4\,SO_4) + 14\,H_2O + 3\,S_2.$$

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, $Na_2SO_3, 7\,H_2O$, the commonest salt.

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

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

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

$AgNO_3$, white pr. 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 reduced to ferrous salts: $Fe_2Cl_6 + SO_2 + 2\,H_2O = 4\,HCl + FeCl_2 + FeSO_4$.

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 pr. No residue on platinum.

IV. Thiosulphates. Salts of alkaline metals, of Ca and Sr, soluble. The ordinary salt, $Na_2S_2O_3, 5\,H_2O$. 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.

$$Na_2S_2O_3 + 2\,HCl = 2\,NaCl + H_2O + SO_2 + S.$$

$AgNO_3$, white pr. $Ag_2S_2O_3$, 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 $Cu2NO_2$.

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 pr. $AgNO_2$, 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 white, curd-like $AgCl$, 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 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 pr., changing from red to brown PbO_2.

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

It is a mixture of $KBrO$ with KBr.

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 $AgCN$, very soluble in KCN, in NH_4OH and in strong, boiling 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 pr. of $2FeC_2N_2,KCy$. Boiled with KOH, on addition of HCl gives Prussian blue, $2Fe_2C_6N_6,3FeC_2N_2,18H_2O$.

$(NH_4)_2S_2$ added to soluble cyanide, and evaporated to dryness, leaves sulphocyanide, NH_4CNS, which gives blood-red, soluble ferric sulphocyanide, 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, evolves HCN, which may be detected as above. $HCl+H_2S$ gives white chloro-sulphide, changing through yellow, and orange, to black mercuric sulphide, HgS. $HCl+KI$, scarlet HgI_2. Heated, 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.

A. HCl, no increased smell.

$AgNO_3$, white pr. 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, *silica*, SiO_2, as a white, amorphous, insoluble powder.

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

$BaCl_2$, white pr. 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 pr., 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 pr. 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 pr., when heated, of ammonium-phospho-molybdate. $2(NH_4)_3PO_4,22MoO_3,12H_2O$.

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

A. HCl changes yellow color to bright yellow-red. See Group **B. XIX.**, p. 44.

Arsenites, of alkaline metals alone soluble: Alkaline reaction.

A. HCl to concentrated solutions, a white pr. of arsenious oxide, As_2O_3, soluble in excess. Confirmed by H_2S. P. 42.

Sulpharsenites. K_3AsS_3, alkaline, yellow.

A. HCl, yellow pr. of As_2S_3, with H_2S.

Sulpharsenates. K_3AsS_4, alkaline, colorless.

A. HCl, yellow As_2S_5 and H_2S.

Antimonites as $KSbO_2$, soluble, alkaline.

A. HCl, white pr., 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 pr. 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.

A. HCl sets acetic acid free, recognized by odor of vinegar. P. 47.

Urates. Only of alkaline metals soluble.

A. HCl, white pr. of uric acid. P. 50.

Hippurates, alkaline to test-paper.

A. HCl, white needles of hippuric acid. P. 52.

Benzoates. All more or less soluble.

A. HCl, white, glittering scales of benzoic acid. P. 52.

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. 51.

Ferrocyanides. When soluble, bright yellow.

A. HCl, either a bluish tint, or bluish-white pr. in strong solutions. P. 47.

B. Salts, the radicles of which form insoluble compounds with barium chloride.

Includes sulphates (*selenates, silico-fluorides*), ortho-phosphates (pyro-phosphates, metaphosphates, phosphites, fluorides), arsenites, arsenates, borates (iodates, bromates), chromates, and oxalates.

XIV. Sulphates. All soluble in water, except $BaSO_4$, $SrSO_4$ and $PbSO_4$. Neutral or acid to test-papers.

B. $BaCl_2$, white pr. of $BaSO_4$, insoluble in HCl. If HCl has produced no reaction, $BaCl_2$ gives a pr. of $BaSO_4$.

$Pb2C_2H_3O_2$, white pr. of $PbSO_4$.

Any ordinary sulphate 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 pr., HCl no reaction. $BaCl_2$, white pr. 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.

Selenates resemble sulphates.

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

Silico-fluorides, for the most part insoluble.

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

KCl, pr. 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 $BaHPO_4$, soluble in HCl.

$AgNO_3$, canary-yellow pr. of Ag_3PO_4, soluble in NH_4OH and in HNO_3.

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

$Pb2C_2H_3O_2$, white $Pb_3 2PO_4$, soluble in HNO_3.

$CaCl_2$, white $Ca_3 2PO_4$, soluble in acetic acid.

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

$MgSO_4$, after addition of $NH_4Cl + NH_4OH$, white, crystalline pr. of $MgNH_4PO_4,6H_2O$. This pr., by heat, into magnesium pyrophosphate, $Mg_2P_2O_7$.

Ammonium molybdate in HNO_3, by heat, a yellow pr. containing phosphoric acid. *Arsenates* also, containing $(NH_4)_3AsO_4$.

Orthophosphoric acid, H_3PO_4, syrupy liquid.

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

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

B. $BaCl_2$, no pr. 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 pr. 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 pr. of Ag_3PO_4.

Magnesium ammonium orthophosphate, $MgNH_4PO_4.4H_2O$, by heat into water, NH_3 and $Mg_2P_2O_7$.

Pyrophosphoric acid, $H_4P_2O_7$, on evaporation, loses water, and becomes metaphosphoric acid.

Metaphosphates, like ortho- and pyro-phosphates as to solubility.

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 pr. 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 and $MgSO_4$.

Metaphosphoric acid, acid, fusible to clear glass. Very soluble, effervescence with $NaCO_3$.

Phosphites of alkaline metals soluble; others with difficulty.

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

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

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

CaH_2O_2, white pr.

$CaCl_2$, white, 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: $4P(OH)_3 = 3H_3PO_4 + PH_3$.

Hypophosphites. Mostly soluble.

Solutions of salts behave like hypophosphorous acid, H_3PO_2, in reducing salts of Ag, Hg and Au.

BaH_2O_2, and CaH_2O_2, no pr.

$CuSO_4$ to the acid, gives reddish-brown pr. of Cu_2H_2, on warming.

By heat, the acid into PH_3 and H_3PO_4.

Fluorides of alkaline metals soluble.

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

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

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

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

Hydrofluoric acid, HF, very acid even when very dilute. Etches glass. Action upon SiO_2.

$4HF + SiO_2 = SiF_4 + 2H_2O$.

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 white pr. of 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 pr. 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 pr. $BaHAsO_3$, soluble in HCl.

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

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

Arsenious acid, H_3AsO_3, in solution in water is faintly acid. 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 pr. As_2S_3, soluble in NH_4OH.

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

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

$AgNO_3$, slight clouding, with yellow pr. on addition of drop of NH_4OH. Pr. of Ag_3AsO_3, 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 $(As_2O_3)_2$. 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 deposit of silver upon the paper. 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.

With black flux, heated in narrow glass tube closed at one end. 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. Chief salt, $Na_2HAsO_4,12H_2O$: alkaline. Colorless.

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

B. $BaCl_2$, white Ba_32AsO_4, soluble in HCl.

$AgNO_3$, liver-brown pr. 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. pr. $MgNH_4AsO_4,6H_2O$.

Molybdate in HNO_3, on heating yellow pr. P. 39.

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

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

Arsenic acid, H_3AsO_4, is even 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 pr. of Ag_3AsO_4.

B. $BaCl_2$, no precipitate till neutralized.

$CuSO_4$, no precipitate till neutralized.

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 pr. $Ba2BO_2$, soluble in HCl.

$CaCl_2$, white pr. $Ca2BO_2$, soluble in NH_4Cl, and in acetic acid.

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

Intumesces when heated on platinum, fuses, yellow color to flame if sodium 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.

$CaCl_2$, 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, blue iodide.

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

$AgNO_3$, white pr. 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. 46); 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.

A test for morphia (p. 80)

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 $Ba2BrO_3$.

$AgNO_3$, 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. 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, $Cr_2Cl_6 + S_2$. See II. A test for H_2S.

B. $BaCl_2$, yellow $BaCrO_4$, 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 pr. Many chromates somewhat soluble.

H_2SO_4 and alcohol, reduce salts of chromic acid to blue-green chromic oxide salts.

Chromic acid, CrO_3. Acid, crimson. No pr. with $BaCl_2$ or with $AgNO_3$.

Alcohol reduces CrO_3 to Cr_2O_3.

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 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 pr. FeC_2O_4.

Heated on platinum into carbonates, scarcely 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 pr. BaC_2O_4, soluble in HCl.

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

$CaSO_4$, white pr. of CaC_2O_4, insoluble in acetic acid.

CaH_2O_2, white 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, corruscating 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 chlorides, bromides, iodides (cyanides), ferrocyanides, ferricyanides, sulphocyanides, 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 pr. 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 pr. 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 touch 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 dark-red vapors.

Hydrochloric acid or *hydrogen chloride*, HCl, is acid, volatile, suffocating. Na_2CO_3, effervescence without pr. No residue on platinum. With nitric acid, on heating, yellow; aqua regia, and Cl_2 evolved.

Fumes with glass-rod dipped in NH_4OH.

$BaCl_2$, no reaction, except in strong acid, when pr. of $BaCl_2$, soluble in water.

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

MnO_2 gives off Cl_2.

