O Level

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O Level

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O Level Chemistry

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Introduction

This book has been designed to help students to prepare for their Cambridge International O-level chemistry examinations. It is a **revision guide**, which can be used alongside regular textbooks through out the course, and also towards the end when students are revising for their final examination.

I have tried my best to make this book a perfect guide. It covers all the topics in a lucid and to-the-point style, avoiding unnecessary details.

The topics are numbered and entitled as set by the GCE O-Level Syllabus. Every topic starts with the **syllabus content** and **learning outcomes**. The topics are subdivided into key points and unnecessary details have been avoided. Important terms are shown in bold so that they can be easily caught by the eyes.

I hope this book will serve as a good **Reference Book** for students. I would really welcome and appreciate feedback from students and teachers.

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Contents

9. Metals

11. Organic Chemistry

Full Course Formulae

Unit	Formulae
1.2 Methods of Purification and Analysis	R_f value = $\dfrac{\text{distance travelled by the substance}}{\text{distance travelled by solvent}}$
2.2 Atomic Structure	Neutron Number (N) = Nucleon Number (A) - Proton Number (Z)
3. Formulae, Stoichiometry and the Mole Concept	relative atomic mass (A_r) = $\dfrac{\text{mass of one atom of an element}}{\text{mass of 1/12 of an atom of carbon-12}}$
	relative molecular mass (M_r) = $\dfrac{\text{mass of one molecule of an element or compound}}{\text{mass of 1/12 of an atom of carbon-12}}$
	percentage composition of element = $\dfrac{A_r \text{ of element} \times \text{No. of atoms of element in formula}}{M_r \text{ of compound}} \times 100\%$
	molecular formula = ***n*** (empirical formula) where $n = \dfrac{\text{relative molecular mass } (M_r)}{\text{empirical formula mass}}$
	number of moles = $\dfrac{\text{number of particles}}{6 \times 10^{23}}$
	number of moles = $\dfrac{\text{mass of substance in g}}{A_r \text{ or } M_r \text{ in g}}$

Unit	Formulae
3. Formulae, Stoichiometry and the Mole Concept	$\text{number of moles} = \dfrac{\text{volume in dm}^3\text{ at r.t.p.}}{24\text{ dm}^3}$ $\text{number of moles} = \dfrac{\text{volume in cm}^3\text{ at r.t.p.}}{24000\text{ cm}^3}$
	$\text{concentration of solution} = \dfrac{\text{amount of solute in g or in mol}}{\text{volume of solution in dm}^3}$
	$\text{percentage yield} = \dfrac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$
	$\text{percentage purity} = \dfrac{\text{mass of pure substance in sample}}{\text{mass of sample}} \times 100\%$

The Periodic Table of Elements

Group																	
I	II											III	IV	V	VI	VII	VIII
								1 H hydrogen 1									2 He helium 4
3 Li lithium 7	4 Be beryllium 9		**Key** atomic number atomic symbol name of element relative atomic mass									5 B boron 11	6 C carbon 12	7 N nitorgen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg megnesium 24											13 A*l* aluminium 27	14 Si silicon 28	15 P phosphorous 31	16 S sulfur 32	17 C*l* chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zironium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium -	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs cesium 133	56 Ba barium 137	57-71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 T*l* thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium -	85 At astatine -	86 Rn radon -
87 Fr fransium -	88 Ra radium -	89-103 actinoids	104 Rf rutherfordium -	105 Db dubnium -	106 Sg seaborgium -	107 Bh bohrium -	108 Hs hassium -	109 Mt meitnerium -	110 Ds darmstadtium -	111 Rg roentgenium -	112 Cn copernicium -		114 F*l* flerovium -		116 Lv livermorium 292		

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium -	62 Sm smarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium -	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium -	94 Pu plutonium -	95 Am americium -	96 Cm curium -	97 Bk berkelium -	98 Cf californium -	99 Es einstenium -	100 Fm fermium -	101 Md mendelevium -	102 No nobelium -	103 Lr lawrencium -

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.)

