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Objective : helping you understand Fundamental Principles of the subject.

1ST EDITION 2018 NEW CHEMISTRY PRACTICAL GUIDE:

Compendium new chemistry practical guide is without work/note for question number 1 according to Ugandan syllabus (Uganda national examination board) But compendium new chemistry practical guide contain questions number 2 & 3 which is well explained and it's in Uganda advanced certificate of education format and therefore, I really promised to avail question 1 at the time of publication of 2nd edition if need arises.

IN THE NAME OF GOD MOST GRACIOUS, MOST MERCIFUL,

DEDICATION:

I dedicate this book to my parents Mr.P'Ochure Michael Ocaya & Mrs.Ocaya Christian Akumu the late (RIP) for continued love, moral, financial, & spiritual assistance rendered to me since childhood and throughout my life to-date.

There are those special people in this world who give & give without taking who offer without asking for much in return, I dedicate this book to the best of them.

MAY THE ALMIGHTY FATHER REWARD ALL OF YOU ABUNDANTLY.

ACKNOWLEGEMENTS:

I am grateful to my parents for whatever they have rendered to me.
Work of this nation is by no means a single person's effort. It has been a result of many kind and helpful people who have willingly assisted me whenever approached.

I am also grateful to my great teachers, **Mr. Otto Stephen, Mr.Obala Peter RIP, Okello Charles Waliky** & **Mr.Kilama Stephen** of Sir Samuel Baker School, who labored to take me thought the impenetrable maze of science to make me appreciate it to the point of producing work of this nature.

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support and advise they rendered to me when I was carrying out research on the subject.
To my former students of Lira Integrated Senior Secondary School, Especially **Adopo Julius** was my greatest motivators.

PREFACE:

In this era of scientific advancement, Chemistry becomes unavoidable.

This book is intended for use in secondary especially advanced level.
It will enable both the teachers and the students to focus intensively on each practical.
It contains detailed scientific approaches, experiments, explanations and illustrations.

Revision questions and Answers are provided topic by topic meanwhile UNEB sample questions are also provided.
These questions are intended to form the basics of interactions between teachers and students or student discussion groups.

To emphasize this, the simplified language and approach used in this book aims at making chemistry as a subject easy to **understand, straight forward, attractive** & **friendly to students**.
This book has been developed in line with the most recent developments of Uganda national curriculum center teaching syllabus and UNEB syllabus.
It is therefore of great advantage to all secondary schools most especially those which may not be able to provide a wide range of text books for use by their teachers, students & the discussion groups.
The trial questions are intended to enhance group discussion for students, reference questions are for exams & seminars.
We hope that the student who follows the layout of this book will in the end have got enough experience in enabling a wide range of questions in exams.
The students will be fully prepared to both **mock** and **UNEB examinations.**
We have a **vision** as most students will turn as scientists to meet the ever increased demand for science graduate in various technical discipline of medicine, agriculture & forestry.

And finally, I dedicate this book to my special wife Ms Baseke Bridget (Tutor)
Felix Rubangakene Geofrey.

INTRODUCTION TO INORGANIC CHEMISTRY

Definition for Inorganic Chemistry: **Inorganic Chemistry** is the branch of chemistry concerned with the properties and behavior of inorganic compounds. This field covers all chemical compounds **except** the myriad organic compounds (Carbon based compounds, usually containing C-H bonds).

Key learning points:

Many **inorganic compounds** are ionic compounds, consisting of **cations** and **anions** joined by **ionic bonding**. In any salt, the proportions of the ions are such that the electric charges cancel out, so that the bulk compound is electrically neutral. The ions are described by their **oxidation state** and their ease of formation can be inferred from the **ionization potential** for cations or from the **electronaffinity** (anions) of the parent elements.

The structure of the ionic framework in potassium oxide, K_2O

Importance classes of inorganic salts are the **oxides, carbonates, sulphates** and **halides**. Inorganic salts typically are poor **conductors** in the solid state. Another important features is their solubility in water example (see **solubility chart** on the next page), and ease of **crystallization**. Where some salts (e.g. **NaCl**) are very soluble in water, others (e.g. SiO_2) are not.

Solubility of ionic solids in water is a result of an interaction between polar water molecules and ions which make up a crystal. Two forces determine the extent to which solution will occur:

1. **Force of attraction between water molecules and ions of the solid.**

This force tends to brings ions in to solution. If this is the predominant factor, then the compound may be highly soluble in water.

2. **Force of attraction between oppositely charges ions.**
3. This force tends to keep the ions in the solid state. When it is a major factor, then solubility in water may be very low**.**

A solubility chart showing the solubilities of various compounds in water at a pressure of 1 atmosphere and a room temperature (approximately 293.15K).

Cations	Carbonate, CO_3^{2-}	Chloride, Cl^-	Hydroxide, OH^-	Nitrate, NO_3^-	Sulphate, SO_4^{2-}	Oxide, O_2^-	Ethanoate, CH_3COO^-	Ethanediote, C_2O_4
NH_4^+	S	S	S	S	S	X	S	S
Al^{3+}	I	S	I	S	S	I	S	I
Pb^{2+}	I	I	I	S	I	I	S	I
Zn^{2+}	I	S	I	S	S	I	S	I
Ba^{2+}	I	S	I	S	I	sS	S	I
Ca^{2+}	I	S	Ss	S	sS	sS	S	I
Cr^{3+}	I	S	I	S	S	I	S	I
Cu^{2+}	I	S	I	S	S	I	S	I
Co^{2+}	I	S	I	S	S	I	S	I
Ni^{2+}	I	S	I	S	S	I	S	I
Fe^{2+}	I	S	I	S	S	I	S	I
Fe^{3+}	I	S	I	S	sS	I	S	I
Mn^{2+}	I	S	I	S	S	I	S	I

KEY: S = Soluble I = Insolubles sS = Slightly Soluble

Golden tips:

4. All compounds of the ammonium ion (NH_4^+) and of alkali metal (Group 1A) cations, are soluble.
5. All nitrates and acetates (ethanoates) are soluble.
6. All chlorides, bromides and iodides are soluble EXCEPT those of silver, lead and mercury (I).
7. All sulphates are soluble EXCEPT those of silver, lead, mercury (I), barium, strontium and calcium.
8. All carbonates, sulphites and phosphates are insoluble EXCEPT those of ammonium and Alkali metal earth (Group 1A) cations.
9. All hydroxides are insoluble EXCEPT those of ammonium, Alkali metal (Group 1) cations and Alkali earth metal (Group II) cations.
10. All oxides are insoluble EXCEPT those of calcium, barium and Alkali metal (Group I) cations: these soluble ones actually react with water to form hydroxides (hydrolyze).

INORGANIC CHEMISTRY PRACTICAL NOTES:

Qualitative Analysis is concerned with the identification of unknown ions contained in inorganic compounds. The negatively charged ions are called anions and the positively charged ions are called cations.

Qualitative Analysis is a scientific method of identifying the chemical components of a given substance.

The procedure involves one to:

1) Detect the presence of water of hydration/crystallization.
2) Determine which cations or anions that are contained in a compound.

— Usually a solid sample containing two or more cations or anions is supplied for analysis.

— The solid supplied may or may not be hydrated.

The process of investigation may include:

i. Examination of appearance of a solid supplied its smell or even the texture.
ii. Determining the effect of heat on a solid.
iii. Determining the effect of a dilute acid on a solid.
iv. Determining the effect of water on a solid.
v. Determining the effect of an oxidizing agent or reducing agent on the substance.
vi. Separation of mixtures.
vii. Determining the effect of a concentrated acid on the substance.
viii. Carrying out tests of own choice to identify the ions.
ix. Identification of anions in solution.
x. Identification of cations in solution.
xi. Recording observations made and drawing logical deductions/conclusions.

A candidate should master the above skills since all or nearly all, off which are always involved in dealing with one of the questions given in a practical exams.

The safely precautions below must be adhered to when handling reagents and experiments in a chemistry laboratory:

i. Always check that the label on the reagent bottle is that of the chemical you really need.
ii. Never point a test tube, which contains chemicals you are heading towards yourself or anyone.
iii. Always hand acids and other reagents with care.
iv. Never perform unauthorized experiments.
v. Always wash your hands after practical work.

In Qualitative analysis, a student is always provided with a table consisting of tests, observations and conclusions or deductions as the one designed below:

Tests	Observations	Conclusions
(a)		

Students should note the following when attempting qualitative analysis:

a) The column for tests is always filled and serves as instructions to the students.
b) A student is required to record any observations made as soon as possible, and the conclusions are based on these observations.
c) A student should remember that no marks would be awarded for a correct conclusions corresponding to a wrong observation. However, a student can score some marks if the observations are correct, but losses marks for a wrong conclusion.
d) A student is required to read through the column for the tests before attempting the qualitative analysis experiment because the tests provide a clue that help the student to predict the nature of unknown substance to be identified.

Therefore, a student is required to be well versed with theory for laboratory reagents used in Qualitative analysis and the student should also know the purpose of each reagent.

1. PRELIMINARY TESTS OF UNKNOWN SUBSTANCE:

i. Always note the physical properties of the unknown sample. Example: Note the physical appearance.
ii. Colour: which is a good guide as to what metallic ions the sample contains.

1) Nature of the substance:

✓ Powdery substances are normally carbonates.
✓ Crystalline solid indicates probably a sulphate, chloride or a nitrate.
✓ A wet solid indicates a deliquescent salt, probably a chloride or nitrate.

A. A yellow solid may also be an oxide of lead and a black solid substance may be an oxide of copper OR sulphide of copper or iron.
B. If the given unknown substance:
   i. Is in powdered form, then it's probably anhydrous substance such as most carbonates, sulphides and oxides.
   ii. Has a pungent chocking smell of ammonia. Then this predicts an ammonium salt.
   iii. Absorbs water from the atmosphere and gradually dissolves in it to form a solution. Then you can predict a chloride or nitrate ions of a metal.

C. This involves examining the appearance, smell and texture of the given unknown sample. The appearance of the sample gives a rough idea as to what it could be, particularly whether hydrated or not, transitional or non-transitional elements.
   i. Bases and carbonates are mainly Powderly and anhydrous.
   ii. Nitrates, Sulphates and chlorides are mainly crystalline.
   iii. Most crystalline substances are hydrated.
   iv. Coloured solids in pure state may give a clue (hint) about the identity of the cation present in the solid.

Cations/anions	Colour of the solid or Aqueous solution/Deductions/Conlusions
Cu^{2+}	Blue or Green
Fe^{2+}, Cr^{3+}, Ni^{2+}	Green
Fe^{3+}	Yellow/Brown
Co^{2+}	Pink or Red
Mn^{2+}	Pink
$Cr_2O_7^{2-}$	Orange
CrO_4^{2-}	Yellow
Zn^{2+},Pb^{2+},Ca^{2+},Al^{3+},Mg^{2+},NH_4^+ & Ba^{2+}	White

In general coloured solids suggest the presence of transition metal cations. Non-coloured (white) solid suggests that the sample provided contains non-transition metal cations. Examples: **Zn^{2+},Pb^{2+},Ca^{2+},Al^{3+},Mg^{2+},NH_4^+,Sn^{2+},Sn^{4+} or Ba^{2+}**

SOLUBILITY OF COMPOUNDS.

Note: Water and dilute acids are usually used as solvents to dissolve compounds.

a) Completely dissolves in water, forming a solution.	-Soluble salt or a mixture of soluble transition or non-transition salts, depending on the colour of solution.
b) Partially dissolves in water forming a suspension.	-A mixture of soluble and insoluble salts,I.e The residue is an insoluble salt while a filtrate is a soluble salt.

2. ACTION OF HEAT ON SOLIDS:

Heating a compound may results in to decomposition, formation of a sublimate, colourless liquid condensing on cooler parts of the boiling tube or evolution of gases; which must be tested for and formation of a residue.

A spatula end-ful of the unknown sample is heated gently and then very strongly in a dry boiling tube until no further change.

Golden tips:

The purpose of heating a solid is to decompose it in to recognizable products. During heating the following must be noted.

1. Gases evolved.
2. Sublimation is possible.
3. Change of state e.g. melting.
4. Colourless liquid/condensate.
5. Colour of the residue formed/left.
6. Noise may be heard e.g. Decripitation/crackling.

RESIDUE (I.E SOLID SUBSTANCE LEFT IN A BOILING TUBE AFTER HEATING)

Observations	Conclusions
i. Black residue	**CuO or CuS**
ii. Yellow-hot & white-cold	**ZnO**
$\left.\begin{matrix} reddish-hot, White-cold \\ brownish-hot, Yellowish-cold \end{matrix}\right\}$	**PbO**
iii. White residue	**Oxides** of Gp(II) & Gp (III)
iv. Green residue	**NiO, Cr_2O_3**
v. Black-hot, Reddish-brown-cold	**Ferric oxide**

Notes:

— Most solids are hydrated and lose their water of hydration on gentle heating.

— Gentle heating means heating the solid with a small flame or passing part of the test-tube containing the solid in and out of the hot flame without heating the rest of the tube. This ensures that the cooler parts of the test-tube as a colourless condensate.

— The condensate should be tested with anhydrous copper (II) sulphate or cobalt (II) chloride.

— The test-tube should be slanting with its mouth slightly downward so that the condensate does not run back to the hot parts of the test-tube which would break.

— Strong heating involves the use of the hottest flame whereby the part of the test-tube containing the solid is stationed within the flame, on strong heating, the anhydrous solid left undergoes thermal decomposition to produce a gas and a residue.

— Recognizing the gases leads to identification of the anion (or of the cation) in case of an ammonium salt.

Gas	Anion or Cation
Oxygen	Nitrate,Peroxide & dioxide
Ammonia	Ammonium,NH_4^+
Hydrogen chloride	Chloride,Cl^-
Chlorine	Chloride,Cl^-

Bromine	Bromide,Br^-
Iodine vapour	Iodide,I^-
Propanone (Acetone vapour)	Ethanoate,CH_3COO^-
Carbon dioxide	Carbonate, hydrogen carbonate,Oxalate or Ethanoate
Nitrogen dioxide	Nitrate,NO_3^-
Sulphur dioxide	Sulphite,Sulphate or Thiosulphate ions

Notes:

a) If an ammonium salt is heated, it may sublime, leading to the identification of ammonium ions.

b) Most sulphates are stable to heat except iron (III) sulphate and copper (II) sulphate. Which decomposes on heating to their respective oxides according the equation below?
Equations:

$$CuSO_{4(s)} \xrightarrow{\text{Heat}} CuO_{(s)} + SO_{3(g)}$$
$$2FeSO_{4(s)} \longrightarrow Fe_2O_{3(s)} + SO_{3(g)} + SO_{2(g)}$$

c) Many hydrated chlorides undergo self-hydrolysis on heating producing hydrogen chloride and on stronger heating; forms chlorine e.g. hydrated copper (II) chloride.

d) Acetates/ethanoates decompose on heating to give acetone (propanone vapour) which has a sweet smell, carbon dioxide gas and a metallic oxide.
Equations:

$$(CH_3COO)_2Ni_{(s)} \longrightarrow NiO_{(s)} + CH_3COCH_{3(g)} + CO_{2(g)}$$
$$(CH_3COO)_2Pb_{(s)} \longrightarrow PbO_{(s)} + CH_3COCH_{3(g)} + CO_{2(g)}$$
$$MgC_2O_{4(s)} \longrightarrow MgO_{(s)} + CO_{2(g)} + CO_{(g)}$$

Certain solids leave coloured residues on heating which may or may not change colour on cooling.

Residue (Oxide)	Colour of residue
Lead (II) oxide, PbO	Reddish-brown (Orange) when hot and yellow when cold
Zinc oxide, ZnO	Yellow when hot and white when cold
Copper (II) oxide, CuO	Black both when cold and hot
Iron (III) oxide,Fe_2O_3	Dark-brown when hot and reddish-brown when cold

Notes:

- Zinc oxide may be confused with lead (II) oxide. To avoid this confusion; subject the residue to prolonged heating: zinc (II) oxide

remains Powderly while lead (II) oxide melts to a reddish-brown liquid.

3. **Action of a dilute acid on a solid sample**:
   Some solids do not dissolve in water; in this case, the ions in that solid cannot be set free if the solid is insoluble in water. To dissolve such a solid, a dilute acid must be added.
   Expected observations:
   - Note whether the solid dissolves with effervescence. State the colour, odour of the gas and its effect on litmus. Furthermore, its confirmatory test must be carried out.
   - The following gases are produced when an acid in dilute form is added to the following anions:

Gas	Anion
Carbon dioxide,CO_2	CO_3^{2-},HCO_3^-
Sulphur dioxide,SO_2	SO_3^{2-},$S_2O_3^{2-}$
Hydrogen sulphide,H_2S	S^{2-}
Nitrogen dioxide,NO_2	Nitrate, NO_3^-

Notes:
- Hydrogen gas is produced when dilute sulphuric or hydrochloric acid is added to some metals such as zinc.
- If the acid is added to the solid sample and the sample dissolves to give a solution without effervescence, the expected deduction would be: metal oxide or hydroxide suspected.
- When the solid sample dissolves after addition of a dilute acid, state the colour of the resultant solution and deduce the cations accordingly:
  Examples:
  - ✓ Green solution: Cr^{3+}, Ni^{2+}, Cu^{2+}, or Fe^{2+} is suspected.
  - ✓ Colourless solution: Zn^{2+}, Al^{3+}, Pb^{2+}, Mg^{2+}, Ca^{2+}, Sn^{2+}, etc. are suspected.

Observations	Conclusions
Colourless condensate which turns anhydrous copper (II) sulphate to blue	**-Water of crystallization** (or water vapour from a hydrated compound)
White sublimate: A colourless gas turns red litmus paper to blue & forms white fumes when in close contact with a glass rod dipped in concentrated hydrochloric acid.	**-Ammonium** salt **-NH_3** gas (only alkaline gas) from an NH_4^+ salt.

Gas turns litmus red i.e. acidic vapour is evolved examples.	**-An acidic** gas is evolved.
Brown fumes	**-NO_2** gas from Nitrate ion.
Greenish-yellow gas turns litmus red and bleaches it	**-Chloride** gas from chloride ion.
Colourless gas on strong heating decolorizes acidified $KMnO_4$	**-SO_2** gas from a sulphate, Sulphite OR **$S_2O_3^{2-}$**ions.
Misty gas turns moist/damp blue litmus paper red.	**-SO_3** gas from sulphate ion.
NOTE: SO_4^{2-} is not easily decomposed to produce sulphur dioxide gas.	
Gas turns wet litmus paper slightly red and lime water milky.	**CO_2** gas from carbonate, hydrogen carbonate and oxalic acid ions

4. **ADDITION OF CONCENTRATED SULPHURIC ACID TO A SOLID SAMPLE:**
   This reagent is meant to identify a chloride, Cl^- ion, ethanoate, CH_3COO^- or Nitrate, NO_3^- ion.
   In case of a chloride, Cl^- ion, white misty fumes that form dense white fumes with ammonia solution are given off. The fume of hydrogen chloride.
   Equation:
   $$NaCl_{(s)} + H_2SO_{4(l)} \longrightarrow NaHSO_{4(s)} + HCl_{(g)}$$
   Chlorine gas may be produced by adding concentrated sulphuric acid to a chloride in the presence of an oxidizing agent such as manganese (IV) oxide. In the case of hydrogen chloride gas is produced from concentrated sulphuric acid and a chloride.
   But this gas is oxidized to chlorine by the oxidizing agent used.
   In case of ethanoate, a CH_3COO^- ion, a colourless gas with vinegar smells and turns blue litmus paper red is given off. The gas is ethanoic acid/acetic acid vapour.
   Equation:
   $$CH_3COO^-_{(s)} + H^+_{(aq)} \longrightarrow CH_3COOH_{(g)}$$
   In the case of nitrate, nitric acid vapour is produced when concentrated sulphuric acid is added to a solid nitrate, while heating.
5. **IDENTIFYING GASES**:
   Gases may be produced when a solid is heated or when an acid is added to a solid. Whenever a gas is produced marks are allocated according to:
   - The colour of the gas.
   - The odour (smell) of the gas.
   - The confirmatory test of the gas.
   - The effect of that gas on litmus paper.

These four scoring points will be under the observation. In deduction the following will be awarded marks.

— The name of the gas.

— The anion producing the gas.

6. SOLUBILITY IN WATER:

This is used to separate two salts whereby one is soluble in water and the other is insoluble; a spatula end full of the given sample is shaken with about $5cm^3$ of water to produce either a solution or a suspension, which is then filtered to generate a filtrate and residue; solid substance that remains on the filter paper.

a) ADDITION OF WATER TO A SOLID SAMPLE WITHOUT FILTERING:

When water is added to unknown solid and later dissolved completely, then the compound is most likely to be ionic.

Expected observation:

State the colour of the resultant solution.

- ✓ If the solution is colourless, deduce non-transitional metal ions such as Pb^{2+}, Ca^{2+}, Mg^{2+}, Al^{3+}, Ba^{2+}, etc.
- ✓ If the solution is coloured, deduce the corresponding transitional metal cations i.e.Green solution implies the presence of Cr^{3+}, Fe^{2+}, Ni^{2+} & Cu^{2+}.

b) ADDITION OF WATER TO A SOLID SAMPLE,FOLLOWED BY FILTRATION:

When asked to add water to a solid sample and then filter, it means that the sample is partially soluble or it contains both soluble and insoluble components.

Expected observation:

After filtering, state the colour of both filtrate and residue. Then deduce the cations according to the colour of filtrate or residue.

Examples summarized on the table:

Cations/anions	Colour of the filtrate or residue
Cu^{2+}	Blue or Green
Fe^{2+}, Cr^{3+}, Ni^{2+}	Green
Fe^{3+}	Yellow/Brown
Co^{2+}	Pink or Red
Mn^{2+}	Pink
$Cr_2O_7^{2-}$	Orange
CrO_4^{2-}	Yellow
Zn^{2+},Pb^{2+},Ca^{2+},Al^{3+},Mg^{2+},NH_4^+ & Ba^{2+}	White/Colourless
Observation	**Conclusion**

Partially dissolves in water to give a colourless filtrate. Residue is white/Colourless.	Filtrate contains soluble salt of probably Ca^{2+},Ba^{2+},Zn^{2+},Al^{3+},Mg^{2+}& Pb^{2+}
Completely dissolves in water to form a colourless solution.	Soluble salt of probably Zn^{2+},Al^{3+},Mg^{2+} Pb^{2+} & NH_4^+
Completely dissolves in water to form a coloured solution Example blue, green, brown& yellow.	-Blue solution:Cu^{2+}ion -Green solution:Fe^{2+}or Cu^{2+}ions -Yellow solution:Fe^{3+}ion -Pink solution:Mn^{2+} or Co^{2+} ions
Partially dissolves in water to form a green filtrate, Residue is brown, green etc.	-Filtrate is probably Ni^{2+},Cr^{3+},Fe^{2+} or Cu^{2+} ions -Residue is probably CO_3^{2-}, $C_2O_4^{2-}$ or HCO_3^- of transition salts.
Note: ✓ An insoluble salt is usually dissolved in dilute Nitric acid or dilute hydrochloric acid to form a soluble salt. ✓ The colour of the residue or filtrate obtained may help to identify the ion that is most likely to be present.	

7. ADDITION OF ALKALIS I.E SODIUM AND AMMONIUM HYDROXIDE SOLUTION TO IDENTIFY CATIONS:

a) Addition of sodium hydroxide solution, $NaOH_{(aq)}$:

Sodium hydroxide solution is added to a test solution drop wise until in excess.

Observations must be made when little of reagent is added and when excess is added.

Some metallic cations form hydroxides with the reagent as precipitates which may or may not dissolves in excess.

In this case, state the colour of the precipitate and if it dissolves state the colour of the resultant solution.

Notes:

The tests are used to predict and eliminate cations. The amphoteric hydroxides dissolves in excess sodium hydroxide solution to form a solution.