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. Resemble the chlorides. KBr, chief salt.

$BaCl_2$, no reaction.

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

$Hg_2 2NO_3$, yellowish-white 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, from Br_2, soluble with orange-color in chloroform; starch is colored orange.

HNO_3, separates Br_2 on warming, either coloring solution yellow, or even red-brown, with vapors of Br_2 condensing to blood-red drops.

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

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.

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 to colorless HBr and S_2. Starch-paste, orange. Chloroform added, rich orange. $AgNO_3$, yellowish-white $AgBr$.

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

$BaCl_2$, no reaction.

c. $AgNO_3$, pale yellow pr. of AgI, insoluble in ammonia, as well as in HNO_3.

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

$Hg_2 2NO_3$, finch-green, 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, glass-rod dipped into starch-paste.

Mixed $CuSO_4+FeSO_4$, white pr. of 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 dissolves any free I_2.

c. $AgNO_3$, pale-yellow pr. of AgI.

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.**

XXIV. Sulphocyanides. 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 pr. Cu2Csy. Alone to white $Cu_2 2Csy$: at once by added $FeSO_4$.

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

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

$BaCl_2$, white pr. of BaK_2FeCy_6.

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

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

$CuSO_4$, pr. 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 pr. Ag_3FeCy_6, soluble in ammonium hydrate, but not in dilute HNO_3.

Fe_2Cl_6, only deepens brown color.

$FeSO_4$, pr. 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. 37.

$BaCl_2$, no reaction.

Fe_2Cl_6, no reaction.

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

$FeSO_4$, salmon-colored pr.

XXVIII. Acetates. All soluble in water, but $AgC_2H_3O_2$, and $Hg_2 2C_2H_3O_2$ with difficulty. Salts colorless, or colored. Chief salts: $KC_2H_3O_2$. $KC_2H_3O_2,C_2H_4O_2$. $NaC_2H_3O_2,3\,H_2O$. $NH_4C_2H_3O_2$. $Pb2\,C_2H_3O_2,3H_2O$.

$Pb2C_2H_3O_2,2\,PbO$, in Goulard water.

$Cu2C_2H_3O_2,H_2O$.

HCl should have detected acetic acid by its smell of vinegar.

$Ba\,Cl_2$, no reaction.

c. $AgNO_3$, shiny, scum-like pr. of $AgC_2H_3O_2$, easily soluble on boiling. No pr. in weak solutions.

$Hg_22\,NO_3$, white, greasy pr. of $Hg_22\,C_2H_3O_2$, soluble on heating.

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

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. $KC_2H_3O_2$ becomes fused K_2CO_3.

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 soluble.

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

$Hg_22C_2H_3O_2$, 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 $H_2SO_4 = H_2O+CO$.

c. $AgNO_3$, no reaction till neutralized.

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

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

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

$Pb2\,C_2H_3O_2$, white pr. of $Pb_32\,C_7HO_7$ (none with acetate, of course).

$CaCl_2$, white pr. of $Ca_32\,C_7HO_7$.

Meconic acid, $H_3C_7HO_7,3\,H_2O$. 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.

$Pb2\,C_2H_3O_2$, white pr. of $Pb_32\,C_7HO_7$.

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. 45.

XXXI. Tartrates. Neutral tartrates of alkaline metals soluble; cream of tartar, $KHC_4H_4O_6$, and $NH_4HC_4H_4O_6$, 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, a white, crystalline pr. of $KHC_4H_4O_6$ or of $NH_4HC_4H_4O_6$, readily soluble in excess of HCl.

HCl, a white pr. in solutions of tartar emetic, $KSbOC_4H_4O_6$, of antimonous oxy-chloride, SbOCl, soluble in excess as $SbCl_3$, and pr. orange-red by H_2S.

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

D. $CaCl_2$, immediate white pr. 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 pr. of $KHC_4H_4O_6$.

$AgNO_3$, white pr. 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: 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 pr. 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 pr. when acid in excess.

H_2SO_4, boiled with tartaric acid decomposes it, blackens from carbon, and CO evolved.

On platinum, it fuses, becomes yellow like sucrose, browns, gives off burnt sugar smell, burns with flame, carbonizes, and the C burns away.

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

HCl, no reaction.

Fe_2Cl_6, no reaction.

$BaCl_2$, white pr. soluble in HCl.

D. $CaCl_2$, no pr. 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.

CaH_2O_2, no pr. 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 pr. till neutralized and boiled.

$AgNO_3$, no reaction till neutralized.

H_2SO_4 and heat, dissolve 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 pr., soluble in HCl.

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

CaH_2O_2, no precipitate.

$AgNO_3$, white pr. of $Ag_2C_4H_4O_5$, soluble in NH_4OH and in HNO_3 Grey on boiling.

$Pb2C_2H_3O_2$, white, crystalline $PbC_4H_4O_5$, 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.

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: malaeic acid volatilizes, and solid fumaric acid remains.

N.B. *Lime-water distinguishes these four acids, oxalic, tartaric, citric and malic.*

Two or three drops of lime-water pr. white oxalate, insoluble in acetic acid.

Lime-water in excess, pr. 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 pr. 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 with 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, carbonizes without flame, and the carbon burns away. CNH evolved. Also a smell 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. 47.

E. Fe_2Cl_6. Red-brown coloration.

Sulphocyanides, XXIV., p. 47.

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. 47.

E. Fe_2Cl_6. Prussian blue.

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

Acetates, XXVIII., p. 47.

E. Fe_2Cl_6. Dark-red coloration.

Formates, XXIX., p. 48.

E. Fe_2Cl_6. Dark-red coloration.

Meconates, XXX.

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.

HCl, no visible reaction, as tannin so very soluble in water.

E. Fe_2Cl_6, blue-black coloration (very finely divided pr.), yellow by HCl.

$Pb2C_2H_3O_2$, white pr.

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.

HCl, minute white crystals of gallic acid, easily soluble in HCl.

E. Fe_2Cl_6, black, but by HCl, yellow, with pr. of gallic acid.

$Pb2C_2H_3O_2$, white pr. of gallate.

$AgNO_3$, white pr. 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 pr.

Gelatin, no reaction.

Ether, great solvent.

$Pb2C_2H_3O_2$, white pr. of lead gallate.

H_2SO_4, magenta color.

On platinum, when heated, blackens instantly.

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 of 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 pr. of ferric benzoate, decomposed by HCl, giving yellow ferric chloride, Fe_2Cl_6, and scales of benzoic acid.

$CaCl_2$, no reaction.

$AgNO_3$, white pr., 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 pr. of succinate, soluble in HCl without residue.

$BaCl_2$, and ammonia, no pr. till alcohol added.

$Pb2C_2H_3O_2$, white pr., readily soluble in lead acetate.

$AgNO_3$, white pr.

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

E. Fe_2Cl_6, deepened in color.

$BaCl_2$, and ammonia, a white pr. 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 pr., decomposed by HCl, separating the acid. $CaCl_2$, no pr.

$AgNO_3$, white pr., soluble in NH_4OH.

Hippuric acid, $CH_2NHC_7H_5OCOOH = C_9H_9NO_3$. White needles, requiring 600 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.

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 ($2\,FeSO_4,NO$) at the point of junction; increasing on agitation, then disappearing, the solution becoming yellow-red, and nitrous fumes evolved.

H_2SO_4 and copper-turnings, NO evolved, and copper sulphate in solution.

On platinum, KNO_3, or $NaNO_3$, fuse with characteristic flame, 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.

Sulphindigotic acid bleached, or turned yellow.

Stains wool yellow. Beware of spilling HNO_3 on clothes.

Cu gives $3\,Cu2NO_3+4H_2O+2NO$ on heating with $8HNO_3$: 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. 45).

Perchloric acid, $HClO_4$, separated from $KClO_4$ by H_2SO_4. White vapors on heating.

Chlorates, VI., p. 38.

RECAPITULATION OF GROUP-TESTS FOR THE ACIDS, IN COMBINATION, AS WELL AS IN THE FREE STATE.

A. Salts visibly, or detectibly (by color or smell) 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, hypophosphites*, 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), sulphocyanides (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.*

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 potassio-platinic 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 ("Thenard'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 (uric acid test), 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 oxychloride ($NaHCO_3 + HgCl_2$), 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, arsenic, 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 (sodiopotassic 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 (porcellanous stratified), 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 sulphocyanide, 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, æsculin, 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, and a large number of organic compounds; acrolein (intensely pungent, from glycerin by $KHSO_4$ and heat); pungent odor from oxalic, benzoic, citric and succinic acids by heat.

II. THE SUBSTANCE IS INSOLUBLE IN WATER.

(See p. 10.)

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 12.

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. 24); 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. 24, 25). 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 $NH_4MgPO_4,6H_2O$ follows, 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. 35).

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. 13); in any sulphide, the action of nitric acid would be to create a sulphate.

In the case of silicates, evaporate to dryness, ignite and redissolve in HCl; silica SiO_2, remains undissolved.

Phosphates are all decomposed by acids; their detection has been explained at pp. 41, 60.

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 Ag, heated with Na_2CO_3.

Al_2O_3, is white, infusible, and blued, when ignited with $Co2NO_3$ unlocked by fusion with $KHSO_4$.

SnO_2 and Sb_2O_5 give ductile 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.