UNIT 1.1

Experimental Design

O Level Chemistry (5070)
Revision Guide

Syllabus 2017 - 2019

Content

1.1 Experimental Design

Learning Outcomes

Candidates should be able to:

(a) name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes, measuring cylinders and gas syringes

(b) suggest suitable apparatus, given relevant information, for a variety of simple experiments, including collection of gases and measurement of rates of reaction

Unit 1.1 Experimental Design

1.1.1 Experimental Design

- The subject of chemistry involves the measurement of various quantities, like time, temperature, mass, volume and density *etc*.
- Scientists all over the world use **SI units** and their sub-units for the measurement of various quantities.

Quantities	SI Units	Symbols
Mass	kilogram	kg
Time	second	s
Temperature	Kelvin	K
Volume	cubic meter	m^3
Density	kilogram/cubic meter	$kg\ m^{-3}$

table 1.1.1

Measurement of Time

- In laboratory, time intervals are measured using **stopwatches** and **stopclocks**.
- SI unit for time is second (s). Other units, such as **minutes** (min) and **hours** (h) are used to measure longer intervals of time. Remember that

1 min = 60 s
1 h = 60 min = 3600 s

- A common stopwatch can measure a time interval correct upto 0.01s.

fig. 1.1.2

Measurement of Temperature

- In laboratory, the temperature of a liquid or gas is measured using a **mercury-in-glass thermometer**.
- Alcohol-in-glass thermometer and electronic thermometer are also used.
- Two scales, **degree Celsius** (°C) and **Kelvin** (K) are commonly used for temperature measurement. They are related as follows

temperature in K = temperature in °C + 273

- A mercury-in-glass thermometer can measure temperatures from -20 °C to 110 °C.

fig. 1.1.3

Measurement of Mass

- The mass of a substance is the amount of matter it contains.
- SI unit for mass is **kilogram** (kg). However, smaller units like **gram** (g) and **milligram** (mg) are used for smaller amounts while **kilogram** (kg) and **tonnes** are used for larger amounts. Remember that

1 tonne = 1000 kg
1 kg = 1000 g
1 g = 1000 mg

- In laboratory, the mass of a substance is measured using beam balance or electronic balance.
- Electronic balances are more commonly used as compared with beam balance because they are easier to use and measure accurately to 0.01g or even 0.001g.

fig. 1.1.4

Measurement of Volume

- The volume of a substance is the amount of space it occupies.
- SI unit of volume is **cubic metre** (m^3). However, different smaller units are also used for measuring volume such as **cubic centimetres** (cm^3), **cubic decimetres** (dm^3), **litres** (L) and **millilitres** (ml). Remember that

$1\ m^3 = 1000\ dm^3$
$1\ dm^3 = 1000\ cm^3$
$1\ L = 1\ dm^3$
$1\ L = 1000\ ml$

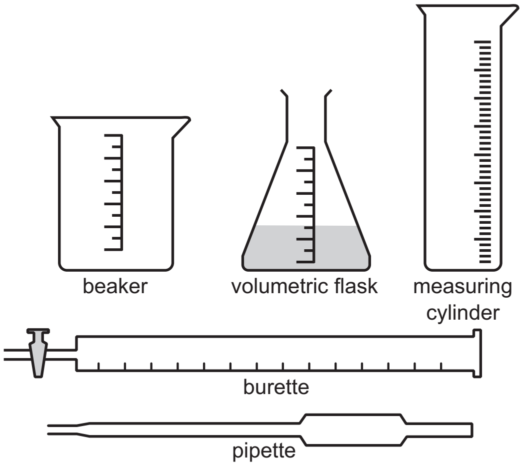

fig. 1.1.5

- The various pieces of apparatus used for measuring volume of a liquid are **beaker, measuring cylinder, pipette, burette** and **volumetric flask**.
  i. A graduated beaker measures approximate volume of a liquid.
  ii. A pipette measures fixed volumes very accurately. Pipettes of volumes 10 cm^3, 20 cm^3 and 25 cm^3 are used in laboratory.
  iii. For accurate measurement of the volume of a liquid, a measuring cylinder is used. It measures the volume of a liquid correct to 1 cm^3.
  iv. For more accurate measurement, a burette is used which can measure the volume of a liquid correct to 0.1 cm^3.
  v. Volumetric flasks are used to measure fixed volumes of liquids. Volumetric flasks of 100 cm^3, 250 cm^3, 500 cm^3 and 1 dm^3 are available in the laboratory.
  Volumetric flasks are also used for preparing solutions of known concentrations.