Observations	Conclusion
No precipitate is formed,a colourless gas that turns moist red litmus paper blue and forms a dense white fumes with Concentrated hydrochloric acid is	-NH_3 gas is evolved hence NH_4^+ ion confirmed present

given off on warming the test solution with sodium hydroxide solution.	
Explanation: Warming or heating of a solution containing NH_4^+ ion gives off ammonia gas. Equation: $NH_4^+{}_{(aq)} + OH^-{}_{(aq)} \longrightarrow H_2O_{(l)} + NH_{3(g)}$	
White precipitate, insoluble in excess aqueous sodium hydroxide solution	-Mg^{2+}, Ba^{2+} & Ca^{2+} ions are suspected present.
White precipitate, soluble in excess aqueous sodium hydroxide solution to form a colourless solution.	-**Al^{3+}, Zn^{2+}, Sn^{2+}, Sn^{4+} & Pb^{2+}** ions are suspected present.
Explanation: Amphoteric hydroxides dissolves in excess sodium hydroxide solution to form soluble complexes: Equations: $Al(OH)_{3(s)} + OH^-{}_{(aq)} \longrightarrow Al(OH)_4^-{}_{(aq)}$ $Zn(OH)_{2(s)} + 2OH^-{}_{(aq)} \longrightarrow Zn(OH)_4^{2-}{}_{(aq)}$ $Pb(OH)_{2(s)} + 2OH^-{}_{(aq)} \longrightarrow Pb(OH)_4^{2-}{}_{(aq)}$	
White precipitate, insoluble in excess sodium hydroxide solution which rapidly turns brown on standing.	-Mn^{2+}, Ag^{2+} ions are suspected present.
Blue precipitate insoluble in excess sodium hydroxide solution turns pink on standing.	-**Co^{2+}** ion is suspected present.
Blue precipitate insoluble in excess sodium hydroxide solution.	-**Cu^{2+}**ion is suspected present.
Grey-green precipitate, soluble in excess sodium hydroxide solution to form a green solution. Note: Green solution turns yellow on addition of hydrogen peroxide.	-**Cr^{3+}** ion is suspected present.
Green or pale green precipitate insoluble in excess sodium hydroxide solution.	-**Ni^{2+}** ion is suspected present.
Dirty green precipitate insoluble in excess sodium hydroxide solution, rapidly turns brown on standing.	-**Fe^{2+}** ion is suspected present. Aerial oxidation of **Fe^{2+}** to **Fe^{3+}** ion
Reddish brown precipitate insoluble in excess sodium hydroxide solution.	- **Fe^{3+}** ion is suspected present.

b) Addition of ammonia solution, $NH_4OH_{(aq)}$:

Ammonia solution is added drop wise until in excess to a test solution.
Observation must be made when little and excess reagent is added.
Note:
Evolution of ammonia gas on warming has no meaning. And its use to eliminate cations.
Examples:

Observations	**Conclusions**
No precipitate, Solution remains colourless.	**-NH_4^+**ion is suspected present.
No observable change occurs or No precipitate, Cloudy solution.	Probably **Ba^{2+}, Ca^{2+}** ions are suspected present.
White precipitate insoluble in excess ammonia solution.	**-Al^{3+}, Sn^{2+}, Mg^{2+}, Ba^{2+} & Pb^{2+}** ions are suspected present.
Green precipitate soluble in excess ammonia solution forming pale-blue solution	**-Ni^{2+}**ion is suspected present.
Dirty green precipitate insoluble in excess ammonia solution, slowly turns brown on standing	**-Fe^{2+}**ion is suspected present. Aerial oxidation of **Fe^{2+} to Fe^{3+}**ion
Reddish brown precipitate insoluble in excess ammonia solution.	**-Fe^{3+} ion**
Grey – green precipitate insoluble in excess dilute ammonia solution. Note: The precipitate dissolves in concentrated ammonia solution.	**-Cr^{3+}** ion is suspected present.
White precipitate soluble in excess ammonia solution forming a colourless solution.	**-Ag^{2+} & Zn^{2+}** ions are suspected present.
Explanation: Zinc (II) hydroxides dissolve in excess ammonia solution to form to form a soluble complex. Equation: $Zn(OH)_{2(s)} + 4NH_{3(aq)} \longrightarrow Zn(NH_3)_{4(aq)} + 2OH^-_{(aq)}$	
Dirty white precipitate insoluble in excess ammonia solution rapidly turns brown on standing	**-Mn^{2+}**ion

Blue precipitate, Insoluble in excess alkali, turns brown on standing. Or: Blue precipitate which dissolves in relatively concentrated ammonia solution, turns red on standing	**-Co^{2+} ion** are suspected present.
Blue precipitate soluble in excess ammonia solution forming a **deep blue** solution	**-Cu^{2+}**ion is suspected present.
Explanation: Copper (II) hydroxide dissolve in excess ammonia solution to form a soluble complex. Equation: $Cu(OH)_{2(s)} + 4NH_{3(aq)} \longrightarrow Cu(NH_3)_{4(aq)} + 2OH^-_{(aq)}$	

8. **SEPARATION OF MIXTURES USING SODIUM HYDROXIDE SOLUTION**:
   Some cations form hydroxides which dissolves in excess sodium hydroxide solution while others do not. Those which dissolves in excess sodium hydroxide solution form soluble complexes and are said to be amphoteric.
   Examples of amphoteric cations:

a) Tin (II), Sn^{2+} ion.
   Equations:

$$Sn^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Sn(OH)_{2(s)}$$
Little — White p.p.t

$$Sn(OH)_{2(s)} + 2OH^-_{(aq)} \rightleftharpoons Sn(OH)_4^-{}_{(s)}$$
Excess — Colourless solution

b) Zinc (II), Zn^{2+} ion.
   Equations:

$$Zn^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Zn(OH)_{2(s)}$$
Little — White p.p.t

$$Zn(OH)_{2(s)} + 2OH^-_{(aq)} \rightleftharpoons Zn(OH)_4^{2-}{}_{(aq)}$$
Excess — Colourless solution

c) Lead (II), Pb^{2+} ion.
   Equations:

$$Pb^{2+}_{(aq)} + 2OH^-_{(aq)} \longrightarrow Pb(OH)_{2(s)}$$
Little — White p.p.t

$$Pb(OH)_{2(s)} + 2OH^-_{(aq)} \rightleftharpoons Pb(OH)_4^{2-}{}_{(aq)}$$
Excess — Colourless solution

d) Aluminium (III), Al^{3+} ion.
   Equations:

$Al^{3+}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Al(OH)_{3(s)}$
Little — White p.p.t

$Al(OH)_{3(s)} + OH^-(aq) \rightleftharpoons Al(OH)_4^-{}_{(aq)}$
Excess — Colourless solution

Those cations which are insoluble in excess sodium hydroxide solution include:
Ba^{2+}, Ca^{2+}, Al^{3+}, Mg^{2+}, Ni^{2+}, Cu^{2+}, Mn^{2+}, Fe^{2+}, Co^{2+}, Fe^{3+},e.t.c.
To separate the soluble cations from insoluble cations, excess sodium hydroxide solution is added to the test solution, followed by filtration.
The residue will contain those cations which are insoluble in excess sodium hydroxide solution.
The filtrate will contain the cations which are soluble in sodium hydroxide solution.
Examples:
Zn^{2+}, Al^{3+}, Pb^{2+} & Sn^{2+}.

9. <u>MAKING THE SOLUTION JUST ACIDIC</u>:
This is usually done by adding a dilute acid e.g. nitric, hydrochloric acid to a solution obtained after treating the solution with sodium hydroxide solution during separation of amphoteric and non-amphoteric cations.
During addition of a dilute acid, a precipitate forms and when it dissolves, addition of the acid should be stopped.
At this stage the solution is said to be just acidic.
<u>Explanation</u>:
During the reaction of the amphoteric cation with sodium hydroxide solution, a precipitate forms which dissolves in excess reagent to form a soluble complex.
Equations:
$Al^{3+}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Al(OH)_{3(s)}$
Little — White p.p.t

$Al(OH)_{3(s)} + OH^-(aq) \rightleftharpoons Al(OH)_4^-{}_{(aq)}$
Excess — Colourless solution

When a dilute acid is added to the above equilibrium, the added acid (H^+) withdraws hydroxyl ions from the equilibrium mixture forming water.
i.e.:
$H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$
Removal of hydroxyl ions shifts the equilibrium from the right to left, hence leading to precipitation of aluminium hydroxide as a white precipitate.

When more acid is added, aluminium hydroxide (white precipitate) reacts with excess acid forming a soluble salt of aluminium (Al^{3+}).

i.e:

$$2Al(OH)_{3(s)} + 6H^{+}_{(aq)} \longrightarrow 2Al^{3+}_{(aq)} + 3H_2O_{(l)}$$

Similar reactions occur when the solution contains:

Zn^{2+}, Pb^{2+}, Sn^{2+}, e.t.c.

10. **WASHING THE RESIDUE WITH DISTILLED WATER AND TREATING WTH AN ACID:**

This is done by pouring water on the residue through the filter paper in a funnel several times. This removes any traces of the soluble cations which might be trapped in the residue.

The washed residue is then dried between filter papers and carefully transferred to a dry test tube.

A dilute acid is then added to the residue until there is no further change. The residue may dissolve with or without effervescence. If the residue dissolves with effervescence, it means a certain gas is evolved which must be identified using its confirmatory test e.g. Carbon dioxide gas from a carbonate, CO_3^{2-} ion or sulphur dioxide gas from a sulphide,SO_3^{2-}or thiosulphate,$S_2O_3^{2-}$ions.

Note the colour of the resultant solution and deduce the possible cations. if the residue dissolves without effervescence, then residue mostly likely contains a hydroxide or oxide.

11. **USE OF REAGENTS TO IDENTIFY ANIONS**:

Reagents used to identify anions include lead (II) nitrate, silver nitrate, magnesium sulphate, dilute acids, barium nitrate barium chloride, e.t.c.

The above reagents are usually used in small quantities(y) e.g. 2.3-drops of the reagent. Therefore there is no need of adding excess reagent.

e.g.

Add 2-3 drops of silver nitrate solution followed by dilute nitric acid.

Observation:

White precipitate insoluble in the acid indicates the presence of chloride, Cl^- ion.

12. **CARRYING OUT TESTS OF OWN CHOICE TO IDENTIFY CATIONS & ANIONS:**

This is done after having carried out several preliminary tests on a sample. Two or more differentiated using an appropriate reagent that will confirm only one ion.

It is advisable to first carry out tests for each of the ions suspected separately.

Then the test which comes out to be positive is written under the Test column with an appropriate observations and deductions.
Note:
When writing a test of own choice the following should be adhered to:

- ✓ Order of addition of reagents. If order is altered, then the test may not give the expected observation.
  Example:
  During identification of manganese (II) ions using concentrated nitric acid and solid sodium bismuthate, the acid is added first followed by solid sodium bismuthate.
- ✓ The physical state of reagent(s) i.e. it may be a solution, solid or liquid e.g. during identification of zinc,Zn^{2+} ion
  Ammonium chloride is used a solid, while disodium hydrogen phosphate and ammonia are used as solutions.
- ✓ Correct spellings of chemical names of the reagents and other technical terms. Any wrong spelling makes the whole reagent wrong.
  The spelling following chemical names and technical terms normally disturb candidates.

Correct spelling	Wrong spelling
Sooty	Shooty
Amine	Ammine
Dissolve	Dessolve
Tertiary	Tertially
Milky	Milk
Anhydrous	Unhydrous
Aromatic	Aromantic
Aliphatic	Alimphatic
Electrophilic	Electrophilic
Carboxylic	Carboxylic
Effervescence	Effavscence
Crystallisation	Crytalization
Dimethylglyoxime	Dimethylglycoxime
Sodium bismuthate	Sodium bimuthate
Ammoniacal silver nitrate	Ammonical silver nitrate
2,4-dinitrophenylhydrazine	2-4-dinitrophenyhydrazine
Potassium hexacyanoferrate (II) or (III)	Potassium hexaciynoferrate (II) or (III)
Disodium hydrogen phosphate	Disodium hydrogen phosphate

13. EFFECT OF OXIDIZING AGENTS AND REDUCING AGENTS:

When oxidizing and reducing agents are used, we must expect redox reactions. The following oxidizing agents are commonly used:

Chlorine water.	Iodine solution.
Bromine water.	Potassium iodate.
Hydrogen peroxide.	Manganese (IV) oxide.
Potassium manganate (VII).	Potassium dichromate (VI).
Concentrated nitric acid.	Concentrated sulphuric acid.

These oxidizing agents may cause a change in the colour of the substances due to the coloured ions being produced.

They may also oxidize intermediary products so that we have different products at the end.

The following reducing agents are commonly used:

Oxalate, $C_2O_4^{2-}$ ion.

Tin (II) chloride.

Sodium sulphite solution.

Sodium thiosulphate to reduce iodide ion in solution.

Iron (II) solution or Iron filings to reduce copper (II) ions in solution.

When reducing agents are used they get oxidized while they reduce the other reactants. This may result in a change of colours.

Note:

When oxidizing or reducing agents are used to form intermediate products during qualitative analysis, the cation or anion identified at the end of the tests should be the one originally present in the sample and not the one formed as an intermediates during a reaction.

Example:

When concentrated nitric acid is added to a solution containing iron (II) ion the green solution turns to yellow/brown implying that iron (II) ion have been oxidized to iron (III) ions.

The cation that should identified is Fe^{2+} not Fe^{3+} ion.

14. STATING OR IDENTIFYING IONS PRESENT IN A GIVEN SAMPLE:

Usually this the last skill tested for during qualitative analysis. The cations or anions should have been confirmed in particular tests during experiment.

- Don't state/identify more ions than those mentioned in the question.
- While identifying ions, make sure you use correct symbols of ions and /or formulae of ions with correct charges.
- Names of the ions with correct oxidation states may be used.
  Eg. Copper (II) ions.

CONFIRMATION TESTS FOR COMMON CATIONS:

Cations	Reagents	Observations
Ca^{2+}ion	To the solution, add solid Ammonium chloride followed by Disodium hydrogen phosphate solution.	White precipitate formed.
	To the solution, add ammonia solution followed by ammonium oxalate solution and then ethanoic acid.	White precipitate insoluble in ethanoic acid.
	To aqueous solution plus ammonium ethanedipate solution.	White precipitate is formed.
	To the solution, add ammonium carbonate solution.	A white precipitate is formed.
	To the solution, add ammonium chloride solution followed by potassium hexacyanoferrate (II) solution.	White precipitate is formed.
	To the solution, add 2-3 drops of dilute sulphuric acid.	White precipitate is formed.
Ba^{2+}ion	To the solution, add potassium chromate (VI) solution followed by dilute sodium hydroxide solution drop wise until in excess.	Yellow precipitate insoluble in dilute sodium hydroxide solution.
	To the solution, add ammonium oxalate (ethanedioate) solution followed by ethanoic acid	White precipitate, soluble in hot ethanoic acid
	To the solution, add 2-3 drops of dilute sulphuric acid	White precipitate is formed.
Zn^{2+} ion	To the solution, add aqueous ammonia drop wise until in excess.	White precipitate dissolves in excess to form to a colourless solution.
	To the solution, add solid ammonium chloride, followed 2-3 drops of Na_2HPO_4 and then ammonia solution until in excess.	White precipitate, soluble in ammonia solution.

	To the solution, add solid ammonium chloride (NH_4Cl) and then add aqueous ammonia until alkaline. Pass hydrogen sulphide through.	White precipitate is form.
Ni^{2+}ion	To the solution, add ammonia solution drop wise until in excess followed by 2-3 drops of Dimethyl glyoxime (butanedione dioxime) solution.	Red/pink precipitate is formed.
	To the solution, add potassium ferrocyanide solution followed by aqueous ammonia.	Green precipitate formed, dissolves in excess base to form a green solution.
Co^{2+} ion	To the solution, add potassium cyanide.	Brown precipitate is formed.
	To the solution, add potassium thiocyanate or ammonium thiocyanate.	A blue solution is formed.
	Heat borax on wire in Bunsen flame to get a colourless bead. Reheating with little solid.	A blue bead is formed.
	To the solution, add potassium nitrite solution	Yellow crystalline precipitate is formed.
Pb^{2+} ion	To the solution, add dilute hydrochloric acid solution and warm.	White precipitate formed, dissolves on warming. The precipitate reappears on cooling.
	To the solution, add potassium iodide solution.	Yellow precipitate is formed.
	To the solution, add potassium chromate (VI) solution followed by dilute sodium hydroxide solution drop wise until in excess.	Yellow precipitate which dissolves in excess in sodium hydroxide solution.
	To the solution, add 2-3 drops of dilute sulphuric acid or sodium sulphate solution	White precipitate is formed.

Mg^{2+}ion	To the solution, add solid ammonium chloride followed by 3-4 drops of disodium hydrogen phosphate (Na_2HPO_4) solution and then ammonia solution drop wise until in excess.	White precipitate insoluble in excess ammonia solution.
	To a slightly acidic solution, add 2 to 3 drops of magnesium and then add sodium hydroxide solution until alkaline.	A blue precipitate is formed.
	To the solution, add ammonium carbonate or sodium carbonate solution.	White precipitate is formed.
NH_4^+ion	To the solution, add dilute sodium hydroxide solution and warm or heat the mixture. Test the gas evolved using moist litmus paper or a glass rod dipped in concentrated hydrochloric acid.	No precipitate formed, On heating, colourless gas evolved, turns moist red litmus paper blue and forms a dense white fume with a glass rod dipped in concentrated hydrochloric acid.
Al^{3+}ion	To the solution, add alizarin solution followed by ammonia solution.	Pink solution (Pink lake) is formed.
	To the solution, add 2-3 drops of litmus paper solution followed by ammonia solution	Blue solution (Blue lake) is formed.
Mn^{2+}ion	To the solution, add concentrated nitric acid followed by solid sodium bismuthate.	A purple solution is solution is formed.
Equation: $2Mn^{2+}_{(aq)} + 5BiO_3^-{}_{(aq)} + 14H^+_{(aq)} \longrightarrow 2MnO_4^-{}_{(aq)} + 5Bi^{3+}_{(aq)} + 7H_2O_{(l)}$		
	To the solution, add a few drops of concentrated nitric acid followed by solid lead (IV) oxide and heat.	Purple solution is formed.
Equation: $2Mn^{2+}_{(aq)} + 5PbO_{2(s)} + 4H^+_{(aq)} \longrightarrow 2MnO_4^{2-}{}_{(aq)} + 5Pb^{2+}_{(aq)} + 2H_2O_{(l)}$		

Cr^{3+} ion	To the solution, add excess sodium hydroxide solution and few drops of hydrogen peroxide and boil the mixture. (do not heat please)	Yellow solution is formed.
	To the solution, add dilute sulphuric acid.	Deep blue solution is formed which fades, in a short time to leave a green solution.
	To the solution, add butan-1-ol and followed by dilute sulphuric acid.	Blue forms in organic layer.
	To the solution, add barium chloride or barium nitrate solution.	Yellow precipitate is formed.
	To the solution, add silver nitrate solution	Red precipitate is formed.
	To the solution, add lead (II) ethanoate or lead (II) nitrate solution.	Yellow precipitate is formed.
Cu^{2+}ion	To the solution, add aqueous ammonia solution drop wise until in excess.	Blue precipitate formed, dissolves in excess to form a deep blue solution.
	To the solution, add potassium iodide solution.	White precipitate in brown solution is formed
	To the solution, add potassium hexacyanoferrate (II) solution.	Chocolate-brown precipitate formed.
	To the solution, add ferrocynanide solution followed by ammonia solution.	A reddish-brown precipitate is formed.
Fe^{2+}ion	To the solution, add potassium hexacyanoferrate (III) solution	Dark /deep blue precipitate is formed.
	To the solution, add few drops of concentrated nitric acid and boil.	Green solution turns to yellow which forms a blood-red solution with potassium thiocynanide solution.

	To the solution, add potassium thiocynanide solution.	No observable change.
	To the solution, add potassium ferric cynanide solution.	A dark blue precipitate, Prussian blue.
Fe^{3+}ion	To the solution, add potassium hexacyanoferrate (II) solution.(Potassium ferro cyanide)	Dark/deep blue precipitate is formed.
	To the solution, add dilute sulphuric acid followed by zinc powder and heat	Green solution is formed.
	To the solution, add potassium or ammonium thiocyanate solution.	Deep blood-red solution is formed.

CONFIRMATORY TESTS FOR COMMON ANIONS:

Cations	Reagents	Observations
SO_4^{2-} ion	To the solution, add 2-3 drops of Barium nitrate solution followed by dilute Nitric acid.	White precipitate insoluble in the acid is formed.
	To the solution, add 2-3 drops of Barium chloride solution followed by dilute hydrochloric acid.	White precipitate insoluble in the acid is formed.
	To the solution, add 2-3 drops of either lead (II) ethanoate or nitrate solution and heat.	White precipitate insoluble on heating is formed.
SO_3^{2-} ion	To the solution, add dilute acid.	Effervescence of a colourless gas turns acidified potassium dichromate (VI) solution from orange to green.
	Equation: $SO_3^{2-}{}_{(aq)} + 2H^+{}_{(aq)} \longrightarrow H_2O_{(l)} + SO_{2(g)}$	
	To the solution, add barium nitrate solution or lead (II) nitrate/ethanoate solution followed by dilute nitric acid.	White precipitate soluble in the acid with effervescence of a colourless gas that turns

		acidified potassium dichromate (VI) solution from orange to green.
	Equations: $Ba^{2+}_{(aq)} + SO_3^{2-}_{(aq)} \longrightarrow BaSO_{3(s)}$ $Pb^{2+}_{(aq)} + SO_3^{2-}_{(aq)} \longrightarrow PbSO_{3(s)}$	
	To the solution, add acidified potassium manganate (VII) solution.	The purple colour of potassium manganate (VII) solution turns to colourless
	Equation: $2MnO_4^-{}_{(aq)} + 5SO_3^{2-}{}_{(aq)} + 6H^+_{(aq)} \longrightarrow 2Mn^{2+}_{(aq)} + 3H_2O_{(l)} + 5SO_4^{2-}{}_{(aq)}$	
	To the solution, add iodine solution.	Brown solution of iodine solution turns to colourless.
	Equation: $I_{2(aq)} + H_2O_{(l)} + SO_3^{2-}{}_{(aq)} \longrightarrow SO_4^{2-}{}_{(aq)} + 2H^+_{(aq)} + 2I^-_{(aq)}$	
CO_3^{2-} ions	To the solution, add dilute mineral acid (i.e. hydrochloric, nitric & sulphuric acid) in either solid or solution state.	Effervescence of a colourless gas that turns moist blue litmus paper red and lime water milky.
	To the solution, add barium nitrate/chloride solution or silver nitrate solution or lead (II) nitrate/ethanoate solution followed by dilute nitric acid.	White precipitate that dissolves in the acid with effervescence of a colourless gas that turns lime water milky.
	To the solution, add magnesium sulphate solution.	White precipitate is formed.
HCO_3^- ions	To the solution, add magnesium sulphate solution.	No precipitate is formed but on

		boiling, a white precipitate is formed.
	Boil a solution containing hydrogen carbonate.	White precipitate is formed and a colourless gas that turns lime water milky is given off.
NO_3^- ion	To the solution, add freshly prepared iron (II) sulphate solution followed by concentrated sulphuric acid which is carefully poured down the sides of the test tube.	Brown ring layer is formed at the interface of the two separate liquids.
<u>Equation</u>: $KNO_{3(aq)} + H_2SO_{4(aq)} \longrightarrow KHSO_{4(aq)} + HNO_{3(aq)}$ $6FeSO_{4(aq)} + 3H_2SO_{4(l)} + 2HNO_{3(aq)} \longrightarrow 3Fe_2(SO_4)_{3(aq)} + 4H_2O_{(l)} + 2NO_{(g)}$ $FeSO_{4(aq)} + NO_{(aq)} + 5H_2O_{(l)} \longrightarrow [Fe(NO)(H_2O)_5]SO_{4(aq)}$ or $[Fe(H_2O)_5(NO)]SO_{4(aq)}$ Or: $3Fe^{2+}_{(aq)} + NO_{(aq)} + 4H^+_{(aq)} \longrightarrow 3Fe^{3+}_{(aq)} + 2H_2O_{(l)} + NO_{(aq)}$ $[Fe(H_2O)_6]^{2+}_{(aq)} + NO_{(aq)} \longrightarrow [Fe(H_2O)_5(NO)]^{2+}_{(aq)} + H_2O_{(l)}$ Pentaaqua nitroso iron (II) sulphate		
	To the solution, add few copper turnings and followed by concentrated sulphuric acid, warm the mixture.	Brown fumes observed and blue solution is formed.
Cl^- ion	To the solution, add silver nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid is formed
	Note: White precipitate of silver chloride dissolves in ammonia solution to a colourless solution due formation of a soluble complex, diamine silver $Ag(NH_3)_2^+$ ions.	
	Add manganese (IV) oxide solid followed by concentrated sulpuric acid and warm.	Pale green is evolved, bleaches damp litmus paper.

	To the solution, add concentrated sulphuric acid to a solid of a chloride and warm.	Misty white fumes which turns moist blue litmus paper red and form white fumes with ammonia solution. The gas is hydrochloride chloride.
	To the solution, add lead (II) ethanoate or lead (II) nitrate solution followed by heating.	White precipitate is formed. Precipitate dissolves on warming and reappears on cooling.
$C_2O_4^{2-}$ ion Oxalates or Ethanedioates	To the solution, add acidified potassium permanganate solution and heat.	Purple solution of Potassium manganate (VII) solution turns to colourless with evolution of a colourless gas that turns lime water milky.
	Equation: $2MnO_4^-{}_{(aq)} + 5C_2O_4^{2-}{}_{(aq)} + 16H^+{}_{(aq)} \longrightarrow 2Mn^{2+}{}_{(aq)} + 10CO_{2(g)} + 8H_2O_{(l)}$	
	To the solution, add barium nitrate solution followed by strong acid e.g. Nitric acid	White precipitate which dissolves in the acid without effervescence.
	To the solution, add calcium chloride solution.	White precipitate of calcium oxalate which is insoluble in acetic acid.

CH_3COO^- ion Ethanoate ion	To the solution, add freshly prepared 2-3 drops of iron (III) chloride solution and heat.	Deep brown/brown precipitate is formed.
	To the solution, add $2cm^3$ of ethanol followed by concentrated sulphuric acid and warm the mixture.	Sweet fruity smell of an ester is given off. The smell becomes stronger when the mixture is diluted with water in a large container.
	To the solution, add dilute hydrochloric acid.	Solution formed, with a smell of vinegar.
	To the solid containing ethanoate ions, add few drops of concentrated sulphuric acid.	Colourless gas that turns blue litmus paper red, the gas has a sharp vinegar smell.
$S_2O_3^{2-}$ ion	To the solution, add lead (II) nitrate or lead (II) ethanoate solution. Warm the solution.	White precipitate soluble in excess and turns grey on warming.
	To the solution, add freshly prepared neutral iron (III) chloride solution.	Dark violet colouration which disappears after a short time leaving a colourless solution.
	To the solution, add silver nitrate solution.	White precipitate that turns brown.