GROUP-TESTS.	COLOR OF PR.	CHARACTERS OF PR.	BASYL.	CONFIRMATORY TESTS.	P.
Group I. **HCl.**	White.	Soluble in NH_4OH.	**Ag.**	KI, pale yellow. $K_2Cr_2O_7$, crimson.	16.
	White.	Insol. in NH_4OH.	**Pb.**	KI, bright yellow. „ yellow.	15.
	White.	Blackened by NH_4OH.	**Hg_2(ous).**	KI, finch-green. „ brick-red.	17.
Group II. **HCl.** and **H_2S.** *a.* Sulphides soluble in ammonium sulphide after neutralizing with Am HO.	Yellow.	Soluble in NH_4OH.	**As(ous).**	$AgNO_3$, yellow $CuSO_4$, green.	42.
	Yellow, after concentration.	„ „	**As(ic).**	$AgNO_3$, liver-brown. $CuSO_4$, light-blue.	43.
	Dull yellow.	Soluble in NH_4OH and sulphide.	**Sn(ic).**	On charcoal with Na_2CO_3 with blowpipe, metallic beads of tin.	20.
	Orange.	Soluble in Am_2S after neutralizing, and in HCl.	**Sb.**	$SbCl_3$, 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 $HCl + H_2S$.	18.
	Brown.	Soluble in Am_2S_2 after neutr.	**Sn(ous).**	$HgCl_2$, white calomel, turning by heat into grey mercury.	19.
b. Sulphides in-	Yellow.	Insoluble	**Cd.**	KI, no reaction. Brown incrustation	

monium sulphide after neutralizing.	Brown-black.	NH_4OH and in $(NH_4)_2S$.	**Bi.**	Sols. very acid. Pr. by water, pr. increased by tartaric acid. KI, dark brown. $K_2Cr_2O_7$, yellow, insoluble in KOH.	23.
	Black.		**Hg(ic).**	Pr. by $HCl+H_2S$, white, yellow, orange, black. KI, scarlet.	22.
	Slate-colored.		**Pb.**	KI, yellow. $K_2Cr_2O_7$, yellow, soluble in KOH.	21.
	Black.		**Cu.**	Sols. blue or green. KI, grey: I_2, free. K_4FeCy_6, maroon pr. Iron precipitates metallic copper.	21.
Group III. **NH_4Cl+** **NH_4OH**	Dull blue, or greenish, slight pr.	Changing to red-brown. Some Ferrous generally pr. in this group: not to be mistaken for Cr_2.	**Fe(ous)** unless free from ferric.	Ferrous salts pale green: acid reaction. K_4FeCy_6, bluish-white. K_3FeCy_6, deep blue pr.	28.
	Red-brown hydroxide.		**Fe_2(ic).**	Sols. yellow or yellow-red: strongly, acid. K_4FeCy_6, deep blue pr. K_3FeCy_6, brown-red coloration.	25.
	White hydroxide.		**Al_2.**	Sols. colorless: acid reaction. KOH, white pr., soluble in excess. Ignited on platinum with $Co2NO_3$, blue.	25

GROUP-TESTS.	COLOR OF PR.	CHARACTERS OF PR.	BASYL.	CONFIRMATORY TESTS.	P.
Group III. (*cont.*) **NH_4Cl+** **NH_4OH**	Pale green hydroxide.	Soluble in excess with rose-color, when heated.	**Cr_2.**	Sols. violet-red, or green: acid reaction. KOH, emerald green solution. On pt. with Na_2CO_3, ignited into Na_2CrO_4, yellow.	26.
Group IV. **NH_4Cl+** **NH_4OH+** **$(NH_4)_2S$.**	Black sulphide.		**Fe(ous).**	Sols. pale green: acid reaction. NH_4OH, pr. dirty greenish-white, to bluish: somewhat soluble. K_3FeCy_6, blue pr.	28.
	Black sulphide.		**Co.**	Sols. pink to red and blue: acid reaction. NH_4OH, blue, basic pr. sol. in excess, slowly browning. K_3FeCy_6, brownish-red pr. Borax bead blue.	28.
	Black sulphide.		**Ni.**	Sols. green: acid reaction. NH_4OH, greenish pr. soluble with plum-color. K_3FeCy_6, yellowish-brown pr. Borax bead purple-brown	29.
	Flesh-tinted sulphide.	Browning on exposure.	**Mn.**	Sols. pale pink to colorless, acid reaction. NH_4OH, white, considerably soluble, on exposure deep red-brown. K_3FeCy_6, red-brown pr. Ignited on pt. with Na_2CO_3, blue-green fused mass.	27.
	White sulphide.		**Zn.**	Sols. colorless, acid reaction. NH_4OH, white, soluble in excess. K_3FeCy_6, brownish-yellow pr. Ignited, yellow whilst hot, white on cooling: with	27

Group V. **NH_4Cl +** **NH_4OH +** **$(NH_4)_2CO_3$.** *a.* Precip.	White carbonate.		**Ba.**	Sols. colorless. $CaSO_4$ immediate white pr. Flame yellow-green.
	White carbonate.		**Sr.**	Sols. colorless. $CaSO_4$ pr. on heating. Flame crimson.
	White carbonate.		**Ca.**	Sols. colorless. $CaSO_4$ of course no reaction. Oxalate of ammonium, white pr. Flame yellow-red.
b. No prec. but by Na_2CO_3 used at commencement.			**Mg.**	Sols. colorless. NH_4OH, white pr. increased by heat (none with Ba, Sr, and Ca). Na_2HPO_4, white pr. increased by NH_4OH.
Group VI. No prec. with above tests.			**$(NH_4)_2$.**	Salts volatile, 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 pr.
			K_2.	Violet color to flame: red through blue glass. 2HCl, $PtCl_4$ yellow pr. 2KCl, $PtCl_4$.
			Na_2.	Strong yellow flame. 2HCl, $PtCl_4$, no reaction.

TABLE OF ACIDS AND SALTS.

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FURTHER PORTIONS FOR EACH TEST.
I. a. **HCl.**	Effervescence with no marked odor.	**Carbonates,** p. 36.	By decanting the gas into lime-water, a white pr. 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 pr. soluble in excess of original solution.
	Smell of burning brimstone on warming: rarely effervescence from escape of SO_2.	**Sulphites,** p. 37.	Confirm smell of SO_2 by addition of dilute sulphuric acid to a fresh portion. $AgNO_3$, white pr., by heat into metallic silver, or grey powder. With zinc and dilute sulphuric acid, H_2S evolved, blackening lead-paper, and depositing yellow S_2. $BaCl_2$ white pr. $BaSO_3$, soluble, if pure, in HCl. *Free acid* H_2SO_3 smells of SO_2; acid reaction; no residue on platinum. $AgNO_3$ white pr.
	Red fumes.	**Nitrites,** p. 38.	$AgNO_3$, white pr. reduced to Ag_2 on boiling. KI + starch paste and acetic acid, blue iodide of starch. Solution of permanganate bleached after addition of acetic acid.
	Smell of bitter almonds.	**Cyanides,** p. 38.	$AgNO_3$ white pr. AgCy, not soluble in dilute, but concentrated nitric acid, and in ammonia. $FeSO_4$, in cyanides, red pr. of $FeCy_2$: then KOH and HCl, Prussian blue. Warmed with tartaric acid, gives vapours of HCN, whitening a glass rod dipped in $AgNO_3$. Soluble cyanides strongly alkaline. *Free acid* CNH, faintly reddens litmus, smells of prussic acid, no effervescence with Na_2CO_3, no residue.

Smell of rotten eggs and sometimes deposit of S_2.	**Sulphides,** p. 36.	All soluble sulphides alkaline to test-paper. $AgNO_3$, black pr. 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. 37.	$AgNO_3$, a white pr. of $Ag_2S_2O_3$, turning yellow, orange, red and finally black Ag_2S. Heated on platinum, melts, burns with yellow flame, blue and red tints on platinum. Soluble salts alkaline. *No free acid.*
Yellow color on warming, and yellow-green gas (euchlorine $Cl_2 + ClO_2$) evolved.	**Chlorates,** p. 38.	Vapors by HCl bleach litmus. $AgNO_3$ no reaction. Salts deflagrate on charcoal. Heated strongly on platinum, into chlorides, soluble in water, pr. by $AgNO_3$ as white AgCl, insoluble in HNO_3, soluble in NH_3.
White, gelatinous pr. except in very dilute solutions.	**Silicates,** p. 39.	Solutions strongly alkaline. Acidulated with HCl, evaporated to dryness, leaves a white powder of silica SiO_2, insoluble. $AgNO_3$ brown pr. NH_4Cl, white gelatinous pr. of H_4SiO_4, unless very dilute.
Smell of vinegar.	**Acetates,** p. 47.	All soluble. $AgNO_3$, white pr. soluble in boiling water: no pr. in weak solutions. $Hg_2 2NO_3$, white scum-like pr. 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 pr. of uric acid, insoluble in excess.	**Urates,** p. 50.	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).