How to Read the Volume of a liquid?

- Whenever a liquid is placed in a container, it forms a curved surface. This curved surface is called **meniscus**.
- A meniscus may be **concave** or **convex**.
- To read the volume of a liquid, align your eyes to the liquid level. If the meniscus is concave, read off the scale at the bottom of the meniscus. If the meniscus is convex, read off the scale at the top of the meniscus.

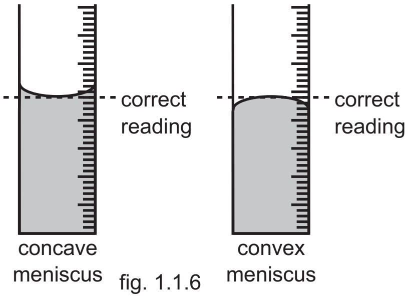

fig. 1.1.6

1.1.2 Collection of Gases

- In a chemical reaction where a gas is given off, the speed of a chemical reaction can be measured by recording the volume of gas given off in a certain time interval. For this purpose **gas syringes** are used.
- A common gas syringe can measure the volume of a gas upto 100 cm^3.
- To collect a gas, two properties may be taken into consideration:
    - **i. its density with respect to air**
    - **ii. its solubility in water**
- There are three methods to collect gases,
    - **i. Displacement of water**
    - **ii. Downward Delivery (**or **Upward Displacement of Air)**
    - **iii. Upward Delivery (**or **Downward Displacement of Air)**

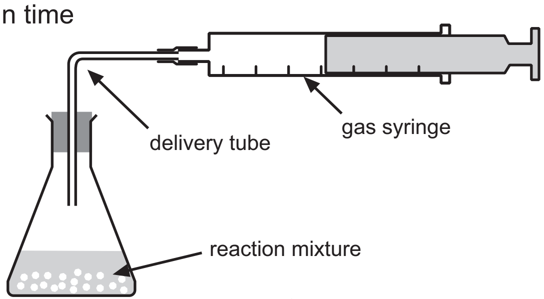

fig. 1.1.7

Displacement of water

- This method is suitable for collecting gases that are insoluble or slightly soluble in water such as **carbon dioxide** (CO_2)**, hydrogen** (H_2) and **oxygen** (O_2). In this method, the gas is passed through water into an upside down jar full of water; the gas starts collecting on the top while the water gets displaced downwards.

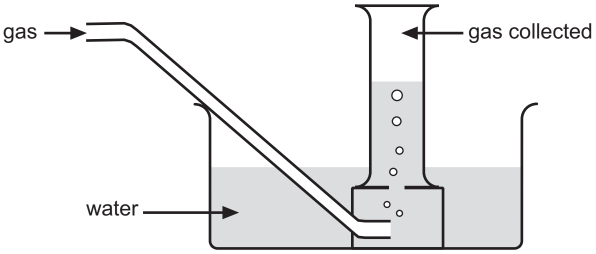

fig. 1.1.8

Downward Delivery

- This method is suitable for collecting gases that are soluble in water and denser than air such as **chlorine** (Cl_2) and **hydrogen chloride** (HCl). In this method, the gas is introduced in a gas jar. Being heavier it starts settling at the bottom and leaving the air to escape from the mouth of the jar. This method is also called **upward displacement of air**.

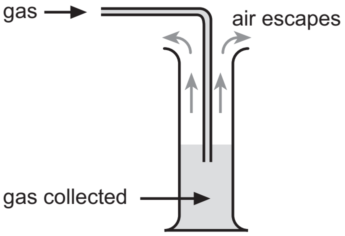

fig. 1.1.9

Upward Delivery

- This method is suitable for collecting gases that are soluble in water and lighter than air such as **ammonia** (NH_3). In this method, the gas is introduced into an upside down gas jar. Being lighter than air, the gas starts rising at the top and leaves the air to escape from the bottom end of the jar. This method is also called **downward displacement of air**.
- Generally, a gas is considered to be less dense than air if its molecular mass is less than 30.