	To the solution, add dilute mineral acid (E.g. Hydrochloric or sulphuric acid).	Effervescence of colourless gas that turns acidified potassium dichromate (VI) solution from orange to green and a yellow solid is deposited.
Nitrite, NO_2^- ion	To the solution, add acidified potassium manganate (VII) solution.	Purple colour turns to colourless.
	Equation: $2MnO_4^-{}_{(aq)} + 3NO_2^-{}_{(aq)} + 6H^+{}_{(aq)} \longrightarrow 2Mn^{2+}{}_{(aq)} + 5NO_3^-{}_{(aq)} + 3H_2O_{(l)}$ To the solution, add acidified potassium dichromate (VI) solution. Observation: Orange solution turns to green.	
	Equation: $Cr_2O_7^{2-}{}_{(aq)} + 3NO_2^-{}_{(aq)} + 8H^+{}_{(aq)} \longrightarrow 2Cr^{3+}{}_{(aq)} + 4H_2O_{(l)} + 3NO_3^-{}_{(aq)}$	
	To the solution, add bromine water.	Brown solution turns to colourless solution.
	Equation: $NO_2^-{}_{(aq)} + Br_{2(aq)} + H_2O_{(l)} \longrightarrow 2Br^-{}_{(aq)} + NO_3^-{}_{(aq)} + 2H^+{}_{(aq)}$	
	To the solution, add dilute sulphuric or hydrochloric acid and warm.	Brown fumes are given off.
	Equation: $NO_2^-{}_{(aq)} + H^+{}_{(aq)} \longrightarrow HNO_{2(aq)}$ This nitrous acid is unstable and decomposes to give nitrogen (II) oxide when warmed. The nitrogen (II) oxide readily combines with atmospheric oxygen to give nitrogen (IV) oxide (brown gas). Equation: $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$	

CrO_4^{2-} ion	To the solution, add lead (II) nitrate or acetate solution.	Yellow precipitate is formed.
	Equation: $Pb^{2+}_{(aq)} + CrO_4^{2-}_{(aq)} \longrightarrow PbCrO_{4(s)}$	
	To the solution, add silver nitrate solution.	Red precipitate is formed.
	Equation: $2Ag^{+}_{(aq)} + CrO_4^{2-}_{(aq)} \longrightarrow Ag_2CrO_{4(s)}$	
	To the solution, add 2-3 drops of hydrogen peroxide solution followed by dilute sulpuric acid.	An intense blue colouration is formed.
	To the solution, add barium nitrate or chloride solution.	Yellow precipitate is formed.
	Equation: $Ba^{2+}_{(aq)} + CrO_4^{2-}_{(aq)} \longrightarrow BaCrO_{4(s)}$	
$Cr_2O_7^{2-}$ ion	To the solution, add a few drops of dilute sodium hydroxide solution.	Orange solution turns to yellow solution.
	Equation: $Cr_2O_7^{2-}_{(aq)} + 2OH^{-}_{(aq)} \longrightarrow 2CrO_4^{2-}_{(aq)} + H_2O_{(l)}$	
PO_4^{3-} ion	To the solution, add barium nitrate/chloride solution followed by dilute hydrochloric or nitric acid.	White precipitate which dissolves in the acid without effervescence.
Br^-/I^- ion	To the solution, add silver nitrate solution followed by ammonia solution drop wise until in excess.	Pale-yellow precipitate insoluble in ammonia solution.
Br^- ion	To the solution, add lead (II) nitrate/ethanoate solution.	White crystalline precipitate is formed which slightly dissolves on warming.
	To the solution, add carbon tetrachloride or chloroform followed by chlorine water and shake the mixture.	Reddish-brown colour appears in the organic layer.

I^- ion	To the solution, add lead (II) nitrate/ethanoate solution.	Yellow precipitate is formed.
	To the solution, add chloroform followed by chlorine water.	Brown layer appears in the organic layer.
	To the solution, add concentrated sulphuric acid followed by sodium thiosulphate solution.	Colourless solution turns to brown and to colourless on adding sodium thiosulphate solution
O_2^{2-} ion	To the solution, add dilute mineral acid.	Colourless gas that relights a glowing splint.
	Equation: $2O_2^{2-}{}_{(aq)} + 4H^+_{(aq)} \longrightarrow 2H_2O_{(l)} + O_{2(g)}$	
OCl^- ion To the solution, add dilute hydrochloric or nitric acid to a solid. Equation: $2OCl^-_{(s)} + 4H^+_{(aq)} \longrightarrow 2H_2O_{(l)} + Cl_{2(g)}$		Greenish-yellow gas with a pungent smell. The gas turns moist blue litmus paper red & then bleaches it.

15. ADDITION OF DILUTE HYDROCHLORIC ACID:

Add little of the acid to test tube containing the solution. Observe any changes and then add the reagent in excess. If there is no reaction, warm gently and identify any gas evolved.

Observations	Deductions
(i). Effervescence occurs and a colourless evolved, turns damp litmus red & lime water milky. Solid dissolves to form a coloured/colourless solution.	Carbon dioxide gas from CO_3^{2-} or HCO_3^- ion insoluble salt dissolves in acid to form a soluble salt. Probably NO_3^-,SO_4^{2-} OR Cl^- of white soluble salt, (If solution is colourless is formed)
(ii). Colourless gas with pungent smell Turns damp litmus paper red and acidified dichromate paper green.	SO_2 gas from SO_3^{2-}. SO_2 gas produced reduces $Cr_2O_3^{2-}$ to Cr^{3+} ion

(iii). White precipitate is formed. Precipitate dissolves on warming/boiling and solid recrystallizes on cooling.	Precipitate of lead (II) chloride, which dissolves in hot water. Hence Pb^{2+} ion present.
(iv). Colorless vapour with faint vinegar smell forms a brown precipitate with neutral iron (III) chloride solution.	Ethanoic acid vapour from an ethanoate (CH_3COO^-) ion

16.<u>ADDITION OF SODIUM CARBONATE SOLUTION</u>.

Addition of little of the sodium carbonate solution to the test tube containing the solution precipitates the insoluble carbonate, hydroxide or oxide.

Observations	Deductions
(i). No gas is evolved. White precipitate is formed.	Pb^{2+},Zn^{2+},Ca^{2+},Ba^{2+} or Mg^{2+} metal CO_3^{2-}
(ii). White precipitate, accompanied by effervescence. A colourless, odourless gas evolved, turns damp litmus red paper red and lime water milky.	$Al(OH)_3$ precipitate. Carbonate is unstable to produce carbon dioxide gas Hence Al^{3+} ion is present.
(iii). Pale blue precipitate is formed. Precipitate darkens on heating and turns black.	Cu^{2+} ion suspected, $CuCO_3$ is precipitated and decomposes on heating to black, CuO.
(iv). Brown prepicitate,accompanied by effervescence of a colourless odourless gas evolved, turns damp litmus paper red and lime water milky.	$Fe(OH)_3$ precipitated. Carbon dioxide gas evolved from CO_3^{2-} ion. Hence Fe^{3+} ion present.
(v). Dark green precipitate is formed, turns brown on standing.	$Fe(OH)_2$ is precipitate,Fe^{2+} ion turns brown due to aerial oxidation to Fe^{3+} ion.

<u>PRACTICAL PRESENTATTION:</u>

<u>Experiment 1 P is a mixture of $(NH_4)_2SO_4$ & $MnCO_3$</u>:

You are provided with substance **P**. Which contains two cations and two anions. You are required to identify the cation and anion in **P**. Carry out the tests below and record your observations and conclusion in the spaces provided. Where a gas is evolved, it should be identified.

Tests	Observations	Deductions
(a). Heat a spatula end full of **P** in a hard glass tube first gently and	<u>Dirty green white</u> crystalline, substance gives <u>colourless liquid</u>,	Probably **P** is <u>non-transition</u> salt.

then strongly until there is no further change.	which turns copper (II) sulphate blue, White sublimate on the cooler parts of the boiling tube. Colourless gas turns wet litmus paper slightly red and lime water milky, Colourless gas also turns wet red litmus paper blue and forms misty fumes with rod dipped in conconcentrated acid. Residue is white.	Water of crystallization from a hydrated non transition salt. Acidic gas, CO_2 gas from CO_3^{2-}/HCO_3^-ions. CO_3^{2-} is confirmed present. Ammonia gas from NH_4^+ salt. Residue is probably an oxide of Mn^{2+}, Mg^{2+} ion.
(b). To about one spatula end full of **P**, add 5cm^3 of water and filter. Keep filtrate and residue. Divide in to 4 parts.	**P** partially dissolves in water to form a colourless filtrate and a white residue.	Filtrate probably contains: Zn^{2+},Al^{3+},Or Pb^{2+} Residue probably contains: CO_3^{2-} of Pb^{2+},Al^{3+}, or Zn^{2+} ions
(i). To the first portion, add dilute sodium hydroxide solution drop wise until in excess and heat.	No precipitate is formed. Solution remains colourless. On heating,colourless gas given off turns wet litmus paper blue and forms misty fumes with a rod dipped in concentrated hydrochloric acid.	Ammonia gas from NH_4^+ salt hence NH_4^+ ion confirmed.
(ii). To the second portion, add dilute ammonia solution drop wise until in excess.	No precipitate formed, solution remains colourless	NH_4^+ ion present
(iii). To the third portion, add dilute acid followed by 2-3 drops of barium nitrate solution.	White precipitate is formed.	SO_4^{2-}ion. Confirmed present.

(c). Wash the residue and dissolve it in dilute nitric acid. Divide the resultant solution in to 3 parts.	Effervescence occurs and a colourless gas evolved, turns wet litmus paper slightly red and lime water milky. Residue dissolves in dilute nitric acid to form a pale pink solution.	Acidic gas, CO_2 gas from CO_3^{2-} ion. A soluble nitrate of Mn^{2+} or Co^{2+} salt
(i). To the first part, add dilute sodium hydroxide solution drop wise until in excess.	Dirty white precipitate, insoluble in excess. Precipitate rapidly turns brown.	Mn^{2+}ion Suspected present.
(ii). To the second part, add dilute ammonia solution drop wise until in excess.	Dirty white Precipitate, insoluble in excess. Precipitate turns brown on standing.	Mn^{2+}ion Suspected present.
(iii). To the third part, carry out a test of your choice to confirm the cation in the residue. **Tests:** To the last part, concentrated nitric acid was added followed by solid sodium bismuthate.	A purple colouration was observed.	Mn^{2+} is oxidized to MnO_4^- ion. Hence Mn^{2+} ion confirmed present.

Identify the:

i. Cations present in compound **P**.
   NH_4^+ ion is confirmed in b (i).
   Mn^{2+} ion is confirmed in c (iii).
ii. Anions present in compound **P**.
   SO_4^{2-}ion is confirmed in b (iii).
   CO_3^{2-} ion is confirmed in (a).

Experiment 2, X is a mixture of $BaCl_2$ & $PbCO_3$:

You are provided with substance **X** which contains two cations and two anions. You are required to carry out the following tests on **X** to identify the cations and anions in **X**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions

(a).Heat a spatula end-ful of **X** in a dry test tube.	Colourless liquid/condensate that turns anhydrous copper (II) sulphate blue. Colourless gas that turns moist blue litmus paper red & lime water milky. Reddish-brown/Orange residue when hot & yellow when cold.	Water of crystallization ∴hydrate/hydrated salt. Carbon dioxide is given off.∴CO_3^{2-}, $C_2O_4^{2-}$ & HCO_3^- are suspected present. PbO is formed. ∴Pb^{2+} salt is suspected present.
(b).Shake two spatula end-ful of **X** with about 5cm^3 of water and filter. Keep both the filtrate and residue. Divide the filtrate in to six portions.	White residue. Colourless filtrate.	Al^{3+}, Zn^{2+}, Ca^{2+} & Mg^{2+} ions are suspected present. Pb^{2+}, Ca^{2+}, Ba^{2+}, Sn^{2+} & Sn^{4+} ions are probably suspected present in both filtrate and residue.
b.(i).To the 1st portion of the filtrate, add dilute sodium hydroxide solution drop-wise until in excess.	White precipitate insoluble in excess.	Ca^{2+}, Mg^{2+} & Ba^{2+} ions are suspected present.
b.(ii).To the 2nd portion of the filtrate, add ammonia solution drop-wise until in excess.	White precipitate insoluble in excess.	Mg^{2+} & Ba^{2+} ions are suspected present.
b.(iii).To the 3rd portion of the filtrate, add 2-3 drops of dilute sulphuric acid.	White precipitate.	Ba^{2+} ion is suspected present.
b.(iv).To the 4th portion of the filtrate, add 2-3 drops of potassium chromate (VI) solution and then add dilute sodium hydroxide solution drop-wise until in excess & allow the mixture to stand.	Yellow precipitate insoluble in excess sodium hydroxide solution.	Ba^{2+} ion is confirmed present.

b.(v).To the 5th portion of the filtrate, add 2-3 drops of lead (II) nitrate solution, heat and allow to stand.	White precipitate dissolves on heating & reappears on cooling.	Cl^- ion is suspected present.
b.(vi).Use the 6th portion of the filtrate to carry out a test of your choice to confirm one of the anions present in **X**. **Test:** To the 6th portion of the filtrate, add silver nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid.	Cl^- ion is confirmed present.
c. Wash the residue with water, transfer to a test tube & add dilute nitric acid drop-wise to dissolve the residue. Divide the solution in to five parts.	Effervescence of colourless gas that turns moist blue litmus red/pink & lime water milky. Colourless solution formed.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Non-transitional metal ions,Ie.Pb^{2+}, Zn^{2+}, Ba^{2+},Ca^{2+},Mg^{2+} & Al^{3+} ions are suspected present.
c.(i).To the 1st part of the solution, add dilute sodium hydroxide solution until in excess.	White precipitate soluble in excess to form a colourless solution.	Al^{3+}, Pb^{2+}, Zn^{2+}, Sn^{2+} & Sn^{4+} ions are suspected present.
c.(ii).To the 2nd part of the solution, add dilute ammonia solution until in excess.	White precipitate insoluble in excess.	Al^{3+} & Pb^{2+} ions are suspected present.
c.(iii).To the 3rd part of the solution, add 2-3 drops of dilute sulphuric acid.	White precipitate.	Pb^{2+} ion is suspected present.
c.(iv).To the 4th part of the solution, add 2-3	Yellow precipitate soluble in excess sodium	Pb^{2+} ion is suspected present.

drops of potassium chromate (VI) solution and then add dilute sodium hydroxide solution drop wise until in excess.	hydroxide solution to give a yellow solution.	
c.(v).Use the 5th part of the solution to carry out a test of your own choice to confirm one of the cations in **X**. **Test**: To the 5th part of the solution, add potassium iodide solution.	Yellow precipitate.	Pb^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **X**.
   Ba^{2+} ion is confirmed in b (iv).
   Pb^{2+} ion is confirmed in c (v).
ii. Anions present in compound **X**.
   Cl^- ion is confirmed in b (vi).
   CO_3^{2-} ion is confirmed in c.

Experiment 3, Y is a mixture of $(CH_3COO)_2Ni$ & $CuCO_3$:

You are provided with substance **Y** which contains two cations and two anions. You are required to carry out the following tests on **Y** to identify the cations and anions in **Y**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat one spatula end-ful of **Y** in a dry test tube.	**Y** is a green solid. Colourless liquid/condensate that turns anhydrous copper (II) sulphate blue. Colourless gas that turns moist blue litmus paper red & lime water milky.	Transitional metal ions, Cr^{3+}, Ni^{2+}, Cu^{2+} & Fe^{2+} ions are suspected present. Water is given off. ∴hydrated salt. Carbon dioxide gas is given off.

	Colourless vapour with a sweet smell and forms a yellow precipitate with Braddy's reagent. Black residue is formed.	$\therefore CO_3^{2-}$, $C_2O_4^{2-}$ & HCO_3^- ions are suspected present. Propanone vapour is given off. $\therefore CH_3COO^-$ ion is suspected present. CuO, FeO & NiO salts are suspected present
(b).To one spatula end-ful of **Y** in a dry test tube,add 2-3 drops of concentrated sulphuric acid and warm it gently.	Effervescence of colourless gas that turns moist blue litmus paper red & has a sharp vinegar smell.	Acetic acid vapour is given off. $\therefore CH_3COO^-$ ion is suspected present.
(c).put two spatula end-ful of **Y** in a test tube, add about $5cm^3$ of distilled water, shake well & filter. Keep both the filtrate and residue	Green filtrate & residue.	Fe^{2+}, Ni^{2+}, Cu^{2+} & Cr^{3+} ions are suspected both in the residue & filtrate.
(d).Divide the filtrate in to four portions. d. (i). To the 1st portion of the filtrate, add 5 drops of neutral iron (III) chloride solution & heat gently to boiling.	Reddish-brown solution, forms a brown precipitate on boiling.	$\therefore CH_3COO^-$ ion is confirmed present.
d.(ii).To the 2nd portion of the filtrate, add dilute sodium hydroxide solution drop-wise until in excess. Heat the mixture.	Green precipitate insoluble in excess. No observable change on heating occurs.	Ni^{2+} ion is suspected present. Rej; Fe^{2+} ion b'se $Fe(OH)_2$ decompose on heating.
d.(iii).To the 3rd portion of the filtrate, add ammonia solution drop-wise until in excess.	Green precipitate soluble in excess forming a pale-blue solution.	Ni^{2+} ion is suspected present.
d.(iv).Use the 4th portion of the filtrate to carry		

out a test of your own choice to confirm one of the cations in **Y**. **Test**: To the 4th portion of the filtrate, add dilute ammonia solution drop-wise until in excess followed by 2-3 drops of dimethylglyoxime solution.	Red precipitate. Rej: pink precipitate.	Ni^{2+} ion is confirmed present.
(e).Wash the residue with a little distilled water. Transfer in to a test tube and dissolve in dilute hydrochloric acid & divide the solution in to three portions.	Dissolve with effervescence of colourless gas that turned moist blue litmus paper red & lime water milky. Green solution is formed.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Fe^{2+}, Cu^{2+}, Ni^{2+} & Cr^{3+} ions are suspected present.
e.(i).To the 1st portion of the filtrate, add dilute sodium hydroxide solution drop-wise until in excess & heat the mixture,	Blue precipitate insoluble in excess, turned black on heating.	CuO is formed. $\therefore Cu^{2+}$ ion is suspected present.
e.(ii).To the 2nd portion of the filtrate, add ammonia solution drop-wise until in excess.	Blue precipitate soluble in excess to form a deep-blue solution.	Cu^{2+} ion is suspected present.
e.(iii).Use the 3rd portion of the solution to carry out a test of your own choice to confirm of the cations in **Y**. **Test**: To the 3rd portion of the solution, add 2-3 drops of potassium	Brown precipitate	Cu^{2+} ion is confirmed present.

hexacyanoferrate (II) solution. Or: Add 2 drops of potassium iodide solution.	White precipitate in a brown solution.	

Identify the:

i. Cations present in compound **Y**.
   Ni^{2+} ion is confirmed in d (iv).
   Cu^{2+} ion is confirmed in e (iii).
ii. Anions present in compound **Y**.
   CH_3COO^- ion is confirmed in d (i).
   CO_3^{2-} ion is confirmed in e.

Experiment 4, Z is a mixture of $BaCl_2$ & $ZnCO_3$:

You are provided with substance **Z** which contains two cations and two anions. You are required to carry out the following tests on **Z** to identify the cations and anions in **Z**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat strongly one spatula end-ful of **Z** in a dry test tube.	Colourless liquid/condensate that turns anhydrous copper (II) sulphate blue. Colourless gas that turns moist blue litmus paper red & lime water milky. White powder turns to yellow residue-hot & white-cooling	Water of crystallization is given off. ∴hydrated salt is present Carbon dioxide gas is given off. ∴CO_3^{2-}, C_2O_4 & HCO_3^- are suspected present. Non-transitional metal ions, Zn^{2+}, Ba^{2+}, Ca^{2+}& Al^{3+} ions are suspected present. ZnO is formed.
(b).To one spatula end-ful of **Z** in a test-tube, add 2-3 drops of concentrated sulphuric acid.	Effervescence, Misty fumes with a chocking smell, turned moist blue litmus paper red and forms dense white fumes with ammonia solution.	Hydrogen chloride gas is given off. ∴Cl^- ion is suspected present.

(c).To two spatula end ful of Z in a test tube, add about 5cm^3 of distilled water, shake vigorously and filter. Keep both the residue and filtrate.	Colourless filtrate. & White residue.	Al^{3+}, Zn^{2+}, Pb^{2+}, Ca^{2+}, Ba^{2+} & Mg^{2+} ions are suspected present in both filtrate & residue.
(d).Divide the filtrate in to six portions. d.(i).To the 1st portion of the filtrate, add dilute sodium hydroxide solution drop-wise until in excess.	White precipitate insoluble in excess.	Mg^{2+}, Ca^{2+} & Ba^{2+} ions are suspected present.
d.(ii).To the 2nd portion of the filtrate, add dilute ammonia solution.	White precipitate insoluble in excess.	Mg^{2+}& Ba^{2+} ions are suspected present.
d.(iii).To the 3rd portion of the filtrate, add a spatula end-ful of solid ammonium chloride followed by 3-4 drops of disodium hydrogen phosphate solution & the add ammonia solution drop-wise until in excess.	White precipitate insoluble in excess ammonia solution.	Mg^{2+}& Ba^{2+} ions are suspected present.
d.(iv).To the 4th portion of the filtrate, add 2-3 drops of potassium chromate (VI) solution followed by dilute sodium hydroxide solution drop wise until in excess.	Yellow precipitate insoluble in excess sodium hydroxide solution.	Ba^{2+} ion is confirmed present.
d.(v).To the 5th portion of the filtrate, add 2-3 drops of lead (II) nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid.	Cl^- & SO_4^{2-} ions are suspected present.

d.(vi).Use the 6th portion of the filtrate to carry out a test of your own choice to confirm one of the anions in **Z**. **Test**: To the 6th portion of the filtrate, add 3 drops of silver nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid.	Cl^- ion is confirmed present.
(e).Wash the residue with distilled water, transfer the residue in to a test tube & dissolve in dilute nitric acid & then divide the solution in to three portions.	Effervescence of colourless gas that turns moist blue litmus paper red & lime water milky. Colourless solution is formed.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Al^{3+}, Ca^{2+}, Zn^{2+}, Pb^{2+} & Mg^{2+} ions are suspected present.
e.(i).To the 1st portion of the solution, add dilute sodium hydroxide solution drop wise until in excess.	White precipitate soluble in excess to form a colourless solution.	Zn^{2+}, Pb^{2+} & Al^{3+} ions are suspected present.
e.(ii).To the 2nd portion of the solution, add dilute ammonia solution drop-wise until in excess.	White precipitate soluble in excess to form colourless solution.	Zn^{2+} ion is suspected present.
e.(iii).Use the 3rd portion of the solution to carry out a test of your own choice to confirm one of the cations in the solution in **Z**. **Test**: To the 3rd portion of the solution, add a spatula end-ful of solid ammoniu		Zn^{2+} ion is confirmed present.

chloride followed by 4 drops of disodium hydrogen phosphate solution & then add ammonia solution drop-wise until in excess.	White precipitate soluble in aqueous ammonia solution.	

Identify the:

i. Cations present in compound **Z**.
   Ba^{2+} ion is confirmed in d (iv).
   Zn^{2+} ion is confirmed in e (iii).
ii. Anions present in compound **Z**.
   Cl^- ion is confirmed in d (vi).
   CO_3^{2-} ion is confirmed in e.

Experiment 5, W is a mixture of $MnSO_4$ & $CuCO_3$:

You are provided with substance **W** which contains two cations and two anions. You are required to carry out the following tests on **W** to identify the cations and anions in **W**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat one spatula end-ful of **W** strongly in a dry test tube.	Colourless liquid that turns anhydrous copper (II) sulphate blue. Colourless gas that turns moist blue litmus paper red & limet water milky. Black residue remains.	Water of crystallization. ∴hydrated salt present. Carbon dioxide gas is given off. ∴CO_3^{2-}, $C_2O_4^{2-}$ & HCO_3^- ions are suspected present. CuO,FeO & NiO are suspected present.
(b).To two spatula end-fuls of **W** in a test tube, add about 5cm^3 of water, shake & filter. Keep both the filtrate & residue. Divide the filtrate in to five parts.	Colourless filtrate. & Green residue.	Pb^{2+}, Zn^{2+}, Ba^{2+}, Ca^{2+}, Mg^{2+} & Al^{3+} ions are suspected present. Cu^{2+}, Fe^{2+}, Ni^{2+} & Cr^{3+} ions are suspected present.
b.(i).To the 1st part of the filtrate, add dilute sodium hydroxide	White precipitate insoluble in excess, turns brown on standing.	Mn^{2+} ion is suspected present.

solution drop-wise until in excess.		
b.(ii).To the 2nd part of the filtrate, add dilute ammonia solution drop-wise until in excess.	White precipitate insoluble in excess, turns brown on standing.	Mn^{2+} ion is suspected present.
b.(iii).Use the 3rd part of the filtrate to carry out a test of your own choice to confirm one of the cation present in **W**. **Test**: To the 3rd part of the filtrate, add concentrated nitric acid followed by solid sodium bismuthate.	Purple solution.	Mn^{2+} ion is confirmed present.
b.(iv).To the 4th part of the filtrate, add 2-3 drops of lead (II) nitrate solution.	White precipitate.	SO_4^{2-}, CO_3^{2-}, SO_3^{2-} & Cl^- ions are suspected present.
b.(v).Use the 5th part of the filtrate to carry out a test of your own choice to confirm one of the anions present in **W**. **Test**: To the 5th part of the filtrate, add barium nitrate solution followed by dilute nitric acid. Or Add barium chloride followed by dilute hydrochloric acid.	White precipitate insoluble in the acid.	SO_4^{2-} ion is confirmed present.
(c).Wash the residue with distilled water & dissolve in in dilute hydrochloric acid &	Effervescence of colourless gas that turns moist blue litmus red & lime water milky.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present.

divide the solution in to four parts.	Blue solution. Green solution.	Cu^{2+} & Cu^{2+}, Ni^{2+}, Fe^{2+} & Cr^{3+} ions are suspected present
c.(i).To the 1st part of the solution, add dilute sodium hydroxide solution drop-wise until in excess.	Pale-blue precipitate insoluble in excess.	Cu^{2+} ion is suspected present.
c.(ii).To the 2nd part of the solution, add dilute ammonia solution drop-wise until in excess.	Blue precipitate soluble in excess ammonia solution forming a deep-blue solution.	Cu^{2+} ion is suspected present.
c.(iii).To the 3rd part of the solution, add 2-3 drops of potassium thiocyanate solution.	Greenish-brown solution. Accept: Green solution or Greenish black.	Cu^{2+} ion is suspected present.
c.(iv).Use the 4th part of the solution to carry out a test of your own choice to identify one of the cations in **W**. Test: To the 2nd part of the solution, add 3 drops of potassium iodide solution. Or: Add 3 drops of potassium hexacyanoferrate(II) solution	White precipitate & brown solution. Dark-brown precipitate.	Cu^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **W**.
   Mn^{2+} ion is confirmed in b (iii).
   Cu^{2+} ion is confirmed in c (iv).
ii. Anions present in compound **W**.
   SO_4^{2-} ion is confirmed in b (v).
   CO_3^{2-} ion is confirmed in c.