TABLE OF ACIDS AND SALTS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FURTHER PORTIONS FOR EACH TEST.
I. a. (*cont.*) **HCl.**	Shiny scales, generally smelling of gum benzoin.	**Benzoates,** p. 52.	Fe_2Cl_6, pale salmon-colored pr., depositing scales of *benzoic acid* on addition of HCl. Group IV.
	Small needles, dissolved on boiling, and re-crystallizing in long needles.	**Hippurates,** p. 52.	Fe_2Cl_6, pale buff-colored pr. depositing needles of *hippuric acid* on addition of HCl. Group IV.
	Tiny needles, readily soluble in excess of Group-test.	**Gallates,** p. 51.	Fe_2Cl_6, blue-black pr., bleached by HCl, separating *gallic acid* in needles. Group IV.
	Small needles.	**Salicylates,** p. 52.	Fe_2Cl_6, deep purple color. Group IV.
	White cryst. pr. readily soluble in HCl.	**Neutral tartrate of potassium or ammonium,** p. 49.	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. 42.	Soluble salts alkaline. $AgNO_3$ yellow pr. soluble both in HNO_3 and in NH_4OH. $CuSO_4$, green pr. 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 pr. with $CuSO_4$. Slight pr. with $AgNO_3$. $HCl+H_2S$, precipitates As_2S_3, soluble in NH_4OH. *Arsenious oxide*, 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 pr. of $As_2S_3+S_2$.	**Arsenates,** p. 43.	$AgNO_3$, liver-brown pr. of Ag_3AsO_4, soluble in NH_4OH and in HNO_3. $CuSO_4$, light blue pr. 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 pr. $CuSO_4$, no pr.
	Solution changes from yellow-red to bluish-green, with deposit of sulphur.	**Chromates,** p. 44.	Neutral chromates yellow: acid chromates yellow-red. $AgNO_3$, crimson pr. of Ag_2CrO_4. $Pb2C_2H_3O_2$, yellow pr. of $PbCrO_4$. $BaCl_2$, yellow pr. of $BaCrO_4$. H_2SO_4 and alcohol reduce salts of chromic acid, to sulphate of chromic oxide, with smell of aldehyde.
II. a. **$BaCl_2$** **or** **$Ba2NO_3$.**	White precipitate of barium sulphate $BaSO_4$, insoluble in HCl, and also in HNO_3.	**Sulphates,** p. 41.	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, sulphate reduced to sulphide, and mass moistened on a silver coin, gives black stain. Free sulphuric acid, even when very dilute, reddens litmus, effervesces with Na_2CO_3, is precipitated by $BaCl_2$, and the pr. is insoluble in HCl. A drop of the free acid, though dilute, chars blotting-paper when heated. Sets free nitric acid from nitrates.

N.B.—Radicles of many salts in Group I., as carbonates, sulphites, thiosulphates, silicates, arsenites, arsenates, and chromates also give precipitates of barium carbonate, &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.

TABLE OF ACIDS AND SALTS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FURTHER PORTIONS FOR EACH TEST.
II. b. **$CaCl_2$.**	White pr. soluble in aceticacid, insoluble in NH_4Cl, and in cold KOH.	**Ortho-phosphates,** p. 41.	Phosphates of alkaline metals soluble. $AgNO_3$, yellow pr. 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 pr. Ammonium molybdate in HNO_3, yellow pr. onheating. $NH_4Cl+NH_4OH+MgSO_4$, white, crystalline pr. of $MgNH_4PO_4 . 6H_2O$. *Free phosphoric acid*, strongly acid, effervescence with Na_2CO_3, glassy residue on platinum.
	White pr. soluble in acetic acid and in ammonium chloride NH_4Cl. Insoluble in cold KOH.	**Borates,** p. 44.	Borates of alkaline metals chief soluble. Borax $Na_2B_4O_7,10H_2O$, chief salt: alkaline. $AgNO_3$, white pr. 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 pr. insoluble in acetic acid, or in NH_4Cl, or in KOH.	**Oxalates,** p. 45.	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 pr. insoluble in acetic acid.

water immediate white pr. insoluble in acetic acid.

		H_2SO_4 heated, gives CO and CO_2. Suffocating vapors, with white corruscation, and no residue, when heated on platinum.
White pr. soluble in acetic acid, and, when well washed, in KOH.	**Tartrates,** p. 49.	Char with burnt-sugar odor, when heated on platinum: carbonates probably left. Evaporated and heated with H_2SO_4, blackens, with evolution of CO and CO_2. Calcium tartrate, crystal of $AgNO_3$, and added NH_4OH, by heat, a mirror of silver. KOH and acetic acid in excess, on shaking, cryst. pr. of hydro-potassic tartrate. **Tartaric acid**, reddens litmus, effervescence with Na_2CO_3. Lime-water, in excess, white pr. of tartrate, soluble in acetic acid, but $CaCl_2$ no reaction till neutralized. KOH or NH_4OH, white, cryst. pr. if acid kept in excess. On platinum, fuses, turns yellow, smells of burnt sugar, inflames, carbonizes, and entirely combusted by heat. In sols. of neutral potassium and ammonium tartrate, HCl gives white cryst. pr. of acid salts of K and NH_4.
White pr. when heated, soluble in acetic acid, soluble in NH_4Cl, insoluble in cold KOH.	**Citrates,** p. 49.	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 pr. only grey by heat. **Citric acid** reddens litmus, effervescence with Na_2CO_3. Lime-water in excess, on boiling for a minute or more, white pr. of citrate of calcium. $CaCl_2$ no pr. until neutralized and heated. Heated with H_2SO_4, torrents of CO, and scarce change of color. On platinum fuses, gives off suffocating odor, burns quietly, carbonizes, and completely combusts.

TABLE OF ACIDS AND SALTS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FURTHER PORTIONS FOR EACH TEST.
II. b. (*cont.*) **$CaCl_2$.**	White pr. only after addition of alcohol, or by heat, in very concentr. solutions.	**Malates,** p. 50.	Char on platinum. Evaporated to dryness, and heated with H_2SO_4, blacken, and evolve combustible CO. $Pb2C_2H_3O_2$, white pr. fusing under boiling water. **Malic acid** reddens litmus; effervescence 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 pr. of AgCl soluble in NH_4OH, insoluble in HNO_3.	**Chlorides,** p. 45.	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, tawny pr. of Hg_2Cl_2, calomel, blackened by $2NH_3$. *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. 46.	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 in starch paste, orange color. Cl_2 to a bromide, separates Br_2 with yellow color: Br_2 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. 46.	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. Cl_2 gives brown color to solution, bluing starch: shaken with chloroform, the latter amethystine from the 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. 38.	All cyanides decomposed by HCl. Group I.
	White precipitate, insoluble in dilute HNO_3.	**Ferrocyanides,** p. 47.	Group IV.
	White precipitate, insoluble in dilute HNO_3.	**Sulphocyanides,** p. 47.	Group IV.
	Orange precipitate, insoluble in dilute HNO_3.	**Ferricyanides,** p. 47.	Group IV.
IV. **Fe_2Cl_6**	Red color, changed to yellow at once by dilute HCl.	**Acetates,** p. 47.	See Group I. p. 67. $Hg_2 2NO_3$, white scum-like pr. of $Hg_2 2C_2H_3O_2$.

TABLE OF ACIDS AND SALTS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FURTHER PORTIONS FOR EACH TEST.
IV. (*cont.*) **Fe_2Cl_6.**	Cherry-red color, removed with greater difficulty by HCl.	**Meconates,** p. 48.	Solution evaporated blackens with H_2SO_4 when heated $CaCl_2$, white pr. $Pb\overline{A}_2$, white pr. Chars on platinum.
	Deep purple color.	**Salicylates,** p. 52.	HCl, white pr. 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 $HgCl_2$.	**Sulphocyanides,** p. 47.	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. 47.	$FeSO_4$ deep blue pr. H_2SO_4 gives HCN (Group I.). On platinum burns with scintillations, leaving brown oxide of iron. $AgNO_3$, orange pt. sol. in NH_4OH, insol. in dil. HNO_3.
	Prussian blue.	**Ferrocyanides,** p. 47.	$FeSO_4$, pale blue or white pr. In strong solutions HCl white pr. turning blue on exposure. $CuSO_4$, maroon pr. Dil. H_2SO_4 gives HCN: strong H_2SO_4 on solid, gives CO, combustible with blue flame.

Blue-black precipitate.	**Tannates,** p. 51.	HCl no pr. in tannates. Heated with H_2SO_4 or on platinum, blackens. KOH brown color. Precipitates gelatine from solution.
Blue-black precipitate.	**Gallates,** p. 51.	HCl pr. gallic acid in minute white needles. Same as tannate but does not pr. gelatine, and HCl does pr. *gallic acid* as white cryst: powder sol. in boiling water.
Pale buff precipitate	**Benzoates,** p. 52.	HCl gives cryst. plates of benzoic acid. Heated on Pt. aromatic pungent fumes and smoky flame. *Free acid* no pr. with Fe_2Cl_6 till neutralized. Burns completely away: vapors most irritating.
Pale buff precipitate.	**Hippurates,** p. 52.	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. 52.	On platinum fuses to clear liquid, pungent vapors, and burns away with sootless flame, leaving carbonate, unless free acid or salt of ammonium. $BaCl_2 +$ $NH_4OH +$ alcohol, white pr., but not with benzoate. *Free acid* no pr. till neutralised: effervescence.
Reddish brown precipitate.	**Hydrates,** p. 2.	$AgNO_3$ grey-brown pr. sol in NH_4OH, and in HNO_3.