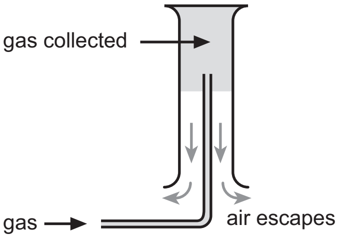

fig. 1.1.10

- The table given as below shows the solubility and density of some common gases.

Gas	Solubility in Water	Density
hydrogen	insoluble	less denser
oxygen	slightly soluble	slightly denser
chlorine	soluble	denser
carbon dioxide	slightly soluble	denser
ammonia	extremely soluble	less denser
hydrogen chloride	very soluble	denser

table 1.1.11

Drying of Gases

- Some gases when collected over water contain water vapour as impurity. In order to collect a dry sample of a gas, it should be passed through a drying agent.
- Some commonly used drying agents are
  - **i.** **conc. sulfuric acid** (H_2SO_4)
  - **ii.** **quicklime** *i.e.* **calcium oxide** (CaO)
  - **iii.** **sodalime** (mixture of sodium hydroxide and calcium hydroxide)
  - **iv.** **fused calcium chloride** ($CaCl_2$) *i.e.* calcium chloride that has been previously heated
- Different sets of apparatus are used for different gases and drying agents.

Using Conc. Sulfuric Acid (H_2SO_4)

- To dry a gas with concentrated sulfuric acid, a double neck bottle or a conical flask with two delivery tubes (see fig. 1.1.12) are used. The tube introducing the gas should be immersed in the acid while the exiting tube should remain out of the acid.
- Concentrated sulfuric acid is used to dry gases such as **chlorine** (Cl_2) and **hydrogen chloride** (HCl). It cannot be used for **ammonia** (NH_3) which is alkaline and leads to a chemical reaction.

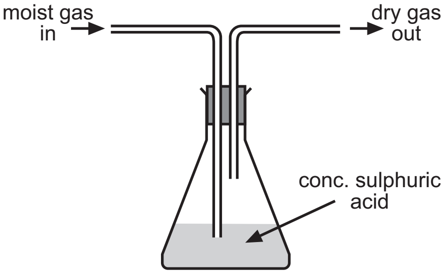

fig. 1.1.12

Using Solid Drying Agents

- Solid drying agents such as quicklime, sodalime or fused calcium chloride are used for drying gases which may react with conc. sulfuric acid *e.g.* ammonia (NH_3).
- The drying of gases through solid drying agents require a U-shaped tube or a specially designed jar with two openings one at the bottom and the other at the top.

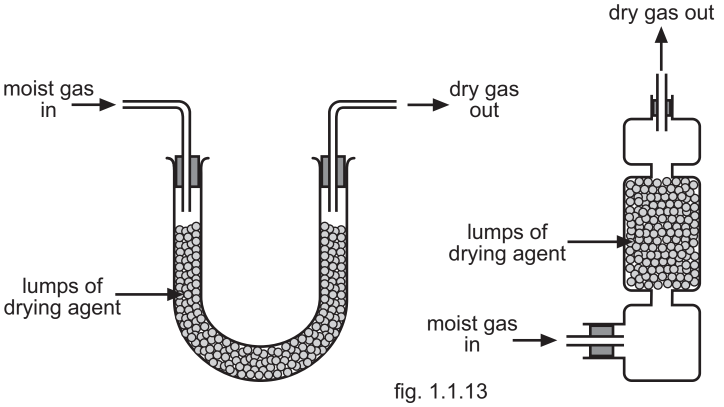

fig. 1.1.13

UNIT 1.2

Methods of Purification and Analysis

O Level Chemistry (5070)
Revision Guide

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Content
1.2 Methods of Purification and Analysis

Learning Outcomes
Candidates should be able to:
(a) describe methods of purification by the use of a suitable solvent, filtration and crystallisation, distillation and fractional distillation, with particular references to the fractional distillation of crude oil, liquid air and fermented liquor
(b) suggest suitable methods of purification, given information about the substances involved
(c) describe paper chromatography and interpret chromatograms including comparison with ‘known’ samples and the use of R_f values
(d) explain the need to use locating agents in the chromatography of colourless compounds
(e) deduce from the given melting point and boiling point the identities of substances and their purity
(f) explain that the measurement of purity in substances used in everyday life, *e.g.* foodstuffs and drugs, is important

Unit 1.2 Methods of Purification and Analysis

Pure and Impure Substances

- A **pure substance** is a single substance *i.e.* it is made up of same particles.
- An **impure substance** is mixture of two or more substances that are not chemically combined.