Experiment 6, V is a mixture of $CuSO_4$-5-H_2O & $(NH_4)_2SO_4$:

You are provided with substance **V** which contains three cations and two anions. You are required to carry out the following tests on **V** to identify the cations and anions in **V**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat a spatula end-ful of **V** in a dry test tube until there is no further change.	Melts to form a blue solution. Colourless liquid that turns anhydrouse copper (II) sulphate blue. White fumes that turns moist blue litmus paper red & acidified $K_2Cr_2O_7$ solution from orange to green. White sublimate forms on a cooler part of the test tube. White-black solid.	Water of crystallization. ∴hydrate salt is present. Sulphur dioxide gas is given off. ∴SO_3^{2-} & SO_4^{2-} ions are suspected present. CuO is formed.
(b).Shake two spatula end-fuls of **V** with about $3cm^3$ of distilled water. Add sodium hydroxide solution to the mixture drop-wise until in excess. Warm & filter. Keep both the filtrate & residue.	Blue solution. Blue precipitate turns black on heating. Colourless gas that turns moist red litmus paper blue & forms dense white fumes with concentrated hydrochloric acid. Colourless filtrate. Black residue.	Cu^{2+} ion is suspected present. Ammonia gas is given off. ∴NH_4^+ ion is suspected present. Rej:If conc.HCl isn't used. Pb^{2+}, Zn^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+} ions are suspected present. CuO is formed.
(c).To the filtrate, add dilute nitric acid drop-wise until the solution is just acidic. Divide the solution in to six portions.	White precipitate soluble in excess forming a colourless solution.	Al^{3+}, Pb^{2+}, Zn^{2+}, Sn^{2+} & Sn^{4+} ions are suspected present.

c. (i).To the 1st part of acidic solution, add dilute sodium hydroxide solution drop-wise until in excess.	White precipitate soluble in excess to give a colourless solution. Colourless gas which turns moist red litmus paper blue & forms white fumes with concentrated hydrochloric acid.	Al^{3+}, Pb^{2+}, Zn^{2+}, Sn^{2+} & Sn^{4+} ions are suspected present. Ammonia gas is given off. $\therefore NH_4^+$ ion is confirmed present.
c. (ii).To the 2nd part of the acidified solution, add dilute ammonia solution drop-wise until in excess.	White precipitate insoluble in excess.	Al^{3+}, Pb^{2+}, Sn^{2+} & Sn^{4+} ions are suspected present.
c. (iii).To the 3rd part of the acidic solution, add 2-3 drops of potassium iodide solution.	No observable change occurs. Or No yellow precipitate.	Pb^{2+} ion is absent. Rej:Al^{3+} ion present
c. (iv).To the 4th part of the acidified solution, add 2-3 drops of litmus solution followed by ammonia solution drop-wise until in excess.	Blue precipitate soluble forming a blue solution. Or Blue lake.	Al^{3+} ion confirmed present.
c.(v).To the 5th part of the acidified solution, add 2-3 drops of lead (II) ethanoate solution.	White precipitate.	SO_4^{2-} & Cl^- ions are suspected present. CO_3^{2-} & SO_3^{2-} are rejected b'se the solution was acidic.
c. (vi).Use the 6th part of the acidified solution to carry out a test of your own choice to confirm one of the anion in **V**. Test: To the 6th part of the acidified solution, add 3 drops of barium nitrate	White precipitate.	SO_4^{2-} ion is confirmed present.

solution/barium chloride solution. Note: No need of adding the acid b'se the solution was acidic.		
(d).Wash the residue with distilled water & dissolve it in dilute hydrochloric acid. Divide the solution in to three parts.	Residue dissolves to give a blue solution. Accept: Green solution.	Cu^{2+} ion is suspected present. Ni^{2+}, Cu^{2+}, Fe^{2+} & Cr^{3+} ions are suspected present.
d. (i).To the 1st part of the acidic solution, add dilute sodium hydroxide solution drop-wise until in excess.	Blue precipitate insoluble in excess.	Cu^{2+} ion is suspected present.
d. (ii). To the 1st part of the acidic solution, add dilute ammonium hydroxide solution drop-wise until in excess.	Blue precipitate soluble in excess forming a deep-blue solution.	Cu^{2+} ion is suspected present.
d. (iii). To the 1st part of the acidic solution, add 2-3 drops of potassium hexacyanoferrate (II) solution.	Brown precipitate. Accept; Maroon precipitate.	Cu^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **V**.
   Al^{3+} ion is confirmed in c (iv).
   Cu^{2+} ion is confirmed in d (iii).
   NH_4^+ ion is confirmed in c (i).
ii. Anions present in compound **V**.
   SO_4^{2-} ion is confirmed in c (vi).

Experiment 7, U is a mixture of $NiCO_3$ & $FeSO_4.7H_2O$:

You are provided with substance **U** which contains three cations and two anions. You are required to carry out the following tests on **U** to identify the cations and anions in **U**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions

(a).Heat one spatula end-ful of **U** in a dry test tube.	Colourless liquid /condensate that turns anhydrous copper (II) sulphate blue. Colourless gas that turns moist blue litmus paper red & lime water milky. White fumes that turns acidified potassium dichromate (VI) solution from orange to green. Green solid turns black/brown residue.	Hydrate salt/water of crystallization is present. Carbon dioxide gas is given off. $\therefore CO_3^{2-}$, $C_2O_4^{2-}$, HCO_3^- & CH_3COO^- ions are suspected present. Sulphur dioxide gas is given off. $\therefore SO_4^{2-}$, SO_3^{2-} ions are suspected present. CuO & FeO or Fe_2O_3 (For brown solid)
(b).To two spatula end-fuls of **U**, add about $5cm^3$ of water. Shake vigorously and filter. Divide the filtrate in to five parts. Keep the residue.	Green filtrate. Green residue.	Transitional metal ions, Fe^{2+}, Cu^{2+}, Ni^{2+} & Cr^{3+} ions are suspected in both filtrate and residue.
b. (i).To the 1st part of the filtrate, add dilute sodium hydroxide solution drop-wise until in excess.	Green precipitate insoluble in excess.	Ni^{2+} & Fe^{2+} ions are suspected present.
b.(ii).To the 2nd part of the filtrate, add dilute ammonia solution drop-wise until in excess.	Green precipitate insoluble in excess, turns brown	Fe^{2+} ion is suspected present.
b.(iii).To the 3rd part of the filtrate, add 3-4 drops of concentrated nitric acid followed by 2-3 drops of potassium thiocyanate solution.	Green solution turns yellow then blood-red on addition of $KSCN_{(aq)}$.	Fe^{2+} ion is oxidized to Fe^{3+} ion. $\therefore Fe^{2+}$ ion is confirmed present.

b.(iv).To the 4th part of the filtrate, add 2-3 drops of lead (II) nitrate solution. Heat and allow the mixture to cool.	White precipitate insoluble on heating.	Cl- ion is absent. $\therefore SO_3^{2-}$ & SO_4^{2-} ions are suspected present.
b.(v).Use the 5th part of the filtrate to carry out a test of your own choice to confirm one of the anions in **U**. **Test**: To the 5th part of the filtrate, add barium nitrate followed by dilute nitric acid. Or $BaCl_2$/HCl	White precipitate insoluble in the acid.	SO_4^{2-} ion is confirmed present.
(c).Wash the residue with distilled water and dissolve it in dilute hydrochloric acid & divide the resultant solution in to three parts.	Effervescence/ bubbles. Colourless gas that turns moist blue litmus paper red & lime water milky. Green solution is formed.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Cr^{3+}, Fe^{2+}, Cu^{2+}, Ni^{2+} are suspected present.
c.(i).To the 1st part of the solution, add dilute sodium hydroxide solution drop-wise until in excess.	Green precipitate insoluble in excess.	Ni^{2+}& Fe^{2+} ions are suspected present.
c. (ii).To the 2nd part of the solution, add dilute ammonium hydroxide solution drop-wise until in excess.	Green precipitate soluble in excess to a form a pale-blue solution.	Ni^{2+} ion is suspected present.
c.(iii).Use the 3rd part of the solution, add carry out a test of your own choice to confirm one of the cations in **U**.		

Test: To the 3rd part of the solution, add aqueous ammonia solution until the solution is alkaline, then add 2 drops of dimethylglyoxime solution.	Red precipitate.	Ni^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **U**.
   Ni^{2+} ion confirmed in c (iii).
   Fe^{2+} ion is confirmed in b (iii).
ii. Anions present in compound **U**.
   SO_4^{2-} ion is confirmed in b (v).
   CO_3^{2-} ion is confirmed in c.

Experiment 8, T is a mixture of $(CH_3COO)_2Ni$ & Al_2SO_4:

You are provided with substance **T** which contains two cations and two anions. You are required to carry out the following tests on **T** to identify the cations and anions in **T**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat two spatula end-fuls of **T** strongly in a dry test tube.	Colourless condensate/liquid that turns anhydrous copper (II) sulphate blue. Colourless gas that turns moist blue litmus paper red & acidified potassium dichromate (VI) solution from orange to green. Colourless gas with sweet smell & forms yellow ppt with Brady's reagent. Colourless gas that turns lime water milky.	Water is given off. ∴ Hydrated salt is present. Sulphur dioxide gas is given off. $\therefore SO_3^{2-}$, & SO_4^{2-} ions are suspected present. Propanone is given off. $\therefore CH_3COO^-$ ion is suspected present. Carbon dioxide gas is given off. $\therefore CO_3^{2-}$, $C_2O_4^{2-}$ & HCO_3^- ions are suspected present.

	Green solid turns to black residue.	NiO, CuO & FeO salts are present.
(b).To two spatula end-fuls of T in a dry test tube, add 5 drops of concentrated sulphuric acid and warm.	Colourless that turns moist blue litmus red & has a sharp vinegar smell.	Gas is ethanoic acid vapour. $\therefore CH_3COO^-$ ion is suspected present.
(c).Dissolves three spatula endfuls of **T** in about $5cm^3$ of distilled water to make a solution	Dissolves to give a green solution.	Cr^{3+}, Ni^{2+}, Fe^{2+} & Cu^{2+} ions are suspected present.
c.(i).Use $1cm^3$ of the solution of **T** to carry out a test of your own choice to confirm one of the anions in **T**. Test: To the solution of **T**, add 3 drops of iron (III) chloride solution and heat. Or: Add a few drops of concentrated sulphuric acid followed by ethanol and heat.	Reddish-brown solution forms a brown precipitate. Sweet fruity smell.	CH_3COO^- ion is confirmed present.
c.(ii).To the remaining solution of T, add dilute sodium hydroxide solution drop-wise until there is no further change. Filter & keep both the filtrate and residue.	Green precipitate insoluble in excess. Colourless filtrate. Green residue.	Ni^{2+} & Fe^{2+} ions are suspected present. Rej: Cu^{2+} & Cr^{3+} ions. Al^{3+}, Zn^{2+}, Pb^{2+}, Sn^{2+} & Sn^{4+} ions are suspected present. Rej: Ca^{2+} & Ba^{2+} ions.

		Ni^{2+} & Fe^{2+} ions are suspected present. Rej: Cu^{2+} & Cr^{3+} ions.
(d).Add dilute hydrochloric acid drop-wise to the filtrate until the solution is just acidic. Divide the solution in to four portions.	White precipitate soluble in dilute hydrochloric acid to form a colourless solution.	Al^{3+}, Zn^{2+} & Sn^{2+} ions are suspected present. Rej: Pb^{2+} ion, b'se it forms a white ppt with $HCl_{(aq)}$.
d.(i).To the 1st portion of the acidified filtrate, add dilute sodium hydroxide solution drop-wise until in excess.	White precipitate soluble in dilute hydrochloric acid to form a colourless solution.	Al^{3+}, Zn^{2+} & Sn^{2+} ions are suspected present. Rej: Pb^{2+} ion, b'se it forms a white ppt with $HCl_{(aq)}$.
d.(ii).To the 2nd portion of the acidified filtrate, add potassium iodide solution.	No observable change occurs.	Pb^{2+} ion is absent.
d.(iii).To 3rd portion of the acidified filtrate, add 5 drops of litmus solution followed by dilute ammonia solution drop wise until in excess.	Blue solution/blue lake.	Al^{3+} ion is confirmed present.
d.(iv).To the 4th portion of the acidified filtrate, add 5 drops of barium bitrate solution.	White precipitate.	SO_4^{2-} ion is confirmed present.
(e).Wash the residue with distilled water and dissolve in dilute hydrochloric acid & divide the acidic solution in to three portions.	Dissolves to give a green solution.	Ni^{2+} & Fe^{2+} ions are suspected present.
e.(i).To the 1st portion of the acidic solution, add dilute sodium hydroxide	Green precipitate insoluble in excess.	Ni^{2+} & Fe^{2+} ions are suspected present.

solution drop-wise until in excess.		
e.(ii).To the 2nd portion of the acidic solution, add dilute ammonia solution drop-wise until in excess.	Green precipitate dissolves to give a light blue solution.	Ni^{2+} ion is suspected present.
e.(iii).Use the 3rd portion of the acidic solution to carry out a test of your own choice to confirm one of the cations in **T**. Test: To the 3rd portion of the acidic solution, add dilute ammonia solution drop-wise until in excess and follow by 3 drops of dimethylglyoxide solution.	Red precipitate	Ni^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **T**.
   Al^{3+} ion is confirmed in d (iii).
   Ni^{2+} ion confirmed in e (iii).
ii. Anions present in compound **T**.
   CH_3COO^- ion is confirmed in c (i).
   SO_4^{2-} ion is confirmed in d (iv).

Experiment 9, S is a mixture of $MnCl_2$ & $PbCO_3$:

You are provided with substance **S** which contains two cations and two anions. You are required to carry out the following tests on **S** to identify the cations and anions in **S**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat one spatula end-fuls of **S** strongly in a dry test tube until there is no further change.	Colourless liquid/condensate that turns anhydrous copper (II) sulphate blue. Colourless that turns moist blue litmus paper red & lime water milky.	Water is given off. ∴hydrated salt is present. Carbon dioxide gas is given off.

	Reddish-brown residue –hot & yellow-cold.	∴CO_3^{2-}, $C_2O_4^{2-}$, & HCO_3^- ions are suspected present. PbO is formed.
(b).To a spatula end-fuls of **S**, add 2-3 drops of concentrated sulphuric acid and warm.	Effervescence, Misty fumes which turns moist blue litmus red and forms white fumes with concentrated ammonia solution.	Hydrogen chloride gas is given off. ∴Cl^- ion is suspected present.
(c).To two spatula end-fuls of **S**, add dilute nitric acid until there is no further change then add dilute sodium hydroxide solution drop-wise until in excess. Filter & keep the filtrate & residue.	Effervescence/bubbles of a colourless gas that turns moist blue litmus paper red & lime water milky. White precipitate insoluble in excess, turns brown. Colourless filtrate & Brown residue.	Carbon dioxide gas is given off. ∴CO_3^{2-} ion is confirmed present. Mn2+ ion is suspected present. Pb^{2+}, Zn^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+}- ions are suspected present. Rej: Ca^{2+}, Ba^{2+} & Mg^{2+} ions. Mn^{2+} ion is suspected present.
(d).To the filtrate add dilute nitric acid until the solution is just acidic. The divide the resultant solution in to four parts.	White precipitate soluble in the acid to form a colourless solution.	Pb^{2+}, Zn^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+}- ions are suspected present.
d.(i).To the 1st part of the acidic solution, add dilute sodium hydroxide solution drop-wise until in excess.	White precipitate soluble in the acid to form a colourless solution.	Pb^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+}- ions are suspected present.
d.(ii).To the 2nd part of the acidic solution, add aqueous ammonia drop-wise until in excess	White precipitate insoluble in excess.	Pb^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+}- ions are suspected present.

d.(iii).To the 3rd part of the acidic solution, add dilute sulphuric acid.	White precipitate.	Pb^{2+} ion is suspected present.
d.(iv).Use the 4th part of the acidic solution to carry out a test of your own choice to confirm of the cations in **S**. Test: To the 4th of the acidic solution, add 2-3 drops of potassium iodide solution. Or: Add potassium chromate (VI) solution followed by sodium hydroxide solution drop-wise until in excess.	Yellow precipitate. Yellow precipitate soluble to form a yellow solution.	Pb^{2+} ion is confirmed present.
(e).To two spatula end-fuls of S, add about $5cm^3$ of water, shake & filter. Divide the filtrate in to five parts.	Colourless filtrate. & White residue.	Non-transitional metal ions, Al^{3+},Zn^{2+},Pb^{2+},Ba^{2+}, Ca^{2+} & Mg^{2+} ions are suspected present in both filtrate & residue.
e.(i).To the 1st part of the filtrate, add sodium hydroxide solution drop-wise until in excess.	White precipitate insoluble in excess turns to brown.	Mn^{2+} ion is suspected present. Note Award no mark if insoluble is not mentioned.
e.(ii).To the 2nd part of the filtrate, add aqueous ammonia solution drop-wise until in excess.	White precipitate insoluble in excess turns to brown.	Mn^{2+} ion is suspected present.
e.(iii).Use the 3rd part of the filtrate to carry out a test of your own choice		

to confirm one of the cations in **S**. **Test**: To the 3rd part of the filtrate, add concentrated nitric acid followed by solid sodium bismuthate. Or: Add concentrated nitric acid & PbO_2 & heat.	Purple solution. Rej: Sodium bismuthate solution. — Insist on order of reagents. —Insist on heating.	Mn^{2+} ion is confirmed present.
e.(iv).To 4th part of the filtrate, add 2-3 drops of lead (II) nitrate solution and heat.	White precipitate soluble on heating.	Cl- ion is suspected present.
e.(v).Use the 3rd part of the filtrate to carry out a test of your own choice to confirm one of the cations in **S**. **Test**: To the 3rd part of the filtrate, add silver nitrate solution followed by dilute nitric acid.	White precipitate insoluble on heating.	Cl- ion is confirmed present.

Identify the:

i. Cations present in compound **S**.
   Pb^{2+} ion confirmed in d (iv).
   Mn^{2+} ion is confirmed in e (iii).
ii. Anions present in compound **S**.
   CO_3^{2-} ion is confirmed in c.
   Cl^- ion is confirmed in e (v).

Experiment 10, R is a mixture of BaO, $ZnCO_3$ & KI or $BaCO_3$, ZnO & KI:

You are provided with substance **R** which contains two cations and two anions. You are required to carry out the following tests on **R** to identify the cations and anions in **R**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions

(a).Heat two spatula end-fuls of **R** strongly in a dry test tube.	Colourless gas that turns moist blue red & lime water milky. Yellow residue-hot & white –cold.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$, C_2O_4 & HCO_3^- ions are suspected present. ZnO is formed.
(b).To three spatula end-ful of **R**, add dilute nitric drop-wise until no further change & warm.	Dissolves with bubbles/effervescence of colourless of a colourless gas that turns moist blue litmus red & lime water milky. Colourless solution.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Ca^{2+}, Ba^{2+} & Mg^{2+} ions are suspected present.
(c).To the solution from (b) above, add dilute sodium hydroxide solution drop-wise until in excess. Filter the mixture. Keep both the filtrate & residue.	White precipitate insoluble in excess. White residue. Colourless filtrate	Ca^{2+}, Ba^{2+} & Mg^{2+} ions are suspected present. Al^{3+}, Zn^{2+}, Pb^{2+}, Sn^{2+} & Sn^{4+} ions are suspected present.
(d).To the filtrate, add dilute nitric acid until the solution is just acidic & divide the acidic solution in to six parts.	White precipitate soluble forming colourless solution.	Al^{3+}, Zn^{2+}, Pb^{2+}, Sn^{2+} & Sn^{4+} ions are suspected present.
d.(i). To the 1st part of the acidified solution, add 2-3 drops of silver nitrate solution followed by dilute ammonia solution drop-wise until in excess.	Pale-yellow precipitate insoluble in ammonia solution.	Br^- & I^- ions are suspected present.
d.(ii). To the 2nd part of the acidified filtrate, add	Colourless solution turns brown & then turns to	I_2 vapour is given off.

6 drops of concentrated sulphuric acid & warm then to the mixture, add sodium thiosulphate solution.	colourless on adding $Na_2S_2O_{3(aq0}$	$\therefore I^-$ ion is suspected present.
d.(iii).To the 3rd part of the acidified filtrate, add 2-3 drops of lead (II) nitrate solution.	Yellow precipitate.	I^- ion is confirmed present.
d.(iv).To the 4th part of the acidified filtrate, add dilute sodium hydroxide solution drop- wise until in excess.	White precipiate soluble in excess forming colourless solution.	Al^{3+}, Zn^{2+}, Pb^{2+}, Sn^{2+} & Sn^{4+} ions are suspected present.
d.(v). To the 5th part of the acidic filtrate, add dilute ammonia solution drop-wise until in excess	White precipiate soluble in excess forming colourless solution.	Zn^{2+}ion is suspected present.
d.(vi). To the 6th part of the acidic filtrate, add a spatula end-ful of ammonium chloride solution followed by 3-4 drops of disodium hydrogen phosphate followed by drop-wise addition of aqueous ammonia solution until in excess.	White precipitate soluble in ammonia solution forming a colourless solution.	Zn^{2+}ion is confirmed present.
(e).Wash the residue with distilled water & dissolve in dilute hydrochloric acid & divide the solution in to three parts.	Dissolves forming colourless solution.	Ba^{2+}, Ca^{2+} & Mg^{2+} ions are suspected present.
e.(i).To the 1st part of the acidic solution, add dilute sodium hydroxide	White precipitate insoluble in excess.	Ba^{2+}, Ca^{2+} & Mg^{2+} ions are suspected present.

solution drop-wise until in excess.		
e.(ii).To the 2nd part of the acidic solution, add dilute ammonia solution drop-wise until in excess	White precipitate insoluble in excess.	Ba^{2+} & Mg^{2+} ions are suspected present.
e.(iii).To the 3rd part of the acidic solution, add 2-3 drops of potassium chromate (VI) solution.	Yellow precipitate.	Ba^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **S**.
   Zn^{2+} ion confirmed in d (vi).
   Ba^{2+} ion is confirmed in e (iii).
ii. Anions present in compound **S**.
   CO_3^{2-} ion is confirmed in b.
   I^- ion is confirmed in d (iii).

Experiment 11, Q is a mixture of $CuCO_3$ & $(NH_4)_2FeSO_4$ (Ammonium ferric sulphate:

You are provided with substance **Q** which contains three cations and two anions. You are required to carry out the following tests on **Q** to identify the cations and anions in **Q**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat one spatula end-ful of **Q** strongly in a dry test tube until no further change.	Colourless liquid/condensate that turns anhydrous copper (II) sulphate blue. Colourless that turns moist blue litmus paper red & lime water milky. Colourless gas that turns moist red litmus paper blue & forms white fumes with concentrated hydrochloric acid. White sublimate. Green solid decomposes to leave black residue.	Water is given off. ∴hydrate salt is suspected present. Carbon dioxide gas is given off. ∴CO_3^{2-} , $C_2O_4^{2-}$ & HCO_3^- ions are suspected present. Ammonia gas is given off ∴NH_4^+ ion is suspected present. FeO, NiO & CuO are formed.

(b).Put two spatula end-fuls of **Q** in a test tube. Add about $6cm^3$ of distilled water & shake well, Allow the mixture to stand for 5 minutes with occasional shaking, filter. Keep both the filtrate & residue & divide the filtrate in to five parts.	Dissolves with effervescence of colourless gas that turns moist blue litmus red & lime water milky. Green filtrate. Brown residue.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Cu^{2+}, Fe^{2+}, Ni^{2+} & Cr^{3+} ions are suspected present. Fe^{3+} ion is suspected present.
b.(i).To the 1st part of the filtrate, add dilute sodium hydroxide solution drop-wise until in excess, heat the mixture.	Blue precipitate insoluble in excess, turns black on heating. Colourless gas turns moist red litmus paper blue & forms white fumes with concentrated hydrochloric acid.	Cu^{2+} ion is suspected present. $\therefore$CuO is formed. Ammonia gas is given off. $\therefore NH_4^+$ ion is confirmed present.
b.(ii).To the 2nd part of the filtrate, add dilute ammonia solution drop-wise until in excess.	Blue precipitate soluble in excess to form a deep-blue solution.	Cu^{2+} ion is suspected present.
b.(iii).To the 3rd part of the filtrate, add a few drops of potassium hexacyanoferrate (II) solution.	Dark-brown precipitate.	Cu^{2+} ion is confirmed present.
b.(iv).To the 4th part of the filtrate, add 3 drops of lead (II) nitrate solution and heat.	White precipitate insoluble on heating.	Cl^- ion is absent. But: SO_4^{2-} & SO_3^{2-} ions are suspected present.
b.(v).Use the 5th part of the filtrate to carry out a test of your own to confirm one of the anions present in **Q**. Test:		

To the 5th part of the filtrate, add 3 drops of barium nitrate solution followed by dilute nitric acid. Or: Add barium chloride followed by dilute hydrochloric acid.	White precipitate insoluble in the acid.	SO_4^{2-} ion is confirmed present.
(c).Wash the residue with distilled water. Heat a small portion of the residue strongly	Brown solid is formed.	Fe_2O_3 formed hence: Fe^{3+} ion is suspected present.
(d).Transfer the rest of the residue in to a test tube & dissolve it in dilute hydrochloric acid hence divide the solution in to three parts.	Dissolves to give a yellow solution.	Fe^{3+} ion is suspected present.
d.(i).To the 1st part of the solution, add dilute sodium hydroxide solution drop wise until in excess.	Reddish-brown precipitate insoluble in excess.	Fe^{3+} ion is suspected present.
d.(ii).To 2nd part of the solution, add dilute ammonia solution drop wise until in excess.	Reddish-brown precipitate insoluble in excess.	Fe^{3+} ion is suspected present.
d.(iii).To 3rd part of the solution, add 2-3 drops of potassium thiocyanate solution	Deep-red solution. Or Blood-red solution.	Fe^{3+} ion is confirmed present.

Identify the:

i. Cations present in compound **Q**.
   NH_4^+ ion confirmed in b (i).
   Cu^{2+} ion is confirmed in b (iii).
   Fe^{3+} ion is confirmed in d (iii).
ii. Anions present in compound **Q**.
   CO_3^{2-} ion is confirmed in b.

SO_4^{2-} ion is confirmed in b (v).