TABLE OF ACIDS AND SALTS—*continued.*

GROUP-TEST.	REACTION.	INDICATES	CONFIRMATORY TESTS APPLIED TO ORIGINAL SOLUTION, TAKING FURTHER PORTIONS FOR EACH TEST.
V.	No precipitate with group-tests.	**Nitrates,** p. 53.	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. 38.	Group I.
		Perchlorates, p. 54.	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 $AgNO_3$.

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One of the following substances may be given:

A. **Neutral bodies:** alcohol, urea, sucrose, glucose, starch and glycerin.

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, sulphocyanides, 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, with evolution of hydrocyanic acid.

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 soot, 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 pr. 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, and ascertain degree of solubility, 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. If present they must be as salts. Starch is at once recognised, or proved to be absent.

Now add Na_2CO_3 very carefully to a small portion; a pr., 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 pr. 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 effervesence, but no pr., it indicates a free acid, or an acid salt of K_2, Na_2, or $(NH_4)_2$, 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 behavior. Add calcium hypochlorite (chloride of lime in solution); 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, scrunching 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 some time with dilute sulphuric acid, it is changed into glucose; then a few drops of $CuSO_4$, and excess of potash, on boiling, give red pr. 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 precipitates urea nitrate.

Oxalic acid precipitates urea oxalate.

By nitrous acid into CO_2, N_2 and H_2O. (See Russell and West's test.)

If there is effervescence, 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, white crystalline plates of urea nitrate are precipitated. $Hg2NO_3$, white pr. $Ca2ClO$, 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. 53).

Urea oxalate, $2[CO(NH_2)_2],H_2C_2O_4$. White, granular crystals. Does not deflagrate when heated on platinum, nor blacken.

With lime-water, immediate white pr., insoluble in CH_3COOH.

b. It has a spirituous odor, burns with bluish flame, and leaves no residue upon platinum. Probably **alcohol**.

3. **Alcohol**, C_2H_5OH. Colorless, neutral, inflammable liquid; volatile. Moderately dilute, containing only ten per cent. of alcohol, it 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 combusts. 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, $C_6H_{12}O_5$.

A drop of $CuSO_4$ to a small portion, then excess of KOH, give 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.

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, $C_6H_{12}O_5,SO_3$.

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 **glycerin.**

6. **Glycerin,** $C_3H_5(OH)_3$. When pure: colorless, viscid liquid. of sp. gr. 1·27, boiling at 200° 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. They 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 pr. of the respective alkaloid.

KI_3, gives, with all alkaloids and their salts, a brown resinous precipitate. (The test extemporized, 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.)

Phospho-molybdic acid gives a yellow pr.

Phospho-tungstic acid, a white pr.

7. **Morphia,** $C_{17}H_{19}NO_3,H_2O$, in short, rectangular prisms, or as a white powder, 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 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 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 pr. of strychnia; precipitate shaken with chloroform is dissolved. The chloroform solution evaporated in small porcelain capsule, mixed with a little pounded $K_2Cr_2O_7$, and stirred with a rod dipped into H_2SO_4, gives blue-purple streaks.

Chlorine water gives a white pr.

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 solution, fluorescent, reflect bluish tint.

NH_4OH, or Na_2CO_3, white pr. 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. **Cinchona,** $C_{20}H_{24}N_2O$. 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 cinchona more soluble than those of quina.

Not fluorescent.

KOH or NH_4OH, or Na_2CO_3, white pr. of cinchona, insoluble in ether.

K_4FeCy_6, white, flocculent ferrocyanide, soluble in excess, and, after gentle heat, separates in golden scales (requires skill).

Chlorine water and then NH_3, a yellowish-white pr.

Solutions bitter.

Group C. Acids and their salts.

a. Ferric chloride does not precipitate either free **oxalic, tartaric, 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 oxalic acid, even; 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 and CO_2. The CO is combustible.

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 **sulphocyanides,** 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.

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 chloride. Acidimetry and alkalimetry, therefore, are used only for such acids and bases as produce salts 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 soda, NaOH, being 40, 1 c.c. of the oxalic solution = $\frac{4}{1000}$ = ·004 gramme of NaOH. (See Table, p. 86.)

Potash 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 NH_3, or ·0035 grm. of 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		
Calcium oxide, CaO	·0028		
,, hydroxide, $Ca(OH)_2$	·0037		
,, carbonate, $CaCO_3$	·0050		

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.

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 As_2O_3 present.

Of course the solution must not contain other substances capable of acting upon iodine.

ESTIMATION OF ALCOHOL IN WINE, &c.

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 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 carbonic acid, 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.

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 in 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 100c.c. required 12·8c.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 Cl or NaCl 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 process are used for testing the amount of chloride in the ash of milks, &c.

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.

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. 90). 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, warm and stir 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 which averages 9·3 per cent. If below 9 the milk has been watered.

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 pr. 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 pr. 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.

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 concent. 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 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.

$AgCl = 108 + 35{\cdot}4 = 143{\cdot}4.$

$$143{\cdot}4 : 58{\cdot}4 :: \text{weight of AgCl} : \text{weight of NaCl}.$$
$$143{\cdot}4 : 35{\cdot}4 :: \text{weight of AgCl} : \text{weight of Cl}.$$

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 tiny 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 Cu_2O deposits. To ascertain the amount, titrate with Fehling's solution (p. 92).

For bile, see p. 93.

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.

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 posssible, 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. 90).

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 lime, 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 Fe, 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. 92), 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

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 90.

Hardness. See page 88.

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 (vide infra); 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.

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 pr. 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 pr. (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.

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 concent. 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."

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 a low bulk, a minute quantity of $KClO_3$ added, the evaporation carried 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 pr. if more. In case a pr. 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 $Mg_2P_2O_7$. 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 impurity. 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.

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 pr. 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 pptd. with baryta water, boiled down to a low bulk, 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 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 tiny 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 porcelain dish, 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 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, pptd. by $BaCl_2$, boiled till the pr. 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 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, and 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 is probable.

ULTIMATE ORGANIC ANALYSIS

Is rarely of use except for finding the formula of a pure compound.

To estimate the **carbon** and **hydrogen**. About 0·2 grm. of dried substance is taken. A perfectly clean hard-glass tube, about thirty inches long, closed at one end (tube-retort), is filled as follows. Granulated cupric oxide is ignited in a crucible, and allowed to cool. While still warm, one inch of the tube is filled with it, then the substance, mixed rapidly with more of the warm cupric oxide, is added. The mixture should now occupy three inches of the tube-retort. Add cupric oxide (hot from the crucible) up to 27 inches, put in a plug of ignited asbestos, and attach by a perforated cork the absorption apparatus. This consists, firstly, of a previously weighed U-tube containing H_2SO_4, and, secondly, of a Liebig's potash bulb containing KOH in solution. When the tube-retort is heated to redness in a combustion-furnace, the carbon and hydrogen are oxydized by the cupric oxide to carbon dioxide and water. The former is absorbed by the potash, and the latter by the sulphuric acid, and the gain in weight gives by calculation the amount of carbon and hydrogen.

For some substances, fused and pounded lead chromate is used instead of cupric oxide.

To estimate the **nitrogen,** the substance is burnt as above, a plug of metallic copper being substituted for the asbestos, so as to reduce any oxides of nitrogen. The tube is previously exhausted by a Sprengel pump. At the end of the combustion, the Sprengel is set to pump the N_2 and the CO_2, formed by the combustion, into a measuring tube. The mixed CO_2 and N_2 are measured, the CO_2 absorbed by passing up a fragment of KOH, and the residual N_2 calculated. The CO_2 found, gives confirmation of the carbon found in the previous determination of carbon and hydrogen.

By a simpler, but less accurate method, the nitrogen may be determined as ammonia, employing soda-lime instead of cupric oxide. The ammonia is absorbed in a bulb-tube containing a known volume of standard oxalic acid solution (p. 85); this is afterwards titrated by standard alkali, and the loss of acidity indicates the amount of ammonia, and, by calculation, that of the nitrogen in the original substance.

Sulphur, phosphorus, chlorine, bromine and **iodine** are determined by mixing the substance with sodium carbonate and potassium nitrate, and heating in a long, hard-glass tube, till the carbon, &c., are oxydized. Dissolved in water, the filtrate is examined for the radicles in the usual way.

Oxygen is estimated by difference.

The ash must, of course, be first deducted, if any there be.

THE CHEMICAL PORTION OF THE PRACTICAL EXAMINATION IN FORENSIC MEDICINE AT THE UNIVERSITY OF LONDON.

Class A comprises simple solutions of carbolic acid, chloroform, chloral, nitro-benzol, anilin, alcohol, morphia and meconic acid, strychnia and brucia.

Class B comprises in admixture with foreign substances: Caustic alkalies. Mineral acids. Oxalic acid. Carbolic acid. Prussic acid and other cyanides. Phosphorus. Compounds of arsenic, antimony, mercury, lead, copper, silver, zinc and barium.

CLASS A. SIMPLE SOLUTIONS.

Carbolic acid or **phenol**, C_6H_5OH, is recognised by its peculiar odor. Aqueous bromine should give a white pr. of tri-brom-phenol, $C_6H_2Br_3OH$. Dilute ferric chloride is colored violet. A shaving of deal is colored blue on drying. It precipitates albumen.

When in admixture, 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°. Requires about 15 parts of water for solution.