Purity of a Substance

- A **pure solid** has a fixed and exact melting point.
- Presence of impurity lowers the melting point and causes the substance to melt over a range of temperature. For example, pure ice melts at exactly 0 °C at normal atmospheric pressure. When salt is added, it lowers the melting point to values between -5 °C to -25 °C, depending upon the quantity of salt added.
- In cold countries, salt is spread on icy roads to melt the ice. Similarly, sea water does not freeze at 0 °C rather it freezes at much lower temperature due to the presence of dissolved salts.
- A **pure liquid** also has a fixed and exact boiling point.
- Presence of impurity raises the boiling point and causes the liquid to boil over a range of temperature. For example, pure water boils at exactly 100 °C at normal atmospheric pressure. When salt is added, it raises the boiling point to values between 105 °C to 112 °C, depending upon the quantity of salt added.

1.2.1 Purification and Separation Techniques

- **Purification** means to remove unwanted materials from a given substance.
- In chemistry, the term **purification** is applied to a physical process in which different components of a mixture are separated using physical methods.
- Many purification techniques are used to purify mixtures. While choosing a suitable technique, one should take into account the properties of each substance present in the mixture.
- Some of the commonly used purification techniques are:

Separation Technique	What Separates .... ?
magnetic separation	separates magetic materials from non-magnatic materials
decanting	separates large insoluble solid particles from liquid
filtration	separates small insoluble solid particles from liquid
sublimation	separates a substance that sublimes from one that does not
evaporation to dryness	separates a soluble substance from its solution
desalination	separates salts from sea water
crystallization	separates a soluble substance from its solution through heating
simple distillation	separates a liquid from its solution
fractional distillation	separates two or more miscible liquids
separating funnel	separates two or more immiscible liquids
chromatography	separates two or more compounds with similar properties

table 1.2.1

Key Terms

- The following are the important terms used in separation techniques.

Term	Meaning
mixture	an impure substance containing two or more substances that are not chemically combined
impurities	unwanted materials present in a given substance
suspension	a mixture in which insoluble solid particles are suspended in a liquid
precipitate	an insoluble solid substance formed in a solution as the result of a chemical reaction
filter or filter medium	the porous material through which only liquids and dissolved substances can pass through but solids or suspended particles are left behind. Filter paper, closely packed glass fibres, cotton, woven wire, cloth, sand etc. are some important filter media.
filtrate	the liquid or dissolved substance that is obtained after passing the mixture through a filter
residue	the insoluble solid particles that are left behind on the filter during filtration
sublimate	the substance that sublimes upon heating
solution	a homogeneous mixture of two or more substances
solute	a component of solution in lesser amount
solvent	a component of solution in larger amount
saturated solution	a solution that contains maximum amount of dissolved solid at a given temperature
saturation point or **crystalisation point**	the point at which the greatest possible amount of a solid substance is present in the solution at a given temperature
distillate	the pure liquid obtained by distillation
fraction	a component of a mixture separated after fractional distillation
miscible liquids	two or more liquids that are able to dissolve into each other
immiscible liquids	two or more liquids that are unable to dissolve into each other
dye	any coloured substance
chromatogram	the chromatography paper with separated components
locating agent	a substance, usually a liquid that helps to separate and analyse colourless substances in chromatography by reacting with the colourless substances to form coloured spots on the chromatogram
solvent front	the furthest distance travelled by the solvent along the chromatography paper