Experiment 12, I is a mixture of $NiCO_3$ & $CrCl_3.6H_2O$:

You are provided with substance **I** which contains two cations and two anions. You are required to carry out the following tests on **I** to identify the cations and anions in **I**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat two spatula end-fuls of **I** strongly in a dry test tube.	Colourless condensate that turns anhydrous copper (II) sulphate blue Colourless gas that turns moist blue litmus paper red & lime water milky. Green solid turns to black residue.	Water is given off. ∴hydrated salt is present Carbon dioxide gas is given off. ∴CO_3^{2-}, $C_2O_4^{2-}$, & HCO_3^- ions are suspected present. CuO, NiO & FeO are formed. ∴Ni^{2+}, Cu^{2+}, & Fe^{2+} ions are suspected present.
(b).To two spatula end-fuls of **I**, add about $5cm^3$ of distilled water, shake vigorously & filter. Keep both the filtrate & residue then divide the filtrate in four parts.	Green filtrate. & Green residue.	Ni^{2+}, Fe^{2+}, Cu^{2+} & Cr^{3+} ions are suspected present in both filtrate & residue.
b.(i).To the 1st part of the filtrate, add dilute sodium hydroxide solution drop-wise until in excess.	Grey-green precipitate soluble forming a green solution.	Cr^{3+} ion is suspected present.
b.(ii).To the 2nd part of the filtrate, add dilute ammonia solution drop-wise until in excess.	Grey-green precipitate insoluble forming a green solution.	Cr^{3+} ion is suspected present.
b.(iii).To the 3rd part of the filtrate, add dilute sodium hydroxide solution drop wise until in excess followed by 2-3	Grey-green precipitate soluble forming a green solution & on boiling, green solution turns to yellow.	CrO_4^{2-} ion is formed. ∴Cr^{3+} ion is suspected present.

drops of hydrogen peroxide, boil the mixture & divide it in to two parts.		
b.(i).To the 1st part of the solution, add 2-3 drops of lead (II) ethanoate solution. Allow it to cool.	Yellow precipitate.	$PbCrO_4$ is formed. $\therefore Cr^{3+}$ ion is suspected present.
b.(ii).To the 2nd part of the solution, add about 1cm3 of butan-1-ol followed by dilute sulphuric acid.	Blue colour in butan-1-ol layer.	Cr^{3+} ion is confirmed present.
(iii).To the 3rd part of the filtrate, add 3-4 drops of lead (II) ethanoate solution.	White precipitate.	Cl^-, SO_3^{2-}, SO_4^{2-} & CO_3^{2-} ions are suspected present.
(iv).Use the 4th part of the filtrate to carry out a test of your own choice to confirm one of anions in I. Test: To the 4th part of the filtrate, add 3 drops of silver nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid.	Cl^- ion is confirmed present.
(c).Wash the residue with distilled water & dissolve it in 2M sulphuric acid & divide the solution in to three parts.	Effervescence of colourless gas that turns moist blue litmus paper red & lime water milky. Green solution is formed.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Ni^{2+}, Cr^{3+}, Fe^{2+} & Cu^{2+} ions are present.
c.(i).To the 1st part of the solution, add dilute sodium hydroxide	Green precipitate insoluble in excess.	Ni^{2+} & Fe^{2+} ions are suspected present.

solution drop-wise until in excess.		
c.(ii).To the 2nd part of the solution, add dilute ammonia solution drop wise until in excess.	Green precipitate dissolves forming a pale blue solution.	Ni^{2+} ion is suspected present.
c.(iii).Use the 3rd part of the solution to carry out a test of your own choice to confirm one of the cations in **I**. Test: To the 3rd part of the solution, add excess ammonia solution followed by dimethylglyoxime solution.	Red precipitate	Ni^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **I**.
   Cr^{3+} ion confirmed in b (ii).
   Ni^{2+} ion is confirmed in c (iii).
ii. Anions present in compound **I**.
   Cl^- ion is confirmed in b (iv).
   CO_3^{2-} ion is confirmed in c.

Experiment 13, N is a mixture of $CoCl_2.6H_2O$ & $CuCO_3$:

You are provided with substance **N** which contains two cations and two anions. You are required to carry out the following tests on **N** to identify the cations and anions in **N**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat a spatula end-ful of **N** in a dry test tube strongly.	Colourless gas that turns moist blue litmus paper red & lime water milky. Colourless liquid that turns anhydrous copper (II) sulphate blue.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$, $C_2O_4^{2-}$, & HCO_3^- ions are suspected present. Water of crystallization. $\therefore$hydrated salt is present

	Colourless gas with pungent smell that turns moist blue litmus paper red & forms a dense white fumes with ammonia solution. Green-red solid that turns to black.	Hydrogen chloride gas is given off. $\therefore Cl^-$ ion is suspected present. CuO, NiO & FeO are formed.
(b).Put two spatula end-fuls of **N** in a test tube, add about $6cm^3$ of distilled water & shake vigorously then filter. Divide the filtrate in to five parts.	Pink filtrate. & Green residue.	Co^{2+} & Mn^{2+} ions are suspected present. Cu^{2+}, Ni^{2+}, Fe^{2+} & Cr^{3+} ions are suspected present.
b.(i).To the 1st part of the filtrate, add dilute sodium hydroxide solution drop wise until in excess.	Blue precipitate insoluble in excess turns to pink.	Co^{2+}ion is suspected present.
b.(ii).To the 2nd part of the filtrate, add dilute ammonia solution drop wise until in excess.	Blue precipitate soluble in excess giving red solution.	Co^{2+}ion is suspected present.
b.(iii).To the 3rd part of the filtrate, add concentrated (saturated) solution of potassium thiocyanate.	Blue solution is formed.	Co^{2+}ion is confirmed present.
b.(iv).To the 4th part of the filtrate, add 2-3 drops of lead (II) nitrate solution.	White precipitate is formed.	SO_4^{2-}, CO_3^{2-}, SO_3^{2-} & Cl^- ions are suspected present.
b.(v).Use the 5th part of the filtrate to carry out a test of your own choice		

to confirm one of the anions present in **N**. Test: To the 5th part of the filtrate, add silver nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid.	Cl^- ion is confirmed present.
(c).Wash the residue & transfer it in to a test tube. Add dilute hydrochloric acid until there is no further change & divide the solution in to four parts.	Effervescence of colourless gas that turns moist blue litmus paper red & lime water milky. Green solution.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Ni^{2+}, Cu^{2+}, Fe^{2+} & Cr^{3+} ions are present.
c.(i).To the 1st part of the solution, add dilute sodium hydroxide solution drop wise until in excess.	Blue precipitate insoluble in excess.	Cu^{2+} ion is suspected present.
c.(ii).To the 2nd part of the solution, add aqueous ammonia solution drop wise until in excess.	Blue precipitate soluble in excess forming deep-blue solution.	Cu^{2+} ion is suspected present.
c.(iii).To the 3rd part of the solution, add a few drops of potassium iodide solution.	White precipitate and brown solution is formed.	Cu^{2+} ion is suspected present.
c.(iv).To the 4th part of the solution, add potassium hexacyanoferrate (II) solution.	Dark-brown precipitate.	Cu^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **N**.
   Co^{2+} ion confirmed in b (iii).
   Cu^{2+} ion is confirmed in c (iv).
ii. Anions present in compound **N**.
   Cl^- ion is confirmed in b (iv).

CO_3^{2-} ion is confirmed in c.

Experiment 14, M is a mixture of $MgCO_3$ & $Na_2C_2O_4$:

You are provided with substance **M** which contains one cations and two anions. You are required to carry out the following tests on **M** to identify the cations and anions in **M**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat two spatula end-fuls of **M** strongly in a dry test tube.	Colourless gas that turns moist blue litmus paper red & lime water milky. White residue.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$, $C_2O_4^{2-}$ & HCO_3^- ions are suspected present. MgO, CaO & BaO are formed.
(b).To two spatula end-fuls of **M** in a test tube, add about 6cm^3 of distilled water, shake vigorously & filter. Keep both the filtrate & residue. Divide the filtrate in three portions.	Colourless filtrate. & White residue.	Al^{3+}, Mg^{2+}, Ba^{2+},Mg^{2+}, Ca^{2+} & Pb^{2+} ions are suspected present in both filtrate & residue.
b.(i).To the 1st part of the filtrate, add 2-3 drops of barium nitrate solution followed by dilute nitric acid.	White precipitate dissolves giving colourless solution.	SO_3^{2-} , SO_4^{2-} & $C_2O_4^{2-}$ ions are suspected present.
b.(ii).To the 2nd part of the filtrate, add 2-3 drops of silver nitrate solution followed by dilute nitric acid.	White precipitate dissolves giving colourless solution.	$C_2O_4^{2-}$ ion is suspected present.
b.(iii).To the 3rd part of the filtrate, add 2-3 drops of acidified potassium manganate (VII) solution & heat.	Purple colour turns to colourless. Colourless gas that turns moist blue litmus paper red & lime water milky.	Carbon dioxide gas is given off. $\therefore C_2O_4^{2-}$ ion is confirmed present.
(c).Dissolve the residue in dilute nitric acid &	Dissolves with effervescence of colourless gas that turns	Carbon dioxide gas is given off.

divide the solution in to four portions.	moist blue litmus paper red & lime water milky.	$\therefore CO_3^{2-}$ ion is confirmed present.
c.(i).To the 1st part of the solution, add dilute sodium hydroxide solution drop wise until in excess.	White precipitate insoluble in excess.	Mg^{2+}, Ba^{2+} & Ca^{2+} ions are suspected present.
c.(ii).To the 2nd part of the solution, add dilute ammonia solution drop wise until in excess.	White precipitate insoluble in excess.	Mg^{2+}& Ba^{2+} ions are suspected present.
c.(iii).To the 3rd part of the solution, add 2-3 drops of potassium chromate (VI) solution.	No observable change occurs. Or No yellow precipitate.	Ba^{2+} ion is absent.
c.(iv).To the 4th part of the solution, add a spatula end-ful of solid ammonium chloride followed by disodium hydrogen phosphate & then aqueous ammonia solution drop wise until in excess.	White precipitate insoluble in excess.	Mg^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **M**.
   Mg^{2-} ion is confirmed in c (iv).
ii. Anions present in compound **M.**
   $C_2O_4^{2-}$ ion confirmed in b (iii).
   $C0_3^{2-}$ ion is confirmed in c.

Experiment 15, L is a mixture of $ZnSO_3$ & $(NH_4)_2Cr_2O_7$:

You are provided with substance **L** which contains two cations and two anions. You are required to carry out the following tests on **L** to identify the cations and anions in **L.** Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat two spatula end-fuls of **L** in a dry test tube.	Colourless gas that turns moist red litmus paper blue & forms white	Ammonia gas is given off $\therefore NH_4^+$ ion is suspected present.

	fumes with concentrated hydrochloric acid. Green residue. Colourless gas that turns moist blue litmus paper red & $H^+/K_2Cr_2O_{7(aq)}$ from orange to green.	CrO_3 is formed. Sulphur dioxide gas is given off. $\therefore SO_3^{2-}$ & SO_4^{2-} ions are suspected present.
(b).To two spatula end-fuls of **L**, add about $7cm^3$ of distilled water shake well & filter. Keep both the filtrate and residue. Divide the filtrate in two parts.	Orange filtrate. & White residue.	$Cr_2O_7^{2-}$ ion is suspected present. Ca^{2+}, Ba^{2+}, Mg^{2+}, Pb^{2+}, & Al^{3+} ions are suspected present.
b.(i). To the 1st part of the filtrate, add dilute sulphuric acid followed by ethanol & warm.	Orange solution turns to green.	$Cr_2O_7^{2-}$ ion is reduced to Cr^{3+} ion.
b.(ii).To the 2nd part of the filtrate, add excess dilute sodium hydroxide solution & heat, allow to cool & to a little of this solution, add a few drops of silver nitrate solution.	Red precipitate. Colourless gas that turns moist red litmus paper blue & forms a dense white fumes with concentrated hydrochloric acid.	$AgCrO_4$ salt is formed. $\therefore Cr_2O_7^{2-}$ ion is confirmed present. Ammonia gas is given off NH_4^+ ion is confirmed present.
(c).Dissolves the residue in about $5cm^3$ of dilute hydrochloric acid & divide the solution in to two parts.	Effervescence of colourless gas with pungent smell, gas that turns moist blue litmus paper red & acidified $K_2Cr_2O_{7(aq)}$ from orange to green.	Sulphur dioxide gas is given off. $\therefore SO_4^{2-}$ ion is confirmed present.
c.(i).To the 1st of the solution, add dilute sodium hydroxide solution drop wise until in excess.	White precipitate soluble in excess forming a colourless solution.	Zn^{2+},Pb^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+} ions are suspected present.

c.(ii).To the 2nd part of the solution, add aqueous ammonia solution drop wise until in excess.	White precipitate soluble in excess forming a colourless solution.	Zn^{2+}ion is suspected present.
c.(iii).To the 3rd part of the solution, add a spatula end-ful of solid ammonium chloride followed by 3-4 drops of disodium hydrogen phosphate & then ammonia solution drop wise until in excess.	White precipitate soluble in excess forming a colourless solution.	Zn^{2+}ion is confirmed present.

Identify the:

i. Cations present in compound **L**.
   NH_4^+ ion is confirmed in b (ii).
   Zn^{2+} ion is confirmed in c (iii).
ii. Anions present in compound **L**.
   $C_2O_4^{2-}$ ion confirmed in b (ii).
   SO_4^{2-} ion is confirmed in c.

Experiment 16, K is a mixture of $FeBr_3$ & $CaCO_3$:

You are provided with substance **K** which contains two cations and two anions. You are required to carry out the following tests on **K** to identify the cations and anions in **K**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat a spatula end-ful of **K** in a dry test tube.	Colourless gas that turns moist blue litmus red & lime water. Purple (brown) vapour is given off. Brown residue.	Carbon dioxide is given off. $\therefore CO_3^{2-}$ ion is suspected present. I_2 & Br_2 vapour are evolved. I^- & Br^- ions are suspected present. Fe_2O_3 are formed.
(b).To spatula end-fuls of **K**, add about $6cm^3$ of distilled water shake &	Yellowish-brown filtrate. &	Fe^{3+} & CrO_4^{2-} ions are suspected present.

filter. Keep both the filtrate & residue. Divide the filtrate in to 6 parts.	White residue.	Ca^{2+}, Ba^{2+}, Mg^{2+}, Zn^{2+} & Pb^{2+} ions are suspected present.
b.(i).To the 1st part of the filtrate, add dilute sodium hydroxide solution drop wise until in excess.	Brown precipitate insoluble in excess.	Fe^{3+}ion is suspected present.
b.(ii).To the 2nd part of the filtrate, add dilute ammonia solution drop wise until in excess.	Brown precipitate insoluble in excess.	Fe^{3+}ion is suspected present.
b.(iii).To the 3rd part of the filtrate, add 2-3 drops of potassium hexacyanoferrrate (II) solution.	Dark-blue precipitate is formed.	Fe^{3+}ion is confirmed present.
b.(iv).To the 4th part of the filtrate, add potassium dichromate (VII) solution followed by a few drops of concentrated sulphuric acid & warm.	Brown vapour with pungent smell. Orange colour of the solution turns green.	I_2 & Br_2 vapour are evolved. $\therefore I_2^-$ & Br_2^- ions are suspected present.
b.(v).To the 5th part of the filtrated, add silver nitrate solution followed by dilute nitric acid.	Yellow precipitate insoluble in the acid.	I_2^- & Br_2^- ions are suspected present.
b.(vi).To the 6th part of the filtrate, add 1cm^3 of carbon tetrachloride followed by chlorine water.	Reddish-brown colourless appears in the CCl_4 layer.	Br_2^- ion is confirmed present.
(c).Wash the residue with distilled water & then dry it between the filter paper. Heat a little of the residue strongly in a dry test tube strongly.	White solid remains.	BaO, CaO & MgO are formed.

(d).Dissolve the remaining residue in dilute nitric acid & divide the resultant solution in to three portions.	Effervescence of colourless gas that turns lime water milky & moist blue litmus paper red. Colourless solution.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ is confirmed present. Ca^{2+}, Mg^{2+} & Ba^{2+} ions are suspected present.
d.(i).To the 1st part of the solution, add dilute sodium hydroxide solution drop wise until in excess.	White precipitate insoluble in excess.	Ca^{2+}, Mg^{2+} & Ba^{2+} ions are suspected present.
d.(ii).To the 2nd part of the solution, add aqueous ammonia solution drop wise until in excess.	No observable change.	Mg^{2+} & Ba^{2+} are absent. $\therefore Ca^{2+}$ ion is suspected present.
d.(iii).To the 3rd part of the solution, add ammonia solution followed by ammonium ethanedioate (oxalate) & ethanoic acid.	White precipitate insoluble in excess.	$\therefore Ca^{2+}$ ion is confirmed present.

Identify the:

i. Cations present in compound **K**.
   Fe^{3+} ion is confirmed in b (iii).
   Ca^{2+} ion is confirmed in d (iii).
ii. Anions present in compound **K**.
   Br^- ion confirmed in b (vi).
   $C0_3^{2-}$ ion is confirmed in d.

Experiment 17, J is a mixture of $NiSO_4$ & $CuCO_3$:

You are provided with substance **J** which contains two cations and two anions. You are required to carry out the following tests on **J** to identify the cations and anions in **J**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat strongly one spatula end-ful of **J** in a dry test tube	J is green solid.	Transitional metal cations, Cr^{3+}, Ni^{2+}, Fe^{2+} & Cu^{2+} ions are suspected present.

	Colourless liquid that turns anhydrous copper (II) sulphate blue. Colourless gas that turns moist blue litmus paper red & lime water milky. Black residue.	Water of crystallization. ∴hydrated salt is present Carbon dioxide gas is given off. ∴CO_3^{2-} ,$C_2O_4^{2-}$ & HCO_3^- ions are suspected present. CuO, FeO & NiO are formed.
(b).To two spatula end-fuls of **J**, add 5cm^3 of distilled water, shake well & filter. Keep both the filtrate & residue. Divide the filtrate in five parts.	Green filtrate. & Green residue.	Cu^{2+}, Fe^{2+} & Ni^{2+} ions are suspected present in both filtrate & residue.
b.(i).To the 1st part of filtrate, add dilute sodium hydroxide solution drop wise until in excess.	Green precipitate insoluble in excess.	Fe^{2+} & Ni^{2+} ions are suspected present
b.(ii).To the 2nd part of the filtrate, add aqueous ammonia solution drop wise until in excess.	Green precipitate soluble forming pale-blue solution.	Ni^{2+} ion is suspected present
b.(iii).To the 3rd part of the filtrate, add dilute ammonia solution drop wise until in excess & then add 3 drops of dimethylglyoxime solution.	Red precipitate.	Ni^{2+} ion is confirmed present
b.(iv).To the 4th part of the filtrate, add 3-4 drops of lead (II) nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid.	SO_4^{2-} & Cl^- ions are suspected present.

b.(v).Use the 5th part of the filtrate to carry out a test of your own choice to confirm one of the anions present in **J**. Test: To the 5th part of the filtrate, add barium nitrate solution followed by dilute nitric acid. Or Add barium chloride solution followed by dilute hydrochloric acid.	White precipitate insoluble in the acid.	SO_4^{2-} ion is confirmed present.
(c).Wash the residue with a little distilled water, Heat a small portion of the residue.	Colourless gas that turns moist blue litmus red & lime water milky. Black residue.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$, $C_2O_4^{2-}$ & HCO_3^- ions are suspected present. CuO is formed. $\therefore Cu^{2+}$ ion is suspected present.
(d).Transfer the rest of residue in to a test tube & dissolve it in dilute nitric acid. Divide the solution in to three parts.	Effervescence of colourless gas that turns moist blue litmus paper red & lime water milky. Blue solution. Or: Green solution.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ is confirmed present. Cu^{2+} ion sis suspected present. Cu^{2+}, Ni^{2+}, Fe^{2+} & Cr^{3+} ions are suspected present.
d.(i).To the 1st part of the solution, add dilute sodium hydroxide solution drop wise until in excess.	Blue precipitate insoluble, turns black on heating.	CuO is formed. $\therefore Cu^{2+}$ ion is suspected present.

d.(ii).To the 2nd part of the solution, add aqueous ammonia solution drop wise until in excess.	Blue precipitate soluble forming deep blue solution.	Cu^{2+} ion is suspected present.
d.(ii).Use the 3rd part of the solution to carry out a test of your own choice to confirm one of the cations in **J**. Test: To the 3rd part of the solution, add 3 drops of potassium hexacyanoferrate (II) solution. Or Add 3 drops of potassium iodide solution.	Brown precipitate is formed. White precipitate in brown solution.	Cu^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **J**.
   Ni^{2+} ion is confirmed in b (iii).
   Cu^{2+} ion is confirmed in d (ii).
ii. Anions present in compound **J**.
   SO_4^{2-} ion confirmed in b (v).
   $C0_3^{2-}$ ion is confirmed in d.

Experiment 18, W is a mixture of $MnSO_4$ & $PbCO_3$:

You are provided with substance **W** which contains two cations and two anions. You are required to carry out the following tests on **W** to identify the cations and anions in **W**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat one spatula end-ful of W strongly in a dry test tube until there is no further change.	Colourless liquid/condensate that turns anhydrous copper (II) sulphate to blue.	Hydrated salt is suspected present. Carbon dioxide gas is given off.

	Colourless gas that turns moist blue litmus paper red & lime water milky. Reddish-brown residue-hot & yellow-cold. Black residue.	$\therefore CO_3^{2-}$, $C_2O_4^{2-}$ & HCO_3^- ions are suspected present. PbO, MnO & Fe_2O_3 are formed.
(b).To a spatula end-ful of W, add 2-3 drops of concentrated sulphuric acid & warm.	Effervescence/bubbles of colourless that turns moist blue litmus paper red & lime water milky.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ suspected present. Rej: $C_2O_4^{2-}$ ion.
(c).To two spatula end-fuls of W, add dilute nitric acid until there is no further change. Add sodium hydroxide solution drop wise until in excess. Filter & keep the filtrate.	Effervescence/bubbles of colourless gas that turns lime water milky. White precipitate insoluble in excess, turns brown. → Colourless filtrate. Brown residue.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is confirmed present. Mn^{2+} is suspected present. Rej: $C_2O_4^{2-}$ & HCO_3^- ions. Pb^{2+}, Zn^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+} ions are suspected present. Rej: Ca^{2+}, Ba^{2+} & Mg^{2+} ions suspected present. Mn^{2+} is suspected present.
(d).To the filtrate add dilute nitric acid until the solution is just acidic. Divide the resultant solution in to four parts.	White precipitate soluble in acid to form a colourless solution.	Pb^{2+}, Zn^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+} ions are suspected present.

d.(i).To the 1st part of the acidic solution, add sodium hydroxide solution drop wise until in excess.	White precipitate soluble in excess to form a colourless solution.	Pb^{2+}, Zn^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+} ions are suspected present.
d.(ii).To the 2nd part of the acidic solution, add aqueous ammonia solution drop wise until in excess.	White precipitate insoluble in excess.	Pb^{2+}, Sn^{2+}, Al^{3+} & Sn^{4+} ions are suspected present.
d.(iii).To the 3rd part of the acidic solution, add dilute sulphuric acid.	White precipitate.	Pb^{2+}ion is suspected present.
d.(iv).Use the 4th part of the acidic solution to carry out a test of your own choice to confirm one of the cations present in W. Test: To the 4th part of the acidic solution, add 3 drops of potassium iodide solution. Or Add potassium chromate (VI) solution followed by sodium hydroxide solution until in excess.	Yellow precipitate Yellow precipitate soluble forming a yellow solution.	Pb^{2+}ion is confirmed present.
(e).To two spatula end-fuls of W, add about 5cm^3 of distilled water, shake & filter. Divide the filtrate in to five parts.	Colourless filtrate. & White residue.	Non-transitional metals ions, I.e.: Al^{3+}, Pb^{2+}, Zn^{2+}, Mg^{2+}, Ca^{2+}& Ba^{2+} ions are suspected present in both the filtrate & residue.
e.(i).To the 1st part of the filtrate, add sodium	White precipitate insoluble in excess, turns brown.	Mn^{2+} ion is suspected present.

hydroxide solution drop wise until in excess.		
e.(ii).To the 2nd part of the filtrate, add aqueous ammonia solution drop wise until in excess.	White precipitate insoluble in excess turns brown.	Mn^{2+} ion is suspected present.
e.(iii).Use the 3rd part of the filtrate to carry out a test of your own choice to confirm one of the cations in W. **Test**: To the 3rd part of the filtrate, add concentrated nitric acid followed by sodium bismuthate. Or Add concentrated nitric acid followed by lead (IV) oxide & heat	Insist on the order of addition of reagent. Rej: Sodium bismuthate solution. Insist on heat if PbO_2 is used. Purple solution.	Mn^{2+} ion is confirmed present.
e.(iv).To the 4th part of the filtrate, add 2-3 drops of lead (II) nitrate solution & heat.	White precipitate insoluble on heating.	Cl^- ion suspected absent. $\therefore SO_4^{2-}$ & SO_3^{2-} ions are suspected present.
e.(v).Use the 5th part of the filtrate to carry out a test of your own choice to confirm one one of the anions present in W. **Test**: To the 5th part of the filtrate, add barium nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid.	SO_4^{2-} ion is confirmed present.

Identify the:

i. Cations present in compound **W**.
   Pb^{2+} ion is confirmed in d (iv).
   Mn^{2+} ion is confirmed in e (iii).

ii. Anions present in compound **W**.
CO_3^{2-} ion confirmed in c.
SO_4^{2-} ion is confirmed in e (v).