Chloroform, $CHCl_3$, has a sweetish, ethereal odor, immediately distinguishable. By distillation, it may be had in a concentrated form. Boiled with 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 to prevent the separation of free hydrochloric acid; on heating, phenyl isocyanide, C_6H_5NC, will be formed, and the intolerable smell 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.

Chloral, CCl_3CHO, has a pungent odor, quite peculiar, and indescribable. It is easily distinguishable from any other compound in this class. With aqueous potash, it changes into chloroform and formiate of potash: $CCl_3CHO + KOH = HCOOK + CCl_3H$. The chloroform is discovered by aqueous anilin and alcoholic potash.

Chloral is a thin, oily, colorless liquid, exciting to tears. Sp. gr. 1·502. Boils at 94°. Very soluble in water. With water it forms white crystals of hydrate of chloral, the ordinary medicine.

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 at least remarkable.

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 rapidly 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°.

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 aldehyde free.

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, $CH_3COOC_2H_5$.

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 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, but with ferric chloride it will give a cherry-red color, with difficulty removed by hydrochloric acid. Meconates will give a white pr. with acetate of lead and with chloride of calcium. The ferric chloride test is decisive (p. 48). 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. 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 *hydrochloride,* $C_{17}H_{19}NO_3.HCl,3H_2O$, in tufts of needles, very soluble in water. *Acetate,* in needles. Ferric chloride, a port-wine color in an acetate, the color removed by a few drops of hydrochloric acid. In an acetate, lead acetate gives no precipitate as 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 pr. be shaken with chloroform, the liquid becomes clear, and the chloroform on evaporation leaves the strychnia. No change of color with sulphuric acid, but on stirring a mere speck of di-chromate of potassium with this acid mixture, a deep rich blue color is produced, changing to purple, crimson, and red-brown. The same colors with MnO_2, or PbO_2.

Strychnia requires 7000 parts of water for solution; blues red litmus. Crystallizes in octahedra, or in short six-sided prisms. Intensely bitter. 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 alcohol. Nitric acid imparts a rich red color; if warmed and then cooled, stannous chloride changes the red to purple, bleached by excess. Sulphuric acid no change of color, but with potassium di-chromate a red-brown color, changing through green to yellow.

Brucia crystallizes in needles, or four-sided prisms. Insoluble in ether; easily in chloroform. On platinum, when heated, it melts into a pale liquid, darkens, vaporizes in part, and leaves abundant carbon, which combusts without residue.

CLASS B. IN ADMIXTURE WITH FOREIGN SUBSTANCES.

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, HCN. 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 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 neutral, and hydrochloric acid will separate hydrocyanic acid (p. 39). On addition of H_2S, white chloro-sulphide of mercuric, 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. 22).

Phosphorus, P_4, should be recognized by the odor when solution stirred, or shaken up. Distil, and look for signs of phosphorus vapor, and, in the dark, for luminosity. Silver nitrate should give a brownish pr. 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.

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. 33). No reaction with sodium carbonate. Sulphate of copper a pr. 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. 33).

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. 45, 53. Either of these acids will probably be discoverable in the mixture. **Sulphuric acid** will precipitate barium chloride, and the pr. 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 pr. even in very dilute solutions, insoluble in acetic acid: collect on a filter, wash, and prove oxalate of calcium (p. 114). Silver nitrate a pr. soluble in dilute nitric acid. For further tests, p. 70.

Cupric salts may or may not be at once distinguishable by the blue color. A small portion, acidulated with hydrochloric acid, will give the reaction of metallic copper of red color on insertion of a knife-blade, or of a piece of steel. Cupric (p. 21).

Arsenic, antimony and **mercury** are discoverable by Reinsch's test,—a strip of clean copper boiled in hydrochloric acid, —and subsequent addition of some of the suspected fluid. If no coating on the copper, grey, black, or silvery, look for other metals. Tests for arsenious at p. 42, for antimony at p. 18, and for mercury at pp. 17, 22.

Lead and **barium,** will be precipitated by dilute sulphuric acid: lead sulphate thus precipitated will be turned black by sulphide of ammonium. Barium sulphate heated on platinum with hydrochloric acid, will give the yellowish-green color of a soluble barium salt to flame on heating with blowpipe. On incineration with sodium carbonate on charcoal, the metal lead would be indicated by yellow incrustation, and bluish-tinted beads easily flattened under pestle in mortar, soluble as nitrate in nitric acid, and detectible by dichromate of potassium, as yellow lead chromate soluble in potash.

Silver would be precipitated by hydrochloric acid, and the pr. would be insoluble in boiling water, and in nitric acid (not lead); soluble in ammonia. On incineration of a portion, metallic silver will be recognized by its lustre, by the absence of incrustation, and by the significant reactions of the silver nitrate obtained by dissolving the metal in nitric acid.

Arsenic, antimony, mercury, lead, copper, and silver are precipitated by hydrochloric acid (Group-test I., mercurous, lead or silver) or by hydrochloric acid and hydrogen sulphide (Group-test II., arsenic, antimony, mercuric, lead or copper). The precipitates filtered, and washed with solution of hydrogen sulphide, will most probably be of sufficiently characteristic color to recognize. Lead sulphide and copper sulphide are easily dissolved by dilute nitric acid as nitrates: mercuric sulphide is not attacked.

Zinc is precipitated by ammonium sulphide, and cannot be mistaken if Group-tests I. and II. have given no reaction. The precipitated zinc sulphide can be washed on a filter, and calcined on platinum. Yellow whilst hot, white when cold, would prove zinc oxide. Moistened with nitrate of cobalt, and re-heated, Rinman's green would confirm zinc.

Barium would not be precipitated by Group-test IV.

Sodium carbonate would give a pr. with a barium salt, and the pr. after washing, dissolved in hydrochloric acid, could be examined as solution of barium chloride (p. 30).

Of course, if lead or barium has been found, a sulphate need not be looked for. Antimonous chloride has a strongly acid reaction: tartar emetic is faintly acid. If an arsenite is present, the solution would be strongly alkaline.

For further information, the Index must be consulted.

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, dissolves as green cupric chloride, precipitated black by H_2S, and the sulphide when neutralized insoluble in $(NH_4)_2S$, (p. 21). On platinum no change. Heated with HCl, a green and blue flame.

Antimonous sulphide, dissolves as $SbCl_3$, with evolution of H_2S. Orange-red sulphide precipitated by H_2S, soluble, when neutralized, in $(NH_4)_2S$ (p. 18). Confirm H_2S by lead-paper.

Manganese peroxide, dissolves in HCl as manganous chloride, with evolution of chlorine. Ignited on platinum changes to red-brown, and further heated with Na_2CO_3 gives a fused blue-green mass of manganate of sodium (pp. 27 and 46).

Ferrous sulphide, soluble as ferrous chloride with evolution of H_2S. No pr. with H_2S, nor with NH_4OH after addition of NH_4Cl. Black pr. with ammonium sulphide. Confirm ferrous by K_3FeCy_6, and H_2S by lead-paper (p. 27).

Nickel and cobalt sulphides. Soluble in strong HCl, or in HNO_3. Color green or pink (pp. 28 and 29).

Mercuric sulphide. Insoluble in HCl and in dilute HNO_3. Boiled with aqua regia, gives mercuric sulphate and chloride, with sulphur. $HCl + H_2S$, characteristic pr. of mercuric (p. 17). Volatile on platinum.

Bismuth sulphide, almost insoluble in HCl: readily in HNO_3. Brown pr. with H_2S, insoluble, when neutralized, in $(NH_4)_2S$. $K_2Cr_2O_7$, orange pr., insoluble in KOH (p. 23).

Lead sulphide. Native galena has lustre and appearance of lead. Slowly soluble in HCl, with evolution of H_2S. Filtered, with H_2S, slate-colored pr., insoluble, when neutralized, in $(NH_4)_2S$.

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 pr., soluble in KOH (p. 15).

Cupric sulphide, almost insoluble in HCl. Dissolves readily in HNO_3 to blue solution, with deposit of sulphur. H_2S, black pr. Steel deposits red copper (p. 21).

Silver sulphide, 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 pr., soluble in NH_4OH (p. 16).

Carbon as graphite, a soft powder, of semi-metallic lustre: black lead. Insoluble in acids. Combustible with difficulty, 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 upon platinum 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 (p. 22).

Vermilion. Volatile when heated on platinum. Dissolves in aqua regia. Its volatility and color refer to mercuric (p. 22).

Red lead. Heated on platinum, fuses to yellow oxide of lead. Dissolves in HCl, evolving Cl_2, to colorless lead chloride. H_2S, slate-colored pr., insoluble, when neutralized, in $(NH_4)_2S$. With nitric acid, leaves puce-colored peroxide of lead. 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 chromium oxide see p. 26.

III. IF SOME SHADE OF PURPLE-BROWN, OR RED-BROWN.

Possibly, amorphous phosphorus, lead peroxide, or cupric ferrocyanide, ferric hydroxide or ferric oxide.

Heat upon platinum, and boil a further portion with HCl.

Amorphous phosphorus. When heated on platinum, burns like ordinary phosphorus with white, suffocating vapors of phosphorus pentoxide: forms a fusible alloy with the platinum. Untouched by HCl. Slowly dissolved as ortho-phosphoric acid in boiling nitric acid (p. 41).

Lead peroxide. Heated on platinum fuses as yellow oxide of lead. See Red lead (p. 108).

Cupric ferrocyanide. Heated on platinum, burns and blackens.

Boiled with HCl, evolves hydrocyanic acid (p. 39), and gives blue solution of cupric chloride (p. 21).

Ferric oxide, various tints of red-brown. Heated on platinum, a deeper brown. With difficulty soluble in HCl as ferric chloride, with yellow or yellow-red color. Easily soluble in $HNO_3 + HCl$. H_2S reduces to ferrous salt, with deposit of yellow sulphur. K_4FeCy_6, Prussian blue (p. 25).

Ferric hydroxide, dissolves easily in boiling HCl to yellow, or yellow-red ferric chloride (p. 25). 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, cadmium sulphide, lead chromate, sulphur, or lead oxide.

Heat upon platinum, test with ammonium sulphide, and a further portion with HCl.

Antimonous sulphide, orange colored, fuses to black glass, evolves SO_2, gives flame of antimony, and alloys with the 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. 18).

Arsenious sulphide, darkens in color, fuses to a black mass, when heated on platinum: sulphur burns with arsenical flame, and the arsenicum forms a fusible alloy with the platinum. Soluble to colorless solutions 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, precipitated, is yellow. Black when heated, and volatilized as $2Hg + O_2$. Dissolves in 2HCl, as mercuric chloride. Blackened by ammonium sulphide (p. 22).

Cadmium sulphide, yellow. Heated on platinum, 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 pr. (p. 23).

Lead chromate, yellow. When heated on platinum 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 (pp. 14 and 44). Fused with Na_2CO_3, on charcoal, globules of lead with yellow incrustration, and yellow chromate.

Sulphur, pale yellow. Fusible to red-brown liquid, burning with violet flame to sulphur dioxide. No residue, and platinum destroyed. 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. 41).

Lead oxide, or litharge, is deep yellow. Fuses on platinum. Blackened by ammonium sulphide. Slowly dissolved in boiling HCl, with separation of lead chloride. More readily dissolved in boiling HNO_3, to lead nitrate. H_2S, slate coloured PbS. $K_2Cr_2O_7$, yellow lead chromate, soluble in KOH (p. 15).

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. 26).

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 potassium hydroxide to obtain a solution (p. 26).

Emerald green. Cupric aceto-arsenite. Blackened by ammonium sulphide. Dissolves in ammonic hydrate with blue color, in which cupric 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. 21; arsenicum, p. 42; acetates, p. 47. 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 and silver nitrate 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 (p. 38). Heated with potassium hydroxide into brown ferric hydroxide (p. 109), and solution of potassium ferrocyanide (p. 47). On platinum, heated, a copious ash of ferric oxide.

Insoluble **cupric salts** dissolve easily in HCl with blue or green color. Azurite dissolves with effervescence, as it is a carbonate (p. 22).

VII. IF WHITE, OR NEARLY WHITE. Names are legion.

SECTION A. *Blackened by ammonium sulphide.* Compounds of mercury, lead, silver, bismuth 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. 45). Boiled with copper and dilute nitric acid, silvery coating of mercury. Strong hydrochloric acid dissolves mercuric chloride and leaves 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 pr., 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, with only the radicle employed (p. 15).

Lead sulphate, $PbSO_4$, also unchanged by ammonia. Strong HCl dissolves sufficient to give white pr. with barium nitrate, proving sulphate (p. 40). Fused on charcoal with Na_2CO_3, beads of lead, with yellow incrustration; the beads, washed and dissolved in HNO_3, give the reactions of lead nitrate; the mass moistened on a silver coin, give the browning or blackening of a sulphide (p. 36), and the odor of H_2S.

Silver chloride, AgCl. Dissolved by ammonia, and re-precipitated by nitric acid. Insoluble in acids. Fuses on platinum: "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. 45).

Silver cyanide, AgCN. Dissolved by ammonia. With concentrated HCl, yields hydrocyanic acid (p. 38). Heated on charcoal, cyanogen burns with peach-blossom colored flame, and metallic silver remains: the metal tested as at p. 16, 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 pr. increased by tartaric acid; solution gives reactions for bismuth (p. 23). Heated on charcoal, metallic beads, brittle, with scanty incrustation. The powder in a test-tube with ferrous sulphate, gives with H_2SO_4 the reaction of a nitrate (p. 53).

Bismuth oxy-chloride, $BiOCl$; similar to the above, but the solution in nitric acid gives the reaction of a chloride (p. 45), (and not of a nitrate with $FeSO_4$ and H_2SO_4, when the white powder is thus treated).

Ferric phosphate, blackened by ammonium sulphide. Unchanged by ammonia. In HCl soluble with yellow color, re-precipitated by NH_4OH, not redissolved by acetic acid. The solution in HCl gives, when warmed with nitric acid solution of molybdate, a yellow pr. (p. 41), and with K_4FeCy_6, Prussian blue. For ferric, p. 25.

Antimonous oxides. Orange-red by ammonium sulphide, soluble in excess, and depositing Sb_2S_3 on evaporation. No change with ammonia. Dissolve 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. 18).

Antimonous oxy-chloride, $SbOCl$, like the former, but when fused with Na_2CO_3, the mass gives a reaction for a chloride (p. 45). The globules of metallic antimony are brittle, soluble in HCl, and detected as at p. 18.

Stannic oxide, SnO_2, yellow with ammonium sulphide and dissolved if acted upon; 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 give the reactions of stannous (p. 19). When ignited, stannic oxide is insoluble in HCl; may be fused with solid KHO, and then dissolved in HCl as $SnCl_4$.

SECTION B. Not discolored by ammonium sulphide beyond the yellow colour 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. 36); a smell as of a burning brimstone match, sulphites (p. 37).

Test the solution for an **arsenite,** or **arsenate,** by addition of H_2S, and look for both of these acids as directed at pp. 42, 43, and for a **phosphate,** after proving the absence of an arsenate, by means of acid molybdate and heat (p. 41).

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. 39), and chlorides of the basyls will be found in solution.

After ignition, if 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, Rinman's green (p. 27). Dissolved in HCl, no other acid but the solvent discoverable.

Magnesium oxide, MgO, white, very light powder. Unchanged by heat. Ignited with cobalt nitrate, pink. Solution in HCl, gives the reactions of magnesia (p. 32). 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 pr. with Na_2CO_3. Silver nitrate will indicate a hydroxide, and further tests will prove lime (p. 31).

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.

Otherwise, the test of cobalt will declare some form of alumina (p. 25).

Aluminum phosphate, $AlPO_4$, is white, unchangeable. The solution in HCl gives phosphate reaction with acid molybdate (p. 41), and on platinum, when ignited with cobalt nitrate, Thénard's blue (p. 26). 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. 41).

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. 31). Boiled with sodium carbonate, sodium oxalate is found in solution (p. 45).

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. Effervescence from H_2S when sulphide of ammonium added. 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 yellow pr. with $2HCl,PtCl_4$. Very soluble in HCl. Also in KOH, and, on careful addition of HCl, white, crystalline pr. of cream of tartar (p. 68).]

b. **The white substance does not dissolve.**

When hydrochloric 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. 30), and the soluble, containing sulphide and sulphate, indicates the former by blackening silver-coin on which 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. 31), 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. Test for Ca (p. 32), and for sulphate (p. 41).

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. 39. Many silicates are insoluble in all acids, except hydrofluoric acid.

As a rule, if a **substance is insoluble in acids, 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, dissolved in alkalies. Add HCl or HNO_3 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. The best method is to 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. 115.

N.B. In separations, the reagent must always be added till all the substance has been precipitated. It is necessary to pass H_2S gas, instead of adding H_2S solution.

GROUP I., Ag, Pb, Hg_2 (ous).

Add to the solution **hydrochloric acid**: if no pr., Group I. is absent; if a pr., continue the addition till all is thrown down. Collect on a filter, wash with water, collecting the first washings in the filtrate, preserve the filtrate for the other groups.

Treat the pr. with boiling water, **lead chloride** will dissolve, and the filtrate will give with dilute H_2SO_4 a white pr. of $PbSO_4$, with KI yellow PbI_2, with $K_2Cr_2O_7$ yellow $PbCrO_4$. **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. 16). **Silver.**

Mercurous chloride will not dissolve, but will turn black. Confirm mercurous by p. 17. **Mercurous.**

If lead be 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 pr. of sulphur, shows absence of Group II.: a *yellow* pr. proves absence of Hg, Pb, Bi, Cu, and presence of stannic, As or Cd, or it may be only Sulphur.

The pr. is *black:* all the members may be present.

Filter. Keep the filtrate for remaining groups. Wash the pr., 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 pr. is produced, it is sulphur, and As, Sb, Sn, need not be looked for. Otherwise, wash the pr., treat with $(NH_4)_2CO_3$ solution, and filter. *Arsenic* will dissolve, reprecipitated yellow by HCl; collect As_2S_3, and confirm: p. 42. **Arsenic.**

The portion insoluble in $(NH_4)_2CO_3$ should be fused with **ammonium 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. 18).

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 pr. with $HgCl_2$, and a dark brown with H_2S. **Tin** (p. 19).

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 pr. denotes **bismuth** (p. 23).

If the ammoniacal solution is blue; **cupric** (p. 21).