Experiment 18, Y is a mixture of $ZnCO_3$ & $BaCl_2$:

You are provided with substance **Y** which contains two cations and two anions. You are required to carry out the following tests on **Y** to identify the cations and anions in **Y**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat strongly one spatula end-ful of Y in a dry test tube.	White powder turned yellow-hot & white-cold.	Transitional metal ions are absent. Or Non-transitional metal ions are probably Mg^{2+}, Ca^{2+}, Zn^{2+}, & Pb^{2+} suspected present.
	Colourless condensate/liquid that turns anhydrous copper (II) sulphate blue.	Water of crystallization is present. ∴Hydrated salt is present.
	Colourless gas turned moist blue litmus paper red & lime water milky.	Carbon dioxide is given off. ∴CO_3^{2-} , $C_2O_4^{2-}$& HCO_3^- ions are suspected present.
	Yellow residue turned white on cooling.	ZnO is formed. ∴Zn^{2+} ion is suspected present.
(b).To one spatula end-ful of Y in a test tube, add 2-3 drops of concentrated sulphuric acid.	Effervescence/misty fumes with a chocking smell turned wet blue litmus paper red, formed dense white fumes with ammonia gas.	Hydrogen chloride gas. ∴Acidic gas probably Cl^- ion is suspected present.
(c).To two spatula end-fuls of Y, add about $5cm^3$	Partly dissolves to form a colourless filtrate & white residue.	Transition metal ions are suspected absent. Or

of distilled water. Shake vigorously & filter. Keep both the filtrate & residue.	Rej: Clear solution, white p.p.t & white solid.	Non-transition metal ions are suspected present. Or Accept a list of non-transition metal ions of: Mg^{2+},Zn^{2+},Ca^{2+},Ba^{2+},Pb^{2+} & Al^{3+}.
(d).Divide the filtrate in to six portions. (i).To the 1st portion of the filtrate, add dilute sodium hydroxide solution drop wise until in excess.	White precipitate insoluble in excess.	Mg^{2+}, Ca^{2+} & Ba^{2+} ions are suspected present.
(ii).To the 2nd portion of the filtrate, add aqueous ammonia solution drop wise until in excess.	White precipitate insoluble in excess.	Mg^{2+}& Ba^{2+} ions are suspected present. Rej: Ca^{2+} ion b'se it shows no observable change.
(iii).To 3rd portion of the filtrate, add a spatula end-fuls of solid ammonium chloride, followed by 3-4 drops of disodium hydrogen phosphate solution & then ammonia solution drop wise until in excess	White precipitate insoluble in excess ammonia solution. Note: Insoluble must be mentioned.	Mg^{2+}& Ba^{2+} ions are suspected present.
(iv).To the 4th portion of the filtrate, add 2-3 drops of potassium chromate (VI) solution followed by 2-3 drops of dilute sodium hydroxide solution.	Yellow precipitate insoluble in excess alkali. Rej: Orange precipitate.	Ba^{2+} ion is confirmed present.
(v).To the 5th portion of the filtrate, add 2-3	White precipitate insoluble in the acid.	SO_4^{2-} & Cl^- ions are suspected present.

drops of lead (II) nitrate solution, followed by dilute nitric acid.		
(vi).Use the 6th portion of the filtrate to carry out a test of your own choice to confirm one of the anions in Y. **Test:** To the 6th portion of the filtrate, add silver nitrate solution followed by dilute nitric acid.	White precipitate insoluble in the acid.	Cl^- ion is confirmed present.
(e).Wash the residue with a little distilled water. Transfer the residue in to a test tube & dissolves in dilute nitric acid. Divide the solution in to three portions.	Effervescence of colourless gas that turned lime water milky. A colourless solution is formed.	Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ is confirmed present. Rej: HCO_3^- & $C_2O_4^{2-}$ ions. Ba^{2+}, Mg^{2+}, Ca^{2+}, Zn^{2+} & Al^{3+} ions are suspected present.
e.(i).To the 1st portion of the solution, add dilute sodium hydroxide solution drop wise until in excess.	White precipitate soluble in excess to form a colourless solution.	Zn^{2+}, Pb^{2+} & Al^{3+} ions are suspected present.
e.(ii).To the 2nd portion of the solution, add aqueous ammonia solution drop wise until in excess.	White precipitate soluble in excess to form a colourless solution.	Zn^{2+} ion is suspected present.
e.(iii).Use the 3rd portion of the solution to carry out a test of your own choice to confirm one of the cations present in the solution. **Tests**:		

To the 3rd portion of the solution, add solid ammonium chloride followed by disodium hydrogen phosphate & aqueous ammonia solution. Note: Order of addition of the reagents matter.	White precipitate soluble in aqueous ammonia solution.	Zn^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **Y**.
   Ba^{2+} ion is confirmed in d (iv).
   Zn^{2+} ion is confirmed in e (iii).
ii. Anions present in compound **Y**.
   Cl^- ion confirmed in d (vi).
   $C0_3^{2-}$ ion is confirmed in e.

Experiment 18, Z is a mixture of $Al_2(SO_4)_3$,$FeSO_4.7H_2O$ & $Na_2S_2O_3.2H_2O$:

You are provided with substance **Z** which contains two cations and two anions. You are required to carry out the following tests on **Z** to identify the cations and anions in **Z**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat one spatula endful of Z in a dry test tube.	Colourless liquid that turned anhydrous copper (II) sulphate blue Colourless gas turned moist blue litmus paper red & acidified $K_2Cr_2O_{7(aq)}$ green. White fumes, Yellow sublimate/Reddish-brown residue.	Water of crystallization is present. ∴Hydrate salt is present. Sulphur dioxide gas is given off. ∴SO_3^{2-} & SO_4^{2-} ions are suspected present. Fe_2O_3 is formed.
(b).Dissolve three spatula end-fuls of Z in water. Divide the solution in to four parts.		

(i).To the 1st part of the solution, add dilute hydrochloric acid.	No observable change occurs.	Pb^{2+}, Ag^{2+} & Hg^{2+} ions are suspected present.
(ii).To the 2nd part of the solution, add iron (III) chloride solution.	No observable change occurs.	
(iii).To the 3rd part of the solution, add barium nitrate solution.	White precipitate.	SO_4^{2-} , SO_3^{2-} & CO_3^{2-} ions are suspected present.
(iv).To the 4th part of the solution, add dilute sodium hydroxide solution drop wise until in excess & filter. Keep both the filtrate & residue.	Dirty green gelatinous precipitate persisted in excess. White precipitate dissolves in excess.	Fe^{2+} ion is suspected present. Al^{3+}, Zn^{2+} & Sn^{2+} ions are suspected present.
(c).Acidify the filtrate with dilute hydrochloric acid & divide it in to three portions. (i).To the 1st portion of the acidified filtrate, add dilute sodium hydroxide solution drop wise until in excess.	No observable change occurs.	$Al(OH)_4^-$ & $Zn(OH)_4^{2-}$ are formed.
(ii).To the 2nd portion of the acidified filtrate, add dilute ammonia solution drop wise until in excess.	No observable change occurs.	$Al(OH)_4^-$ is formed $\therefore Al^{3+}$ ion is confirmed present.
(iii).To the 3rd portion of the acidified filtrate, add 2-3 drops of potassium iodide solution	No observable change occurs.	Pb^{2+} ion is suspected absent.
(d).Wash the residue & dissolves it in dilute hydrochloric acid. Divide the resultant solution in to two parts.		

(i).To the 1st part of the resultant solution, add dilute sodium hydroxide solution until in excess.	Dirty green gelatinous precipitate insoluble in excess.	Fe^{2+} ion is suspected present.
(ii).To the 2nd part of the resultant solution, add dilute ammonia solution drop wise until in excess.	Dirty green gelatinous precipitate insoluble in excess.	Fe^{2+} ion is confirmed present.

Identify the:

i. Cations present in compound **Z**.
   Al^{3+} ion is confirmed in c (ii).
   Fe^{2+} ion is confirmed in d (ii).
ii. Anions present in compound **Z**.
   SO_4^{2-} ion is confirmed in b (iii).

Experiment 18, U is a mixture of $CuCO_3$ & $Fe(SO_4)_3$:

You are provided with substance **U** which contains two cations and two anions. You are required to carry out the following tests on **U** to identify the cations and anions in **U**. Record your observations and conclusion in the table below.

Tests	Observations	Deductions
(a).Heat a spatula end-ful of strongly in a dry test tube.	U is agreen solid.	Cu^{2+}, Fe^{2+}, Ni^{2+} & Cr^{3+} ions are suspected present.
	Colourless liquid turned anhydrous copper (II) sulphate blue.	Water of crystallization is formed. ∴Hydrated salt is present.
	Colourless gas that turns lime water milky.	Carbon dioxide gas is given off. ∴CO_3^{2-}, $C_2O_4^{2-}$ & HCO_3^- ions are present.
	Colourless gas that turns acidified potassium dichromate from orange to green.	Sulphur dioxide gas is given off. ∴SO_3^{2-} & SO_4^{2-} ions are suspected present.
	Black residue remains.	CuO, NiO & FeO forms

(b).Place two spatula end-fuls of U in a test tube, add about 5cm^3 of distilled water, shake & filter. Keep both the filtrate & residue. Divide the filtrate in to five portions.	Green-blue filtrate. Brown residue. Effervescence of colourless gas that turned lime water milky.	Cu^{2+}, Fe^{2+}& Ni^{2+} ions are suspected present. $Fe(OH)_3$ & MnO_2 are formed. Carbon dioxide gas is given off. $\therefore CO_3^{2-}$ ion is present.
(i).To the 1st portion of the filtrate, add dilute sodium hydroxide solution drop wise in excess.	Blue precipitate insoluble in excess.	Cu^{2+} ion is suspected present.
(ii).To the 2nd portion of the filtrate, add dilute ammonia solution drop wise until in excess.	Blue precipitate soluble to form a deep-blue solution.	$Cu(NH_3)_4^{2+}$ is formed Cu^{2+} ion is suspected present.
(iii).To the 3rd portion of the filtrate, add few drops of potassium hexacyanoferrate (II) solution.	Dark-brown precipitate.	Cu^{2+} ion is confirmed present.
(iv).To the 4th portion of the filtrate, add 2 drops of lead (II) nitrate solution & warm.	White precipitate insoluble on warming.	CO_3^{2-},SO_3^{2-} & SO_4^{2-} ions are suspected present.
(v).Use the 5th portion of the filtrate to carry out a test of your own choice to confirm one of the anions in U. Test: To the 5th portion of the filtrate, add dilute nitric acid followed by barium nitrate solution. Or Dilute HCl/$BaCl_2$	White precipitate insoluble in dilute nitric acid.	SO_4^{2-} ion is confirmed present.

(c).Wash the residue with distilled water. Heat a small portion of the residue strongly in a dry test tube.	Brown residue remains.	$Fe(OH)_3$,Fe_2O_3 & MnO_2 are formed.
(d).Transfer the rest of the residue to a test tube & dissolve in in dilute hydrochloric acid. Divide the solution in to three portions.	Brown residue dissolves to give green-yellow solution.	Fe^{3+} ion is suspected present.
(i).To the 1st part of the solution, add dilute sodium hydroxide solution drop wise until in excess.	Brown precipitate insoluble in excess.	Fe^{3+} ion is suspected present.
(ii).To the 2nd part of the solution, add dilute ammonia solution drop wise until in excess.	Brown precipitate insoluble in excess.	Fe^{3+} ion is suspected present.
(iii).To the 3rd part of the solution, add 2-3 drops of potassium thiocyanate solution	Blood-red solution.	Fe^{3+} ion is confirmed present.

Identify the:

i. Cations present in compound **U**.
   Cu^{2+} ion is confirmed in a (iii).
   Fe^{3+} ion is confirmed in d (iii).
ii. Anions present in compound **U**.
   CO_3^{2-} ion is confirmed in a.
   SO_4^{2-} ion is confirmed in b (v).

ORGANIC PRACTICALS ANALYSIS:

Organic chemistry is a branch of chemistry concerned with the compounds of carbon: **Originally** confined to compounds produced by living organisms but now extended to include man made substances based on carbon, such plastics. Organic compounds consist of molecules held together by weak Vander waals forces or hydrogen bonds. As a result organic compounds are often liquids at room temperature. If they are solids, they easily melt or sublime on heating.

QUALITATIVE ANALYSIS OF ORGANIC COMPOUNDS:

The following skills are tested for during analysis of functional groups in organic chemistry.

1. Physical characteristics of organic compounds.
   In this test note the colour, odour & physical state i.e. solid & liquid of the organic compound provided.
   1) Physical state.
      - In case of liquid sample, may be low molecular mass alcohols, aldehydes, ketones, aliphatic, amines, esters & carboxylic acid.
      - In case of solid sample, may be aromatic carboxylic acid, salts of organic acids & bases or higher members of alcohols, aldehydes, ketones, amines & esters.
   2) Odour.
      - Sweet alcoholic: Aliphatic alcohols.
      - Unpleasant: Lower aldehydes.
      - Pleasant fruity smell: Ketones or esters.
      - Pungent smell/sour smell: Lower carboxylic acids.
      - Fishy ammoniacal smell: Lower amines.
2. Action of heat on the sample.
   During this test, note the nature and colour of the flame.
   - If it is yellow (luminous) & sooty, most likely the substance is aromatic or unsaturated aliphatic or aliphatic with high carbon content i.e high carbon: hydrogen ratio.
   - If the flame is yellow or blue non-sooty, most likely aliphatic compound.
   - Yellow luminous sooty & smoky flame-Aromatic organic compound & unsaturated organic compound.
3. Solubility in water.
   During this test, the organic sample is shaken with distilled water.
   - If the compound is easily soluble in cold water, then most likely polar aliphatic compound of low molecular E.g. alcohol, carboxylic acid, ketones, e.t.c
   - If the compound is insoluble in cold distilled water but soluble on warming, then most likely polar aromatic e.g. aromatic carboxylic acid.
   - If the compound is completely insoluble or immiscible with water, then most likely non-polar. All aromatic compounds are insoluble in cold distilled water.

   Notes:

Polar organic compound with carbon atoms ranging from C_1 to C_2 are miscible with water in all proportions. Such polar compounds include: Alcohols, aldehydes & ketones (Carbonyl compounds), carboxylic acid (alkanoic acid) & amines.
Reasons:
Such compounds interact with water through hydrogen bonding.
Notes:
Polar organic compounds having carbon atoms ranging from C_4 onwards are partially soluble in water to form two layers are formed. Polar aromatic compounds are partially soluble in water. Such polar aromatic organic compounds include: phenol, benzoic acid, bromobenzene, nitrobenzene, aminobenzene, phenylmethanal (benzaldehyde),phenylmethanol & benzenesulphonic acid.
Non-polar organic compounds are immiscible with distilled water & form two distinct layers.

4. Litmus/pH test.
   Here the organic sample or its solution is tested with litmus paper or universal indicator.
   - If blue litmus paper turns to red, then the solution is most likely to carboxylic acid, amines or phenol since the solution is acidic.
   - Phenol partially dissolves in cold distilled water but very soluble in hot water & the solution is slightly acidic hence turns blue litmus pink.
   - If the solution has no effect on litmus papers or pH = 7, most likely to be neutral compounds like, alcohols, carbonyl compounds or esters.

TESTS BASED ON THE REACTIONS OF DIFFERENT FUNCTIONAL GROUPS:

The common examinable areas in organic analysis include alcohols, carbonyl compounds, amines & carboxylic acids.
Preliminary tests are carried out which gives some clue about the identity of the functional groups.
Then the confirmatory tests are also carried out. From the knowledge of the organic chemistry acquired from this book & other organic text books, you can be able to identify the reagents that can confirm a vague (particular) functional groups present.
The reagents used to identify the following groups are as follows:

a) Aldehydes:
   - ✓ Brady's reagent.
   - ✓ Fehling's solution.
   - ✓ Tollen's reagent.

- ✓ Sodium hydrogen sulphite (saturated).
- ✓ Acidified potassium dichromate or acidified potassium permanganate (VII) solution.
- ✓ Iodine solution in dilute sodium hydroxide solution (Iodoform test).

b) Ketones:
- ✓ Brady's reagent.
- ✓ Sodium hydrogen sulphite (saturated).
- ✓ Iodine solution in dilute sodium hydroxide solution (Iodoform test).

c) Alkanols (alcohols):
- ✓ Phosphorus pentachloride.
- ✓ Concentrated sulphuric phosphoric acid.
- ✓ Anhydrous zinc chloride & concentrated hydrochloric acid (Luca's test).
- ✓ Ethanoic or methanoic acid with concentrated sulphuric acid. (Esterification reaction).
- ✓ Acidified potassium dichromate or acidified potassium permanganate (VII) solution.

d) Carboxylic acids:
- ✓ Soda lime.
- ✓ Iron (III) chloride solution.
- ✓ Sodium carbonate solution.
- ✓ Sodium hydroxide solution.
- ✓ Fehling's solution (for methanoic acid).
- ✓ Ethanol or methanol & concentrated sulphuric acid (Esterification reaction).

e) Phenols:
- ✓ Bromine water.
- ✓ Sodium carbonate solution.
- ✓ Sodium hydroxide solution.
- ✓ Neutral iron (III) chloride solution.

f) Amines (aliphatic):
- ✓ Ethanoic acid.
- ✓ Dilute sulphuric acid.
- ✓ Concentrated hydrochloric acid.
- ✓ Nitrous acid (concentrated hydrochloric acid and sodium nitrite solution.

g) Aromatic amines (e.g phenylamine):
- ✓ Bromine water.
- ✓ Dilute sulphuric acid.
- ✓ Naphthaleine-2-ol.
- ✓ Alkaline solution of phenol.
- ✓ Alkaline solution of B-naphthol.
- ✓ Concentrated hydrochloric acid.
- ✓ Nitrous acid (concentrated hydrochloric acid and sodium nitrite solution.

5. Addition of various reagents to identify functional groups.
   The following reagents are commonly used to identify functional groups in organic compounds.
   1) Sodium hydroxide solution.
      When this reagent is add, note whether the compound dissolves or not.
      If the compound dissolves readily in sodium hydroxide solution, most likely it is acidic.
      Examples:
      Phenol. Carboxylic acid.
   2) Sodium carbonate or sodium hydrogen carbonate solution.
      If the compound dissolves with effervescence, most likely carboxylic acid is present. If there is no observable change occurs/no effervescence then carboxylic acid is absent.
   3) Dilute hydrochloric acid.
      If the compound is soluble in dilute hydrochloric acid, most likely an amine.
   4) 2, 4-dintrophenylhydrazine (Brady's reagent) solution.
      This reagent test for carbonyl compounds (functional) groups in aldehydes & ketones.
      If yellow precipitate is formed then aldehyde or ketone is suspected present.
      If there is no yellow precipitate or orange/yellow colour of Brady's reagent remains, then carbonyl compounds are absent.
   5) Tollen's reagent (Ammoniacal silver nitrate solution).
      If silver mirror is formed on warming the compound with the reagent, then aldehyde or methanoic acid is probably present.
   6) Fehling solution (copper (II) ions in excess ammonia solution).
      If a red precipitate or reddish-brown precipitate is formed, then an aldehyde is probably present.
   7) Iodine solution & sodium hydroxide solution (Iodoform test).
      This gives a positive result (i.e yellow precipitate) with secondary alcohols with methyl ($-CH_3$) attached to the carbon carrying the functional group or ketones with a methyl group attached to the carbonyl carbon.
      Notes:
      Ethanol is the ***only primary alcohol*** which gives a positive results while ethanal is the ***only aldehyde*** which gives a positive results with iodoform test.
   8) Acidified potassium dichromate (VI) solution.

This reagent identifies reducing agents such as primary & secondary alcohols or aldehydes. In this case the reagent turns from orange to green if a reducing agent is present.

Note:

Tertiary alcohols & ketones do not give a positive result with this reagent.

9) Acidified potassium manganate (VII) solution.

This reagent identifies reducing agents such as primary & secondary alcohols or aldehydes. It also tests for unsaturated compounds (i.e. alkenes & alkynes).

In this case the reagent turns from purple to colourless if a reducing agent or unsaturated compound is present.

10) Concentrated sulphuric acid with an alcohol E.g.Ethanol,Methanol & warming.

This test identifies the presence of a carboxylic acid. If carboxylic acid is present, then a sweet fruity smell is observed implying that an ester is formed from esterification of carboxylic acid.

11) Addition of concentrated sulphuric acid & carboxylic acid E.g. Ethanoic & Methanoic acid followed by warming.

This reagent tests for the present of an alcohol. In case the alcohol is present, a sweet fruity is formed meaning that an ester is formed from esterification of an alcohol.

12) Bromine water.

This reagent tests for the presence of unsaturated compounds, phenol and aromatic amines.

— In case of unsaturated compound, the solution turns from brown to colourless.

— In case of phenol & aromatic amines, a white precipitate is formed.

13) Neutral iron (III) chloride solution.

This reagent tests for the presence of phenol. In case of phenol is present, a violent/purple colouration is formed.

14) Anhydrous zinc chloride & concentrated hydrochloric acid (Luca's reagent).

This reagent distinguishes primary, secondary & tertiary alcohols.

Observations:

— Formation of an immediate cloudy solution indicates presence of tertiary alcohol.

— If the cloudy solution appears within 5-10 minutes then secondary alcohol is present.

— If no cloudy solution appears at room temperature, then the alcohol is a primary one.

15) Aluminium (III) oxide.
During this tests, the unknown sample is passed over heated aluminium oxide & the gas formed passed over bromine water or acidified potassium manganate (VII) solution.
If both solutions are decolourised then an alcohol is dehydrated to an alkene.

16) Concentrated sulphuric acid.
In this test, the unknown is heated with concentrated sulphuric acid and the gas formed passed via bromine water or acidified potassium manganate (VII) solution. Both solution are decolourized.
In case alcohol is present, implying that the alcohol is dehydrated to an alkene.

SUMMARY ON THE ORGANIC ANALYSIS FOR A NUMBER OF FUNCTIONAL GROUPS IS GIVEN BELOW.

A. Analysis on alcohols.
You are provided substance **E** which is an organic compound. Carry out the following tests to identify the nature of **E**. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a).Burn a small amount of **E** on a crucible lid.	Colourless liquid burns with a non-sooty yellow/blue flame.	Aliphatic saturated compound of low C:H ration is suspected present.
(b).To 1cm^3 of **E** add 1cm^3 of distilled water and test with litmus paper.	Miscible/dissolves in water to form colourless solution. The solution is neutral to litmus.	Alkanol, alkanal, alkanone or ester are suspected present.
(c).To 1cm^3 of **E** add few drops of Brady's reagent.	No observable change occurs. Or: The solution remains yellow.	Carbonyl compounds are absent. ∴Alkanol is suspected present.
(c).To 1cm^3 of **E** add 1cm^3 of acidified potassium dichromate (VI)	On warming, orange solution turns green.	E is reducing agent. It is oxidized to carbonyl compound.

solution & warm. Divide the solution in to two parts.		∴primary or secondary alcohol is suspected present.
c.(i).To the 1st part, add 5 drops of Brady's reagent.	Orange/yellow precipitate is formed.	Carbonyl compounds are formed. ∴primary or secondary alcohol is suspected present.
c.(ii).To the 2nd part, add 5 drops of acidified potassium manganate (VII) solution and warm.	Purple colour of K_2MnO_7 solution is discharged/decolourized.	Alkanal present. ∴primary alcohol is confirmed present.
(e).To 1cm^3 of **E** add 4cm^3 of iodine in potassium iodide solution followed by dilute sodium hydroxide solution drop wise until the iodine colour is discharged & warm.	Yellow precipitate is formed on heating.	Primary alcohol with CH_3 group attached to carbon atom carrying the functional group. ∴E is ethanol.

Identify the nature of E: E is a saturated aliphatic alcohol.

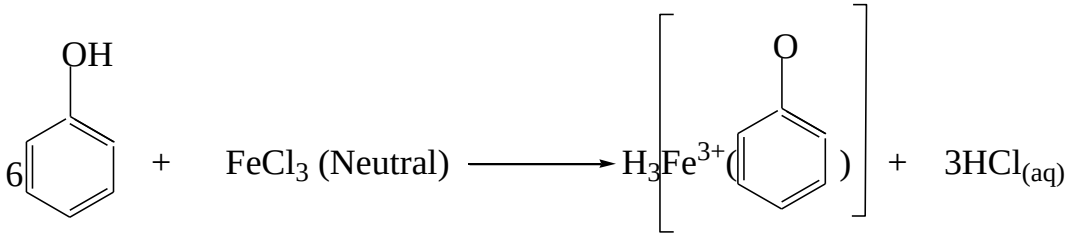
B. Analysis on phenols.

You are provided substance **W** which is an organic compound. Carry out the following tests to identify the nature of **W**. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a).Burn 1 drop of **W** on the tip of spatula.	Red liquid burns with a sooty & smoky flame.	Aromatic compound is suspected present.
(b).To two drops of W add 2cm^3 of distilled water & shake. Allow to stand & test with litmus paper & add sodium carbonate solution.	Slight soluble in water & solution turns blue litmus paper red & no observable change occurs with sodium carbonate solution.	Phenol is suspected present.

(c).To 1 drop of W add bromine water drop wise until in excess.	Red-brown colour of bromine is discharged & white precipitate is formed.	Aromatic compound with polar group such as –OH & -NH_2 present. Phenol is suspected present.
(d).To 2 drops of W add dilute sodium hydroxide solution.	W dissolves in sodium hydroxide solution forming a colourless solution.	Acidic compound is present. ∴Phenol is suspected present.
(e).To 1 drop of W add few drops of neutral iron (III) chloride solution.	Blue-violet coloured solution is formed.	Phenol is confirmed present.

Equation:



Comment on the nature of W.W is phenol.

C. Analysis on carbonyl compounds.

a) Aldehydes.

You are provided substance **Y** which is an organic compound. Carry out the following tests to identify the nature of **Y**. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a).Burn a small amount of Y on a crucible lid.	Cloudy liquid burns with a yellow non-sooty flame.	Aliphatic saturated compound with low C: H ratio.
(b).To 1cm^3 of Y add 1cm^3 of distilled water & test with litmus paper.	Y is soluble in water forming a colourless solution which is neutral to litmus.	Alkanol, Alkanal, Alkanone or ester are suspected present.
(c).To 1cm^3 of Y add few drops of Brady's reagent.	Yellow/orange precipitate is formed.	Alkanal & Alkanone are suspected present.

(d).To 2cm^3 of Y add 1cm^3 of acidified potassium dichromate (VI) solution. (Keep the mixture for test in (h) below.)	On warming, the orange solution turns green.	Reducing agent is suspected present. ∴Alkanal is present.
(e).To 1cm^3 of Y add 5 drops of Tollen's reagent.	Silver mirror is observed on the sides of the test tube.	Alkanal is suspected present.
(f).To 1cm^3 of Y add 5 drops of Fehling's solution & heat the mixture.	Red-brown precipitate is formed.	Alkanal is suspected present.
(g).To 1cm^3 of Y add 4cm^3 of iodine in potassium iodide solution followed by dilute sodium hydroxide solution drop wise until the iodine colour is discharged & warm.	No observable change occurs.	Ethanol is suspected absent. ∴Methanal is suspected present.
(h).To 2cm^3 of the mixture from (d) above, add 3cm^3 of acidified potassium permanganate (VIII) solution & warm.	The purple of potassium permanganate (VIII) solution is discharged.	Methanoic acid is suspected present. ∴Methanal is confirmed present.

Identify the nature of Y. Y is a saturated aliphatic aldehyde.

b) Ketones.

c) You are provided substance **M** which is an organic compound. Carry out the following tests to identify the nature of **M**. Record your observations and deductions in the table below.