1. If copper is absent, add $(NH_4)_2S$: a yellow pr. proves **cadmium** (p. 23).

2. If copper is present, reprecipitate 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.

GROUP III., Al, Cr, Fe.

Boil off all the H_2S, and test a portion of the solution for iron by K_3Cfy; dark blue pr. [Test the original solution with K_4Cfy to see whether ferrous or ferric (pp. 24, 28)]. If iron is present, boil the remainder with HNO_3 till the ferrous is oxidized to ferric.

Add **ammonium chloride** and **ammonia** in slight excess, warm, collect on a filter and wash rapidly. The pr. may contain:

Hydroxides of Al_2, Cr_2, Fe_2.
Phosphates of Al_2, Cr_2, Fe_2, Ba, Sr, Ca, Mg.
Oxalates of Ba, Sr, Ca.

Test a portion for phosphate by dissolving in HCl and warming with ammonium molybdate: yellow pr.

Another portion for oxalate by igniting on platinum; if oxalate, the residue will effervesce and dissolve (p. 45), when the solution may be examined for the bases.

I. **If phosphate is absent.** dissolve the pr. in HCl and add KOH in excess: *ferric hydroxide*, brown, will be precipitated. If chromium be present, the solution will be green: filter and boil for some time: *chromic hydroxide*, bluish green, will separate. Filter again, add HCl and a grain of $KClO_3$ to destroy organic matter, boil, add NH_4OH in excess and warm: *aluminum hydroxide*, white, will be thrown down. Confirm by blowpipe tests, p. 25.

2. **Phosphate is present.** If oxalate has also been found, evaporate and ignite the whole, dissolve in HCl, boil for some time to convert any pyrophosphate into orthophosphate, reprecipitate with KOH. Ferric hydroxide and phosphate, and phosphates of Ca, Sr, Ba, Mg will be precipitated, while chromic hydroxide and phosphate, and aluminic hydroxide and phosphate, will remain in solution.

a. The solution. If the solution contains chromium, it will be green; boil for some time, chromic hydroxide and phosphate will be precipitated; filter, confirm **chromium** by the blowpipe test (p. 26); add to the filtrate *acetic acid* in excess. **Aluminum phosphate,** if present, will precipitate; to the filtrate add ammonia in excess; **alumina** will precipitate if present. Confirm (p. 25).

b. The precipitate. Wash, dissolve in HCl (sparingly used), add sodium acetate in excess, and then nearly neutral ferric chloride solution till the supernatant liquid shows a red color, and boil. Ferric phosphate will precipitate, the excess of iron will go out of solution as basic ferric acetate, and the filtrate will contain the alkaline earths, Ba, Sr, Ca, Mg. Test it as usual, Group V., pp. 30–32.

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 pr.; 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 pr. 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 proceeding groups add $(NH_4)_2CO_3$, and warm. Ba, Sr and Ca will precipitate as carbonates. Wash the pr., 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 pr. by flame test (p. 65).

To a portion of the filtrate from Na_2CO_3, add Na_2HPO_4 solution, stir and allow to stand. **Magnesium** will go down as phosphate. Confirm as at p. 32.

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 pr. 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.

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. 62). 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.

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 pr. 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 pr. is $CaCO_3$, possibly with some $CaSO_3$. Add HNO_3 in excess, boil, add $Ba(NO_3)_2$; if sulphite, a white pr. 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 pr., but the solution boiled with HNO_3 on addition of $BaCl_2$, yields by oxydation a white pr. 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 sulphocyanide test (p. 47).

6. Smell of SO_2, and deposit of S. **Thiosulphate.**

The other tests (p. 37) 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 (p. 47); 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 pr. of the acid, which can be filtered off and specially tested. Uric acid chars on platinum with odor of burnt feathers; also the murexide test, p. 50.

See also page 40.

For arsenious, arsenic and chromic acids, see pages 42 and 44. Silicic acid, p. 39.

Group-test B. $BaCl_2$ or $Ba(NO_3)_2$. Yellow pr. indicates **chromate**; a white one, soluble in HNO_3, points to phosphate, arsenite, arsenate, oxalate, borate, silicate, fluoride, tartrate, citrate: a white pr. insoluble in HNO_3 proves **sulphate.** Sulphite and thiosulphate 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 $Ba(NO_3)_2$ pr., treated cautiously with dilute sulphuric acid, gives the acids of this group in solution.]

Group-test C. $AgNO_3$. Notice the characters of the pr. as given in the preliminary tests, p. 1.

Digest the pr. with dilute HNO_3, everything will dissolve except sulphide (black), chloride (white curdy), bromide (yellowish white), iodide (pale yellow), cyanide (white), ferrocyanide (white), sulphocyanide (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 pr. gently in porcelain, AgCy is decomposed to Ag and Cy, the latter giving the odor 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 water cautiously; red vapors of bromine will be liberated (p. 46); 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* pr. 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 pr. indicates carbonate, sulphite, thiosulphate, arsenite, arsenate, chromate, phosphate, borate, oxalate, tartrate, citrate (?), fluoride, silicate. Most of these have been already found.

Wash the pr. Ignite a portion on platinum. If it chars, a vegetable acid is present. *Tartrate*, burnt-sugar odor; *citrate*, etc., pungent odor, etc. Burn white, dissolve in HCl, and test for inorganic acids.

If it does not char; tartrate, citrate, etc., are absent.

Digest the pr. in acetic acid; all the lime salts will dissolve except oxalate and fluoride. Heat the original with H_2SO_4; glass etched; **fluoride.**

Ignite the pr. 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. 44.

Warm a few drops of the original solution, acidified with HNO_3, with ammonium molybdate; yellow pr. indicates phosphate, or arsenate. Test for arsenic by Marsh's and Reinsch's test, p. 43. 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 the arsenic 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 pr.; **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 pr. of uric acid (Group A).

(*b*) *Soluble in HCl, but not in acetic acid*; phosphate, arsenate, already found; **tannate,** blue-black very finely divided pr.; **gallate,** black pr., with HCl yellow color, with pr. of gallic acid; **pyrogallate,** brown-red pr.

(*c*) *Insoluble in HCl*; **ferrocyanide,** dark blue.

[To separate hippurate, benzoate and succinate, add to the Fe_2Cl_6 pr. 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 $NaCO_3$, 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 pr. 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; **sulphocyanides,** blood-red. The latter are bleached by addition of $HgCl_2$, the former are not. The former give with ferrous sulphate a dark blue pr., the latter yield no reaction.

(*b*) *Removed by HCl.* It can readily be seen in mixtures whether a reduction of color is effected.

Boil the solution. 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 pr. 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 pr., 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 pr. with bromine water of tribromophenol, 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 pr., 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 $FeSO_4$ test, deflagration on charcoal, etc. (p. 53).

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, then again is turned into a chloride, **chlorate** (or perchlorate) has been present (p. 38).

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.

The **atomic weights** of the chief elements are given under their respective heads. The following is a more complete list of the elements, arranged in the order of their atomic weights.

They thus seem to fall naturally into **eight groups**, a classification first suggested by Mr. John Newlands, and extended by Mendelejeff.

In the following Table there will be seen to be a regular periodic recurrence of similar properties, dependent upon the atomic weights.

Table of Newlands and Mendelejeff.

Series.	GROUP.							
	I. R_2O	II. R_2O_2	III. R_2O_3	IV. RH_4 R_2O_4	V. RH_3 R_2O_5	VI. RH_2 R_2O_6	VII. RH R_2O_7	VIII. R_2H R_2O_8
1	H=1							
2	*Li*=7	*Be*=9	*B*=11	*C*=12	*N*=14	*O*=16	*F*=19	
3	Na=23	Mg=24	Al=27	Si=28	P=31	S=32	Cl=35·5	
4	*K*=39	*Ca*=40	*Sc*=44	*Ti*=48	*V*=51·3	*Cr*=52	*Mn*= 56	*Fe*=56 *Co*=58·6 *Ni*=58·6
5	Cu=63·3	Zn=65·3	Ga=68·8	?	As=75	Se=79	Br=80	
6	*Rb*=85·3	*Sr*=87·5	*Y*=89·8	*Zr*=90	*Nb*=94	*Mo*=95·5	?=100	*Ru*=104 *Rh*=104 *Pd*=106
7	Ag=108	Cd=112	In=113·4	Sn=118	Sb=120	Te=125	I=127	
8	*Cs*=133	*Ba*=137	*La*=138·5	*Ce*=140·5	*Di*=146	*Sm*=150		? = 152
9	?	?	?	?	Er=165·9	?	?	
10	?	?	*Yb*=172·8	?	*Ta*=182	*W*=184	?	*Os*=198·6? *Ir*=192·5 *Pt*=194·5
11	Au=196	Hg=200	Tl=204	Pb=207	Bi=208	Ng ? 214	?	
12	?	?	?	*Th*=233·4	?	*U*=238	?	

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 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:—

$$\frac{(F^\circ - 32^\circ) \times 5}{9} = C^\circ. \qquad \Bigg| \qquad \frac{C^\circ \times 9}{5} + 32^\circ = F^\circ.$$

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 = 29·92 inches. (The old standard, 30 inches, = 761·986 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 1·03665).

$$101\cdot 32 \div 1\cdot 03665 = 97\cdot 74 \text{ c.c.}$$

The corrected volume is 97·74 c.c. at 0° and 760 m.m.

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