Tests	Observaions	Deductions
(a).Burn a drop of M on the tip of the spatula.	Colourless liquid burns with yellow noon sooty flame.	Aliphatic saturated compound with low C: H ratio.

(b).To 1cm^3 of M add 1cm^3 of distilled water and test with litmus paper.	M is soluble in water to form a colourless solution which is neutral to litmus.	Alkanol, Alkanal, Alkanone or ester is suspected present.
(c).To 1cm^3 of M add few drops of Brady's reagent.	Yellow/Orange precipitate is formed.	Alkanal or Alkanone is suspected present.
(d).To 2cm^3 of M add 2cm^3 of acidified potassium dichromate VI) solution and warm.	No observable change occurs.	Alkanal is suspected absent. ∴Alkanone is suspected present.
(e).To 1cm^3 of M add 1cm3 of Fehling's solution & heat the mixture.	No observable change occurs.	Alkanone is suspected present.
(f).To 1cm^3 of M add 5cm^3 of iodine in potassium iodide solution, followed by dilute sodium hydroxide solution drop wise until the colour of the iodine discharged & warm.	Yellow precipitate is formed on warming.	Alkanone with -CH_3 is attached to carbon atom next to the one carrying the functional group. ∴Propanone is confirmed present.

Identify the nature of M.M is aliphatic ketone with structure of $CH_3C(=O)-R$

D. Analysis on carboxylic acids.

a) Aliphatic carboxylic acids.

You are provided substance **Q** which is an organic compound. Carry out the following tests to identify the nature of **Q**. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a).Burn a small amount of Q on the tip of the spatula.	Colourless liquid with irritating vinegar smell burns with yellow non-sooty flame	Aliphatic carboxylic acid with low C: H ratio.

(b).To 1cm^3 of Q add 2cm^3 of distilled water & test with litmus paper then add aqueous sodium carbonate solution.	Miscible with water to form a colourless solution that turns blue litmus paper red. On addition of sodium carbonate solution, there is effervescence of colourless gas that turns lime water milky.	Carboxylic acid is suspected present.
(c).To 1cm^3 of Q ad few drops of iron (III) chloride solution & warm the mixture.	No observable change/solution remains yellow.	Phenol is suspected absent. ∴Carboxylic acid is suspected present.
(d).Mix about 1cm^3 of Q with a spatula end-ful of soda lime & heat the mixture.	Colourless gas that burns with yellow flame is evolved. Another colourless gas that turns lime water milky is evolved.	Methane gas is evolved. Decarboxylation occurs. ∴Carboxylic acid is suspected present.
(e).Add 1cm^3 of Q to about 2cm^3 of ethanol followed by 5 drops of concentrated sulphuric acid. Heat the mixture & then pour it in to a beaker containing distilled water.	Fruity/sweet smell detected.	Esterification has taken place. ∴Carboxylic acid is confirmed present.
(f).To 2cm^3 of Q add 1cm^3 of acidified potassium dichromate (VI) solution and warm.	No observable change occurs.	Reducing agent is suspected absent. ∴Ethanoic acid is suspected present.

Identify the nature of Q.Q is aliphatic carboxylic acid.

b) Aromatic carboxylic acids.

You are provided substance **Z** which is an organic compound. Carry out the following tests to identify the nature of **Z**. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a).Burn a small amount of Z on a crucible lid.	White crystals burns with yellow sooty flame.	Aromatic compound is suspected present.
(b).Shake few crystals of Z in about $3cm^3$ of distilled water & test with litmus paper & then add a little sodium hydrogen carbonate powder.	Z partially dissolves & colourless solution formed turns blue litmus red. On addition of sodium hydrogen carbonate, effervescence of colourless gas that turns lime water milky.	Aromatic carboxylic acid is suspected present.
(c).To a spatula end-ful of Z add $2cm^3$ of dilute sodium hydroxide solution & warm to dissolve the solid. Cool & divide the resultant solution in to two parts.	Dissolves to give a colourless solution.	Aromatic carboxylic acid is suspected present.
c.(i).To the 1^{st} part of the solution, add iron (III) chloride solution.	Brown precipitate.	Benzoate ion is formed. ∴Benzoic acid is suspected present.
c.(ii).To the 2^{nd} part of the solution, add dilute sulphuric acid.	White precipitate.	Benzoic acid is suspected present.
(d).To the spatula end-ful of Z add $2cm^3$ of ethanol. Shake well to dissolve the solid & add 5 drops of concentrated	Pleasant fruity smell detected & the product is insoluble in water.	Esterification has taken place. ∴Benzoic acid is confirmed present.

sulphuric acid and heat the mixture. Pour the product in to a beaker of cold water		

Identify the nature of Z.Z is an aromatic carboxylic acid.

E. Analysis on amines.

a) Aliphatic amines.

You are provided substance **S** which is an organic compound. Carry out the following tests to identify the nature of **S**. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a).Burn a small amount of S on the tip of the spatula.	Colourless liquid burns with yellow non-sooty flame.	Aliphatic saturated compound with low C: H ratio.
(b).To 1cm^3 of S add 2cm^3 of distilled water & test with litmus paper.	Miscible with water to form a colourless solution that turns red litmus paper blue.	Aliphatic amine is suspected present.
(c).Place 1cm^3 of S in a test tube & bring a bottle containing concentrated hydrochloric acid near the mouth of the test tube.	Dense white fumes are formed.	Alkyl ammonium salt is formed. ∴ Aliphatic amine is suspected present.
(d).To 1cm^3 of S add cold sodium nitrite solution followed by concentrated hydrochloric acid.	Yellow oily liquid is formed.	Secondary aliphatic amine is confirmed present.

Identify the nature of S.S is secondary aliphatic amine.

b) Aromatic amines.

You are provided substance **K** which is an organic compound. Carry out the following tests to identify the nature of **K**. Record your observations and deductions in the table below.

Tests	Observations	Deductions
(a).Burn a drop of K on a crucible lid.	K burns with luminous sooty flame.	Aromatic compound is suspected present.

(b).Put two drops of K in a test tube & add about $1cm^3$ of distilled water. Shake the mixture. Test the mixture with litmus.	K is slightly soluble in water & the solution turns red litmus paper blue.	Aromatic amine is suspected present.
(c).To $1cm^3$ of K add $2cm^3$ of concentrated hydrochloric acid.	K dissolves to form a colourless liquid & dense white fumes are formed.	K contain basic functional group. ∴ Aromatic amine is suspected present.
(d).To $5cm^3$ of K, add bromine water drop wise until in excess.	Reddish-brown colour of bromine water discharged. White precipitate is formed.	Polar functional group attached to benzene ring. ∴ Aromatic amine is suspected present E.g. Phenylamine.
(e).To $1cm^3$ of K add concentrated hydrochloric acid followed by cold solution of sodium nitrite (5°C).Divide the solution in to two portions.	K dissolves to form a colourless solution.	Diazonium salt is formed. ∴ Aromatic amine is suspected present.
e.(i).Warm the 1st portion.	Effervescence of a colourless neutral gas. Oily liquid is formed.	Aromatic diazonium salt decomposed to form nitrogen gas. ∴ Aromatic amine is suspected present.
e.(ii).To 2nd part, add alkaline solution of naphthaleine-2-ol.	Yellow precipitate is formed.	An azo dye is formed. ∴ Aromatic amine is confirmed present.

Identify the nature of K.K is an aromatic amine, Eg. Phenylamine.

Alcohols.

Functional group: Hydroxyl group (-OH)

Organic compounds Alcohols:

— Aliphatic primary, secondary & tertiary alcohols.

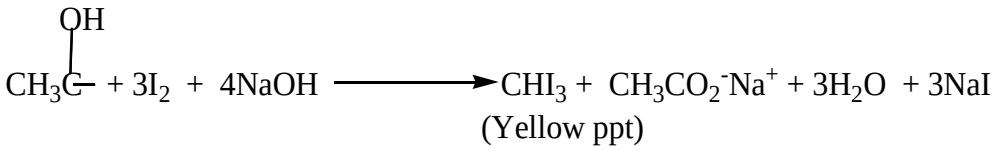
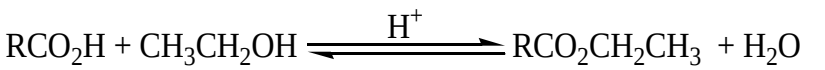
— Aromatic primary, secondary & tertiary alcohols.

Physical Properties:

The presence of the -OH group means that hydrogen bonding occurs between the molecules of alcohols/hydrogen bonding has two consequences.

- ✓ All alcohols with relatively short carbon chains (up to and including propanol) mix with water forming a neutral solution.
  The shorter chain alcohols are normally colourless liquids at room temperature with a pleasant spirit smell.
- ✓ They have boiling points (and melting points) being much higher than those of alkanes of comparable relative molecular mass.

<table>
<tr><th>Common Tests</th><th>Observations</th></tr>
<tr><td>Addition of sodium metal</td><td>Colourless gas which explodes with a pop sound when lit is given off.(Hydrogen gas)</td></tr>
<tr><td>Add of anhydrous zinc (II) chloride followed concentrated hydrochloric acid (Lucas reagent)</td><td>(i). Tertiary alcohol-An immediate cloudy solution is formed at room temperature.
(ii). Secondary alcohol-A cloudy solution is formed after standing for five minutes at room temperature.
(iii). Primary alcohol-No cloudy solution is formed at room temperature.</td></tr>
<tr><td colspan="2">Lucas's test for primary, secondary and tertiary alcohols is summarized in the equations below:
$R_3COH + Conc.HCl \xrightarrow[25°C]{Anhy.\ ZnCl_2} R_3C{-}Cl + H_2O$
3°C Alcohol — Immediate cloudy solution
$R_2CHOH + Conc.HCl \xrightarrow[25°C]{Anhy.\ ZnCl_2} R_2CHCl + H_2O$
2°Alcohol — Cloudy solution on standing about 5Mins
$RCH_2OH + Conc.HCl \xrightarrow[25°C]{Anhy.\ ZnCl_2} RCH_2Cl + H_2O$
1° Alcohol — No observable change occurs.</td></tr>
<tr><td rowspan="2">Oxidation of Alcohols:
Addition of acidified potassium dichromate, and heat.</td><td>Acidified potassium dichromate solution changes from orange to green</td></tr>
<tr><td><u>Explanation:</u>
(i).Primary alcohol-Oxidized to aldehydes and further to carboxylic acids.</td></tr>
</table>

	(ii).Secondary alcohol-Oxidized to ketones and resistant to further oxidation.
Note: Tertiary alcohol: No observable colour change. Solution remains orange (3°alcohols are resistant to oxidization)	
Dehydration of alcohols: (i).Addition of concentrated sulphuric acid, and heat.	All primary, secondary or tertiary alcohols gives off a colourless vapour,if bubbled in: Bromine water, changes it from brown to colourless. Acidified potassium permanganate, from purple to pink.
(ii).Addition of iodine solution followed by sodium hydroxide solution until the colour of iodine is just discharged. (Iodoform test).	A yellow precipitate of CHI_3 is formed.
Equation:  $CH_3C(OH)- + 3I_2 + 4NaOH \longrightarrow CHI_3 + CH_3CO_2^-Na^+ + 3H_2O + 3NaI$ (Yellow ppt)	
Methyl alcohols from a yellow precipitate of CHI_3 (Iodoform). ✓ Ethanol (CH_3CH_2OH) also gives a yellow precipitate. ✓ Tertiary alcohols with structure formula,$(CH_3)_3COH$ do not gives a yellow precipitate of CHI_3	
Addition of dilute sulphuric acid followed by few drops of ethanoic acid and heat. Pour the resultant solution in a beaker containing water.	A solution with sweet smell is formed.
Equation:  $RCO_2H + CH_3CH_2OH \underset{}{\overset{H^+}{\rightleftharpoons}} RCO_2CH_2CH_3 + H_2O$	
Addition of phosphorus pentachloride solution.	Evolution of misty gas hat forms white fumes with ammonia.

NEUTRAL COMPOUNDS: CARBONYL COMPOUNDS:

(Aldehydes and ketones)

Functional Group: Carbonyl group (C=O)

Organic Compounds:

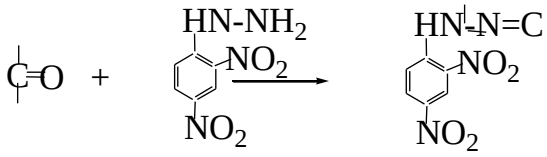
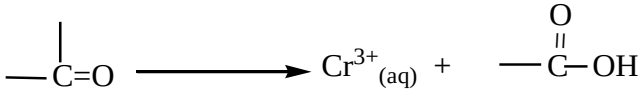
— Aldehydes: Aliphatic Aldehydes & Ketones.
— Ketone: Aromatic Aldehydes & Ketones.

Physical Properties:

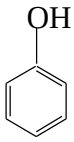
The carbonyl group is strongly polar C═O so dipole-dipole forces between molecules are quite significant:

(i). the shorter chained carbonyl compounds are normally colourless liquids at room temperature and **are completely miscible with water due to formation of hydrogen bonds.** Solubility decreases with increasing length of the carbon chain. Long chained carbonyl compounds are normally solids e.g. glucose.

(ii). this leads to boiling points (and melting points) being higher than those of alkanes of comparable relative molecular mass but not as those of alcohols, where H-bonding can occur between molecules.

General Test	Observations
To about $1cm^3$ of compound, Add 2,4-dinitrophyenylhydrazine (Brady's reagent).	A yellow precipitate is formed with both ketones and aldehydes.
Equation:  Yellow precipitate	
To about $1cm^3$ of compound, Add saturated sodium hydrogen sulphite and warm.	A white precipitate is formed with both ketones and aldehydes. NOTE: Precipitate is not obtained from aliphatic Aldehydes and ketones with C_1.
FUNCTIONAL GROUP TESTS	
Aldehydes	Observations
Add acidified potassium dichromate and warm.	A green solution is formed I.e.: Aldehyde is oxidized to carboxylic acid.
Equation: 	
Add ammoniacal silver nitrate (Tollen's reagent).	A silver deposit on the walls of the test tube.

Equation: $R\text{-}CHO + Ag(NH_3)_2^+OH^- \longrightarrow Ag_{(s)} + RCOO^- + \text{Other product}$ Aldehyde Tollen's reagent Silver mirror	
Add Fehling's solution.	Brown precipitate is formed.
Equation: $RCHO + Cu^{2+}_{(aq)} + 3OH^-_{(aq)} \longrightarrow Cu_2O_{(s)} + CH_3CO_2H + H_2O$ (Blue tartrate complex) Brick red ppt)	
Ketones:	
Add Iodine solution followed by sodium hydroxide solution until colour of iodine is just discharged.	A yellow precipitate is formed for methyl ketones. (CH_3CO^-)
Equation: $CH_3COR + 3I_2 + 4NaOH \longrightarrow CHI_3 + CH_3COO^-Na^+ + 3H_2O + 3NaI$ Yellow p.p.t	



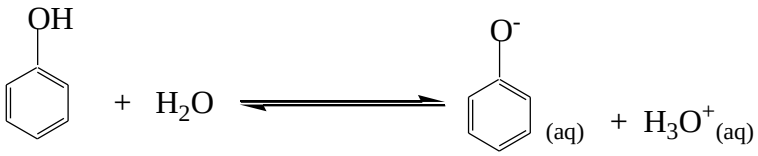
ACIDIC COMPOUNDS: 1. PHENOLS:

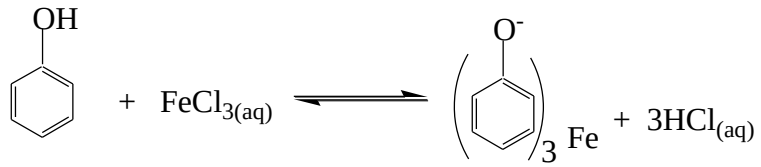
Functional group: Hydroxyl group (-OH) Organic compounds: Phenols

Physical properties:

The presence of the OH group means that hydrogen bonding occurs between the molecules of phenols/Hydrogen bonding has two consequences:

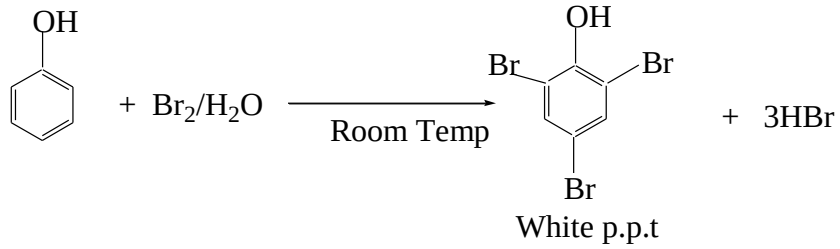
- ✓ It is colourless crystalline solid, with a distinctly antiseptic smell. Phenol acquires a reddish brown tint on exposure to air/light.it is only sparingly soluble in cold water, forming an acidic solution.
- ✓ They have boiling points (and melting points) being much higher than those of alkanes of comparable relative molecular mass.

Tests	Observations
Addition of universal indicator or litmus solution.	Turns universal indicator red (showing that is acidic)
Equation:  	
Add neutral iron (III) chloride solution	Purple/violet colouration is observed.
Equation:	



Addition of bromine water.	White precipitate

Equation:



ACIDIC COMPOUNDS: 2.CARBOXYLIC ACIDS.

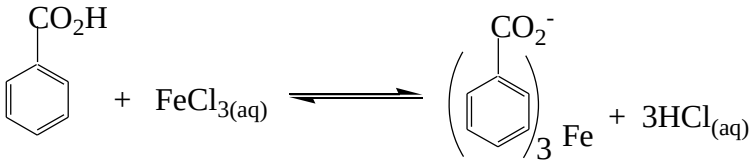
Functional group : Carboxylate group ($-CO_2H$)

Organic compounds : Carboxylic acids: (i). Aliphatic carboxylic acids.
(ii). Aromatic carboxylic acids.

Physical Properties:

- ✓ The acids have a characteristic smell as that of vinegar, the shorter chain acids are normally colourless liquids at room temperature.
- ✓ They form hydrogen bonds with water molecules, this result in carboxylic acids dissolving well in water, provided that their carbon chains are fairly short.

Tests	Observations
Addition of universal indicator or litmus solution	Turns universal indicator red (Showing that it's acidic)
Equation: $RCO_2H_{(l)} + H_2O_{(l)} \overset{H^+}{\rightleftharpoons} RCO_2^-{}_{(aq)} + H_3O^+{}_{(aq)}$	
Addition of saturated Na_2CO_3.	Colourless gas turns lime water milky (CO_2 gas) is evolved
Equation: $2RCO_2H_{(l)} \xrightarrow[\text{Saturated}]{Na_2CO_{3(aq)}} 2RCO_2^-Na^+{}_{(aq)} + CO_{2(g)} + H_2O_{(l)}$	
Add Neutral Iron (III) chloride solution.	Brown precipitate is formed.
Equation:	

	
Add soda lime solution and heat	Colourless gas that turns limewater (CO_2 gas)
Equation: $RCO_2H_{(l)} \xrightarrow[\text{Heat}]{\text{Soda lime}} \underset{\text{Clear solution}}{RH} + CO_{2(g)}$	
Add dilute sulphuric acid followed by 1cm^3 of ethanol and heat. Pour the resultant solution in a beaker containing Water.	A solution with a sweet smell is formed.
Equation: $RCO_2H + CH_3CH_2OH \overset{H^+}{\rightleftharpoons} RCO_2CH_2CH_3 + H_2O$	
Addition of sodium metal	Colourless gas with 'pop' sound when lighted is evolved. A colourless solution is formed.
Equation: $RCO_2H + Na_{(s)} \rightleftharpoons RCO_2^-Na^+ + H_{2(g)}$	

BASIC COMPOUNDS: AMINES

Functional group: Amino group ($-NH_2$)

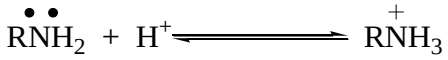
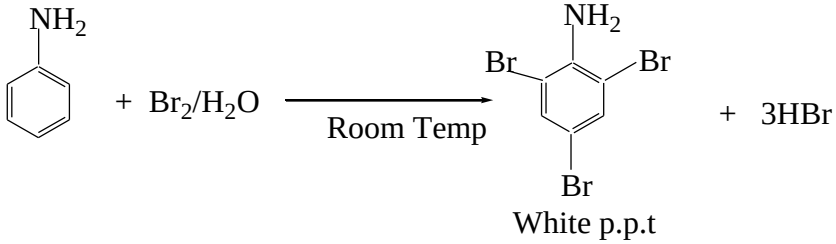
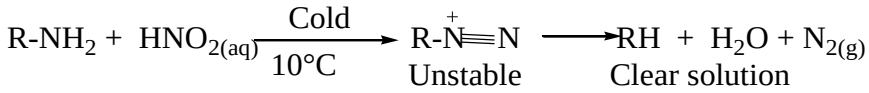
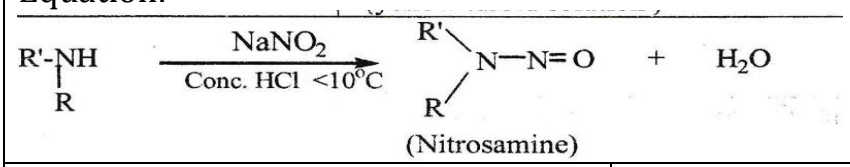
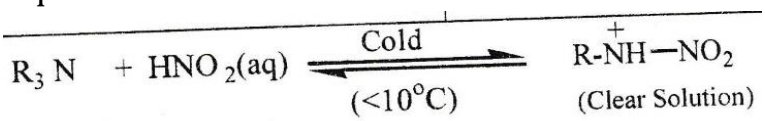
Organic compounds: Amines

- ✓ Aliphatic primary, secondary or tertiary Amines.
- ✓ Aromatic primary, secondary or tertiary Amines.

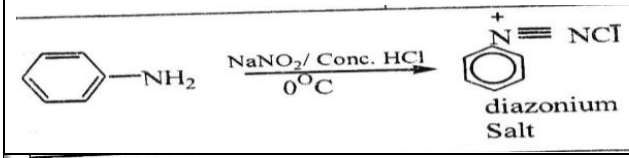
Physical properties:

- ✓ They have a characteristic fishy smell. Indeed of rotting fish. Smell produced by decomposition of proteins.
- ✓ Primary and secondary amines can hydrogen bond to molecules of water or alcohols, so primary amines with chain length up to C_4 are colourless and very soluble in water. Forming a basic solution.
- ✓ Phenyl amine is a brown liquid and not very soluble in water due to the benzene ring.

Tests	Observations
Detect the smell (Take care)	Aliphatic amines have a fishy smell. I.e smell of decaying fish.

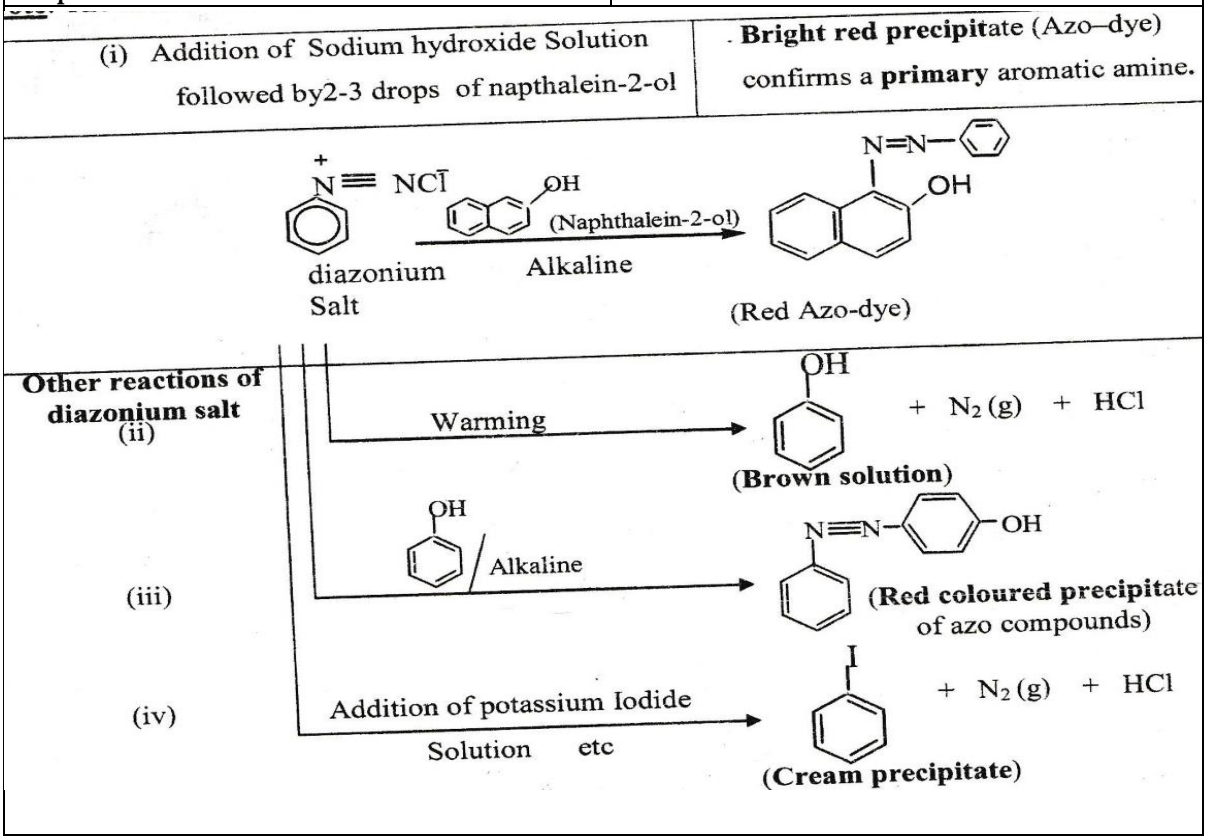
With dilute hydrochloric acid	Compound dissolves (Showing that is basic).
Equation: 	
Addition of bromine water	White precipitate formed with a primary aromatic amine
Equation:  White p.p.t	
Addition of nitrous acid (can be prepared in situ by using sodium nitrite and concentrated hydrochloric acid) and allow to stand in ice cold water.	
(i). Primary aliphatic amine	A bubble of colourless, Nitrogen gas is evolved and a colourless solution is formed, with primary aliphatic amine.
Equation: 	
(ii). Aliphatic and aromatic secondary amines	Yellow oily emulsion of Nitroso compounds.(Yellow turbid solution)
Equation:  (Nitrosamine)	
(iii).Tertiary amines	Clear solution containing substituted ammonium nitriles
Equation 	
(iv). Primary aromatic amine	No bubbles of colourless gas are evolved with aromatic amines. Yellow crystalline aromatic salts formed.

Equation:



Note: The substituent - $\overset{+}{N}\equiv N$ can be replaced with a variety of the groups such as –OH, -I, -Cl etc

(i). Addition of sodium hydroxide solution followed by 2-3 drops of napthalein-2-ol	Bright red precipitate (Azo-dye) confirms a primary aromatic amine.



SAMPLE MARKING GUIDE FOR AN ORGANIC PRACTICAL TYPICAL QUESTIONS ON ORGANIC QUALITATIVE ANALYSIS.

Experiment 1:

1. You are provided with substance **G** which is an organic compound. You are required to determine the nature of **G**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions

(a). Note the appearance of substance **G**.	**G** is a colourless liquid with a spirit smell.	**G** is an alcohol, carbonyl compound or a carboxylic acid.
(b). Burn a small amount of **G** on a spatula or porcelain dish.	**G** burns with a yellow non-sooty flame.	Probably **G** is an aliphatic compound with high molecular mass.
(c). Divide the remaining **G** in to five portions. (i). To the 1st portion, add 3cm^3 of water. Test the solution with litmus paper.	**G** is miscible with water, it's neutral to litmus.	Probably **G** is an aliphatic neutral compound such as an alcohol, ketone or aldehyde.
(ii). To the 2nd portion, add acidified potassium dichromate (VI) solution and heat.	**G** turns acidified potassium dichromate (VI) solution from orange to green.	**G** is a reducing agent. Ketone absent, Probably an aliphatic aldehyde, secondary or primary alcohol present.
(iii).To the 3rd portion, add about 3cm^3 of Brady's reagent.	A yellow precipitate was formed.	Secondary or primary alcohol absent. An aliphatic aldehyde is suspected present.
(iv). To the 4th portion, add silver nitrate solution followed by ammonia solution and warm.	A silver mirror deposited on the sides of the test tube.	An aliphatic aldehyde is confirmed present.
(v).To the 5th portion, add 2cm^3 of Lucas' reagent.	No cloudy solution was formed.	Secondary or tertiary alcohol absent. An aliphatic aldehyde is present.

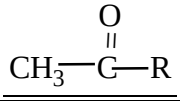
Name:

(i). the functional group(s) in **G**:
Carbonyl group.

(ii). the class of compounds to which **G** belongs to.
G is an aliphatic aldehyde.

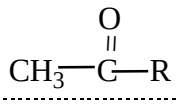
Experiment 2 (H = Acetone or Butanone):

2. You are provided with substance **H** which is an organic compound. You are required to determine the nature of **H**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions
(a).Burn a spatula end-ful of H on a procelain dish (or at the end of a spatula).	Colourless liquid that burns with a blue-non sooty flame.	Aliphatic saturated compound with low C: H ratio or with low carbon content.
(b).Add $2cm^3$ of distilled water to $1cm^3$ of H. Test the mixture with litmus paper.	Dissolves/soluble or miscible with water to form a colourless solution that has no effect on litmus papers.	Polar aliphatic compound of low molecular mass. ∴alcohols, ketones, aldehydes, ester or carboxylic acid are suspected present.
(c).To $1cm^3$ of H, add Brady's reagent.	Yellow precipitate	Aldehyde, ketone & carboxylic acid are suspected present.
(d).To $4cm^3$ of saturated sodium hydrogen sulphite solution, add $2cm^3$ of H.	White precipitate is seen.	Aldehyde & ketone are suspected present.
(e).To 5 drops of H, add $4cm^3$ of iodine solution followed by dilute sodium hydroxide solution until the solution is pale-yellow. Warm the mixture gently & then cool.	Yellow precipitate	CHI_3 is formed. ∴Ketone with a methyl group attached to the carbon carrying the functional group or ethanol or ketone of the type: 
(f).To $3cm^3$ of H, add $1cm^3$ of acidified potassium dichromate (VI) solution & warm the mixture.	No observable change occurs.	Ethanol is suspected absent. ∴Ketone is suspected present.

(g).To 3cm^3 of silver nitrate solution, add 2 drops of dilute sodium hydroxide solution. Then add ammonia solution drop wise until the precipitate just dissolves, Add about 5cm^3 of H & warm.	No observable change occurs. Or: No silver mirror.	Aldehyde is suspected absent. ∴Ketone is suspected present.

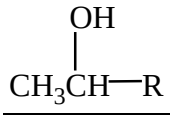
From your results above, comment on the nature of compound H.
H is saturated aliphatic ketone with a methyl group attached to the carbon atom carrying the functional group or ketone of the type:



Experiment 3 (B = Propan-2-ol or Butan-2-ol):

3. You are provided with substance **B** which is an organic compound. You are required to determine the nature of **B**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

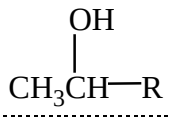
Tests	Observations	Deductions
(a).Burn a small amount of B on a spatula end or in a porcelain dish.	Colourless liquid that burns with a yellow non-sooty flame.	Saturated aliphatic compound with low C: H ratio or low carbon content.
(b).Add 6 drops of B to about 3cm^3 of distilled water, shake & allow to stand. Divide the solution in to three parts.	Miscible with water/dissolves to form a colourless solution that has no effect on litmus.	Polar aliphatic compound of low molecular mass or neutral compound probably alcohol, ketone, aldehyde or ester.
b.(i).To the 1st part of the solution, add 2-3 drops of dilute sodium hydrogen carbonate solution.	No observable change/ No effervescence.	Carboxylic acid is suspected present.
b.(ii).To the 2nd part of the solution, add 2-3	No observable change.	Phenol is suspected absent.

drops of iron (III) chloride solution.		
b.(iii).To the 3rd part of the solution, add 2-3 drops of Brady's reagent.	No observable change. Or No yellow precipitate.	Ketone & aldehyde are suspected absent.
(c).Add 2-3 drops of acidified potassium dichromate (VI) solution to 2cm^3 of B in a test tube & then heat. Divide the resultant solution in to two parts.	Solution turns from orange to green.	Reducing agent probably primary & secondary alcohols are suspected present.
c.(i).To the 1st part of the resultant solution, add Brady's reagent.	Yellow precipitate.	Primary & secondary alcohols are oxidized to carbonyl.
c.(ii).To the 2nd part of the solution, add Tollen's reagent and warm.	No observable change occurs.	Aldehyde not formed. ∴ Primary alcohol is suspected absent.
(d).To about 0.5cm^3 of B, add about 4cm^3 of iodine solution followed by dilute sodium hydroxide solution drop wise until a pale yellow solution is formed. Heat & allow to stand.	Yellow precipitate is formed.	CHI_3 formed. ∴Secondary alcohol of the type, 
(e).To about 1cm^3 of B, add 5 drops of Luca's reagent.	Cloudy solution formed within 5-10 minutes.	Secondary alcohol is presnt.

Comment on the nature of compound B.

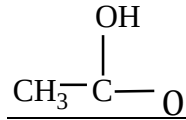
B is saturated aliphatic secondary alcohol with a methyl group attached to the carbon atom carrying the functional group.

∴ Secondary alcohol of the type:



Experiment 4 (C = Propan-2-ol or Ethanol):

4. You are provided with substance **C** which is an organic compound. You are required to determine the nature of **C**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

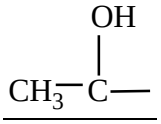
Tests	Observations	Deductions
(a).Burn a small amount of C on a crucible lid or spatula end.	Colourless liquid that burns with a blue non-sooty flame.	Saturated aliphatic compound with C: H ratio.
(b).To 5 drops of C, add about $1cm^3$ of distilled water & shake. Test the mixture with litmus.	Dissolves to form a colourless solution & solution has no effect on litmus paper.	Polar aliphatic compound with low molecular mass. ∴Neutral compound like alcohol, ketone, aldehyde or ester.
(c).To 5 drops of C, add 2-3 drops of acidified potassium manganate (VII) solution & warm.	Purple solution turns to colourless.	Reducing agent probably primary & secondary alcohols or aldehyde are suspected present.
(d).To 5 drops of C, add $1cm^3$ of iodine solution followed by dilute sodium hydroxide solution drop wise until the mixture is pale-yellow. Warm, then cool under running tap	Pale-yellow precipitate	Alcohol of the type:  Or ethanol. ∴Yellow precipitate is CHI_3.
(e).To 5 drops of C, add 2-3 drops of Brady's reagent.	No observable change occurs.	Aldehyde & ketone are suspected absent.
(f).Carry out a test of your own choice to confirm the functional group in C.		

Test: To a few drops of C, add 3 drops of ethanoic acid followed by 2 drops of concentrated sulphuric acid & warm. Or	Colourless solution with pleasant fruity (sweet) smell.	Ester is formed. ∴Alcohol is conformed present.
Add phosphorus pentachloride solution or add sodium metal. Or	White fumes which forms dense white fumes with concentrated ammonia solution.	
Add concentatred sulphuric acid & heat.	Effervescence of colourless gas that turns potassium permanganate (VII) solution from orange to colourless.	Alkene. ∴Alcohol is present.

Comment on the nature of C.

C is saturated aliphatic primary or secondary alcohol.

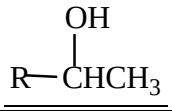
∴ Primary or secondary alcohol of the type:



Experiment 5 (D = 2-Methylpropan-2-ol):

5. You are provided with substance **D** which is an organic compound. You are required to determine the nature of **D**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions
(a).Burn a spatula end-ful of D on a porcelain dish or at the end of spatula.	Colourless liquid that burns with a yellow non-sooty flame.	Aliphatic compound with low C: H ration. Or Saturated aliphatic compound of low carbon content.
(b).Shake 1cm^3 of D with about 3cm^3 of distilled water & test	Immiscible with water. Mixture has no effect on litmus.	Neutral compound probably alcohol, esters re carbonyl

the solution with litmus. Divide the solution in to three parts.		compound s are suspected present.
b.(i).To the 1st part of the solution, add 2-3 drops of sodium carbonate solution.	No observable change occurs. Or No effervescence.	Carboxylic acid is suspected absent.
b.(ii).To the 2nd part of the solution, add 2-3 drops of iron (III) chloride solution.	No observable change occurs. Or No violet colouration.	Phenol is suspected absent.
b.(iii).To the 3rd part of the solution, add 2-3 drops Brady's reagent.	No observable change occurs. Or No yellow precipitate.	Ketone & aldehyde are suspected absent.
(c).To about 1cm^3 of D, add about equal volume of ethanoic acid followed by 4-5 drops of concentrated sulphuric acid. Heat the mixture & pour it in to a small beaker of cold water & stir.	Colourless solution with a pleasant fruity (sweet) smell.	Ester is formed. ∴Alcohol is suspected present.
(d).To about 0.5cm^3 of D, add about 4cm^3 of iodine solution followed by sodium hydroxide solution drop wise until the solution is pale yellow. Warm the mixture & allow to stand.	No observable change Or No yellow precipitate.	Alcohol with methyl radical group attached to the carbon atom containing the functional group is absent. Or 
(e).To about 1cm^3 of D, add about 5 drops of Lucas 'reagent.	Immediate cloudiness Or White precipitate is formed immediate.	Tertiary alcohol is present.

Comment on the nature of D.
D Tertiary alcohol.

Experiment 6 (E = Methanoic acid):

6. You are provided with substance **E** which is an organic compound. You are required to determine the nature of **E**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions
(a).Burn a small amount of E on a crucible lid or spatula end.	Colourless liquid that burns with a blue non-sooty flame.	Aliphatic saturated Or Low C: H ratio or carbon content.
(b).To about $1cm^3$ of E, add about $1cm^3$ of dilute sodium hydroxide solution.	Readily miscible soluble/dissolves to form colourless solution.	Acidic compound probably carboxylic acid is suspected present.
(c).To about $1cm^3$ of E, add 2-3 drops of neutral iron (III) chloride solution & warm.	No observable change occurs. Or No violet/purple	Phenol is suspected absent.
(d).To about $1cm^3$ of E, add about $1cm^3$ of distilled water. Shake & allow to stand. Test the resultant solution with litmus paper & divide the solution in to two portions.	Miscible/soluble/dissolves in water to form a colourless solution that turns blue litmus red.	Carboxylic acid is suspected present.
d.(i).To the 1^{st} portion of the solution, add $1cm^3$ of sodium hydrogen carbonate solution.	Effervescence colourless gas that turns lime water milky.	Carboxylic acid is confirmed present.
d.(ii).To the 2^{nd} portion of the solution, add 2-3 drops of Brady's reagent.	Yellow precipitate	Methanoic acid is suspected present.

(e).To about 0.5cm^3 of E, add about 1cm^3 of Tollen's reagent, warm & allow the mixture to stand.	Silver mirror is formed.	Methanoic acid is confirmed present.

From your results above, deduce the nature of compound E.
E is a saturated aliphatic carboxylic acid or simply methanoic acid.

Experiment 7:

7. You are provided with substance **F** which is an organic compound. You are required to determine the nature of **F**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions
(a).Burn a spatula end-ful of F on a porcelain dish or at the end of a spatula.	White solid burns with a yellow sooty flame.	Aromatic compound. Or Aliphatic unsaturated. Or Aliphatic with high C: H ratio or high content of carbon.
(b).Transfer two spatula end-fuls of F to a test tube containing 5cm^3 of distilled water, warm the mixture & test with litmus. Divide the warmed solution in to four parts	Sparingly soluble in cold water but dissolves on warming to form a colourless solution that turns blue litmus red/	High molecular mass polar, acidic compound probably phenol & carboxylic acid are suspected present.
(b).(i).To the 1st part of the warmed solution, add 2-3 drops of sodium carbonate solution.	Slight effervescence. Or Colourless gas bubbles.	Carboxylic acid is suspected present.
b.(ii).To the 2nd part of the warmed solution, add 2-3 drops of iron (III) chloride solution.	No observable change occurs.	Phenol is suspected absent.
b.(iii).To the 3rd part of the warmed solution, add 2-3 drops of	No observable change occurs.	Primary, secondary alcohols or aldehyde are suspected absent.

potassium dichromate (VII) solution and warm.		
(c).Dissolves one spatula end-ful of F in $2cm^3$ of methanol & add 2-3 drops of Brady's reagent.	No observable change occurs. Or No orange precipitate.	Carbonyl compounds are suspected absent.
(d).To about a spatula end-fuls of F, add about $5cm^3$ of ethanol followed by 2-3 drops of concentrated sulphuric acid. Heat the mixture & pour it in to a small beaker of cold water, allow to stand.	Pleasant fruity (sweet) smelling liquid.	Ester is formed. ∴Carboxylic acid is suspected present.
(e).To a spatula end ful of F in a test tube, add $3cm^3$ of distilled water, warm and add 2-3 drops of acidified potassium permanganate (VII) solution.	Purple solution turns to colourless solution.	Unsaturated compounds are suspected present.

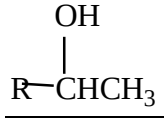
From your results above, Comment the nature of compound F.
F is unsaturated aromatic carboxylic acid.

Experiment 8 (G = Secondary alcohol):

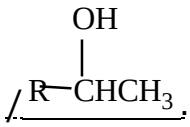
8. You are provided with substance **G** which is an organic compound. You are required to determine the nature of **G**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

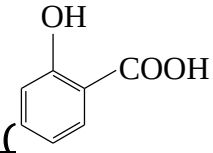
Tests	Observations	Deductions
(a).Burn a small amount of G on a spatula end.	Colourless liquid that burns with a yellow non-sooty flame.	Aliphatic saturated/with low C: H ratio or low carbon content.

(b).To about $1cm^3$ of G, add about $2cm^3$ of distilled water, shake & test the mixture with litmus. Divide the mixture in to three parts.	Miscible/soluble/dissolves in water to form colourless solution which has no effect on litmus.	Polar aliphatic compound with low molecular mass. Neutral compound probably alcohol, carbonyl or ester.
b.(i).To the 1st part of the mixture, add 2-3 drops of Brady's reagent.	No observable change occurs.	Carbonyl compound is suspected absent.
b.(ii).To the 2nd part of the mixture, add 2-3 drops of iron (III) chloride solution.	No observable change occurs.	Phenol is suspected present.
(c).To the 3rd part of the mixture above, add 2-3 drops of acidified $K_2Cr_2O_{7(aq)}$. Heat the mixture & divide the solution in to two parts.	Orange solution turns to green.	Primary & secondary alcohol are suspected present.
c.(i).To the 1st part of the solution, add 2-3 drops of Brady's reagent.	Yellow precipitate.	Primary & secondary alcohol are oxidized to carbonyl compounds.
c.(ii).To the 2nd part of the solution, add about 2-3 drops of Tollen's reagent & warm.	No observable change occurs.	Aldehyde not formed from oxidation. ∴ Primary alcohol is suspected absent. Or Secondary alcohol is oxidized to alkanone.
(d).To about $0.5cm^3$ of G, add 2-3 drops of Lucas reagent.	Cloudy solution formed within 5-10 minutes.	Secondary alcohol is suspected present.

(e).To about 0.5cm^3 of G, add 2-3 drops of sodium hydroxide solution followed by iodine solution until the solution is pale-yellow. Warm the mixture & allow to stand.	Yellow precipitate.	Secondary alcohol with a methyl radical adjacent to the carbon atom carrying the functional group. Or: 

From your results above, Comment the nature of compound G.
G is aliphatic secondary alcohol with a methyl group adjacent to the carbon atom carrying the functional group.



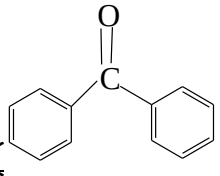
Experiment 9 (H = Salicylic acid () :

9. You are provided with substance **H** which is an organic compound. You are required to determine the nature of **H**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions
(a).Burn a small amount of H on a spatula end-ful or on a crucible lid.	White solid burns with a yellow sooty flame.	Aromatic compound. Or Aliphatic unsaturated compound. Or Aliphatic of compound with low C: H ratio.
(b).Add a spatula end-ful of H to about 5cm^3 of sodium hydroxide solution.	Readily soluble/dissolves to form a colourless solution.	Acidic compound probably carboxylic acid & phenol are suspected present.
(c).To spatula end-ful of H in a test tube add about 5cm^3 of water. Shake vigorously &	Slightly soluble in cold water & dissolves on warming forming a colourless solution that	High molecular mass/aromatic compound which is acidic probably

warm. Test the solution with litmus paper & divide it in to three equal portions.	turns blue litmus paper red.	carboxylic acid & phenol are suspected present.
c.(i).To the 1st portion of the solution, add 2-3 drops of Brady's reagent.	No observable change occurs. Or No orange precipitate.	Carbonyl compounds are suspected absent.
c.(ii).To the 2nd part of the solution, add 2-3 drops of iron (III) chloride solution.	Violet/purple colouration.	Phenol is suspected present.
c.(iii).To the 3rd portion of the solution, add a spatula end-ful of solid sodium hydrogen carbonate.	Effervescence/bubbles of colourless gas.	Carboxylic acid is suspected present.
(d).To 2cm^3 of ethanol, add a spatula end-fuls of H then add 2-3 drops of concentrated sulphuric acid & warm the mixture.	Sweet fruity smell.	Esterification has occurred. ∴Carboxylic acid is confirmed present.

From your results above, Comment the nature of compound H.
H is aromatic compound with a hydroxyl group attached to the benzene ring & also contains a carboxyl (-COOH) group.
Or aromatic carboxylic acid with a hydroxyl group attached to.

Experiment 10 (J = Benzoquinone ( **) :**

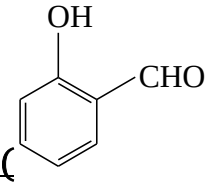
10. You are provided with substance **J** which is an organic compound. You are required to determine the nature of **J**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions

(a).Burn a spatula end-ful of J in a porcelain dish or at the end of a spatula.	White crystalline solid burns with a yellow sooty flame.	Aromatic compound. Or Unsaturated aliphatic compound. Or Aliphatic compound with high C: H ratio.
(b).Shake two spatula end-fuls of J with about 5cm^3 of distilled water, warm & test with litmus.	Insoluble in cold water but slightly soluble on warming. Solution formed has no effect on litmus.	High molecular mass / aromatic compound. ∴Neutral compound probably alcohol, ester or carbonyl are suspected present.
(c).Dissolve two spatula end-fuls of J in methanol & divide the solution in to four parts.		
c.(i).To the 1st part of the solution, add 2-3 drops of iron (III) chloride solution.	No observable change occurs. Or No violet/purple colouration.	Phenol is suspected absent.
c.(ii).To the 2nd part of the solution, 2-3 drops of Brady's reagent.	Orange (Yellow) precipitate.	Carbonyl compound is suspected present.
c.(iii).To the 3rd part of the solution, add about 1cm3 of Fehling's solution & boil.	No observable change occurs. Or No red precipitate/ Reddish-brown.	Alkanal (Aldehyde) is suspected absent. ∴Ketone is suspected present.
c.(iv).To the 4th part of the solution, add about 1cm^3 of iodine solution followed drop wise addition of sodium hydroxide solution until the	No observable change occurs. Or No yellow precipitate.	No methyl group attached to the carbonyl compound.

solution is pale-yellow & warm.		

From your results above, Comment the nature of compound J.
J is aromatic ketone without a methyl group attached to the carbon carrying the functional group.



Experiment 11 (K = Vaniline ( ) :

11. You are provided with substance **J** which is an organic compound. You are required to determine the nature of **J**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions
(a).Burn a small amount of K on a spatula end.	White crystals/solid burns with a yellow sooty flame.	Aromatic compound. Or Aliphatic unsaturated compound. Or Aliphatic compound with low C: H ration.
(b).To a spatula end-ful of K in a test tube, add 3cm^3 of sodium hydroxide solution followed by dilute sulphuric acid.	Dissolves in sodium hydroxide solution to form a colourless solution & on adding dilute sulphuric acid, white precipitate is formed.	Acidic compound probably phenol & carbonyl compounds are suspected present.
(c).To a spatula end-fuls of K in a test tube, add about 4cm^3 of water, warm the mixture & test the solution with litmus. Divide the solution in to five parts.	Insoluble in cold, but dissolves on warming to form a colourless solution that turns blue litmus to red.	High molecular mass/aromatic compound probably phenol & carboxylic acid are suspected present.
c.(i).To the 1st part of the solution, add a half spatula end-ful of sodium carbonate.	No observable change occurs. Or No effervescence.	carboxylic acid is suspected absent

c.(ii).To 2nd part of the solution, add neutral iron (III) chloride solution.	Purple/violet solution is formed.	Phenol is confirmed present.
c.(iii).To the 3rd part of the solution, add 3-4 drops of acidified potassium manganate (VII) solution & warm.	Purple solution of $KMnO_{4(aq)}$ turns to colourless.	Primary, secondary alcohol & aldehyde are suspected present.
c.(iv).To the 4th part of the solution, add 2-3 drops of Brady's reagent.	Orange precipitate is formed.	Aldehyde is suspected present.
c.(v).To the 5th part of the solution, add fehling's solution & heat.	Red precipitate. Or Reddish-brown precipitate. Or Brown precipitate.	Aldehyde is suspected present.
(d).To about $3cm^3$ of silver nitrate solution, add 2 drops of sodium hydroxide solution followed by ammonia solution until the precipitate is just dissolves. Add a spatula end-ful of K, shake & heat in water bath for about 5 minutes.	Silver mirror is formed.	Aldehyde is confirmed present.

From your results above, Comment the nature of compound K.

K is aromatic aldehyde with an –OH group attached to the carbon benzene ring.

Or

K is an aromatic compound with both –OH group and aldehyde group attached the ring. Or K is a phenol with an aldehyde group.

Experiment 12 (L = 2-methylpropan-2-ol:

12.You are provided with substance **L** which is an organic compound. You are required to determine the nature of **L**. carry out the following tests and identify any gases liberated. Record your observations in the table below.

Tests	Observations	Deductions
(a).Burn a spatula end-ful of L on a porcelain.	Colourless liquid that burns with a yellow sooty flame.	Aromatic compound. Or Aliphatic unsaturated compound. Or Aliphatic with high C: H ratio. Or High carbon content.
(b).Shake 1cm^3 of L with about 2cm^3 of distilled water & test with litmus paper. Divide the mixture in to four parts.	Miscible with/soluble/dissolves to form a colourless solution. Solution has no effect no effect on litmus.	Polar aliphatic compound of low molecular mass. Or Neutral compound probably alcohol, ester or carbonyl compounds.
b.(i).To the 1st part of the mixture, add 2-3 drops of sodium carbonate solution.	No observable change occurs. Or No effervescence.	Carboxylic acid is suspected absent.
b.(ii).To 2nd part of the mixture, add 2-3 drops of neutral iron (III) chloride solution	No observable change occurs. Or No violet/purple colouration.	Phenol is suspected absent.
b.(iii).To the 3rd part of the mixture, add 2-3 drops of Brady's reagent.	No observable change occurs. Or No yellow precipitate.	Ketone & aldehyde are suspected absent.
b.(iv).To the 4th part of the mixture, add 2-3 drops of acidified potassium dichromate (VI)	No observable change occurs.	Reducing agent i.e primary & secondary alcohols are suspected present.

solution & heat the mixture.		
(c).To about $1cm^3$ of L, add 4 drops of Lucas reagent.	Cloudy solution is formed immediately.	Tertiary alcohol is suspected present.
(d).To about $1cm^3$ of L, add about an equal volume of ethanoic acid followed by 4-5 drops of concentrated sulphuric acid. Heat the mixture & pour it in to a beaker of water.	Sweet fruity smell.	Ester is formed. ∴Alcohol is suspected present.
(e).To about $1cm^3$ of L, add about $1cm^3$ of concentrated sulphuric acid. Heat the mixture & pass the gas produced through acidified potassium manganate (VII) solution	White fumes/colourless gas that turns acidified potassium manganate (VII) solution from purple to colourless.	Alkene is formed. ∴Alcohol is suspected present. Or Alcohol is dehydrated to an alkene.

Comment on the nature of L.
L is aliphatic tertiary alcohol.