table 1.2.2

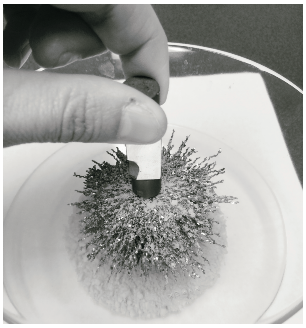


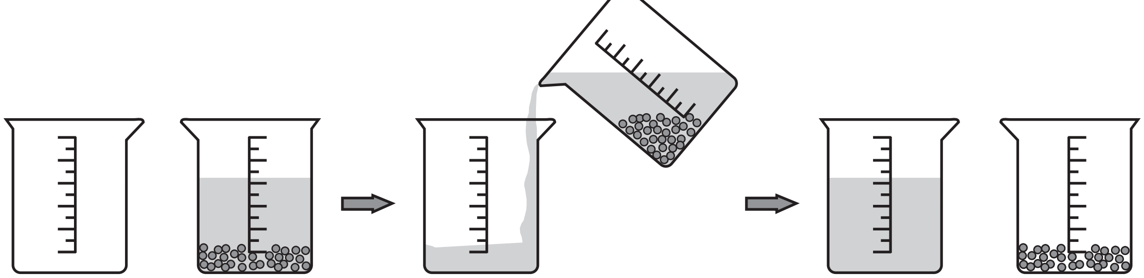
fig. 1.2.3

Magnetic Separation

- **Magnetic Separation** is used to separate magnetic substances such as iron, nickel, cobalt and steel from non-magnetic substances.

Decanting

- **Decanting** is used to separate insoluble solids from a liquid by carefully pouring the liquid away.
- Decanting is suitable for separating solid particles which are usually larger in size and weight and settle at the bottom of the liquid.
- Although decanting is quick process but it is not so effective.



mixture of insoluble solid particles and a liquid

carefully pouring out the mixture into another beaker

mixture separated

fig. 1.2.4

Filtration

- **Filtration** is used to separate small insoluble solid particles or **precipitates** from a liquid by passing the mixture through a porous material called **filter** or **filter medium**.
- The filter acts as a sieve that lets the liquid to pass through it but prevents the solid to do so.
- A mixture of two solids can also be separated by filtration if one of them is soluble in a solvent and the other is not. For example, a mixture of sand and salt can be separated by filtration using water as solvent.
- Filtration is also suitable for separating solid particles which are usually light in weight and may form a **suspension**.
- Although filtration is a slow process but it gives better results than decanting.

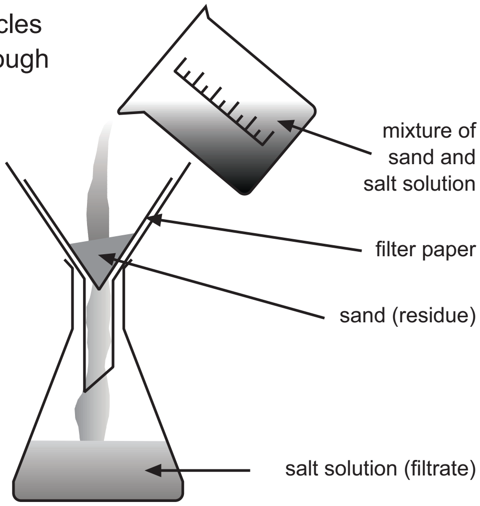


fig. 1.2.5

Sublimation

- Some substances such as ammonium salts, iodine, solid carbon dioxide and naphthalene, upon heating sublime *i.e.* they directly change from solid to gaseous phase (or from gaseous to solid phase) without passing through an intermediate liquid phase. This phenomenon is called **sublimation**.

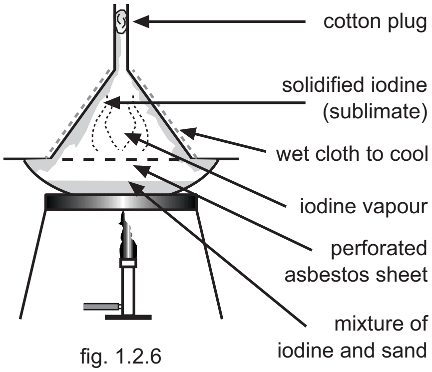


fig. 1.2.6

.- The technique of sublimation can be used to separate a substance that sublimes (sublimate) from one that does not. For example, when a mixture of iodine and sand is heated, iodine sublimes *i.e.* it directly turns into vapour. When these vapour touch a cold surface, they solidify again and are thus separated from sand.

Evaporation to Dryness

- **Evaporation to dryness** is used to separate soluble solids from a solution by evaporating the solvent. For example, when a solution of salt and water is evaporated to dryness, solid salt is obtained.

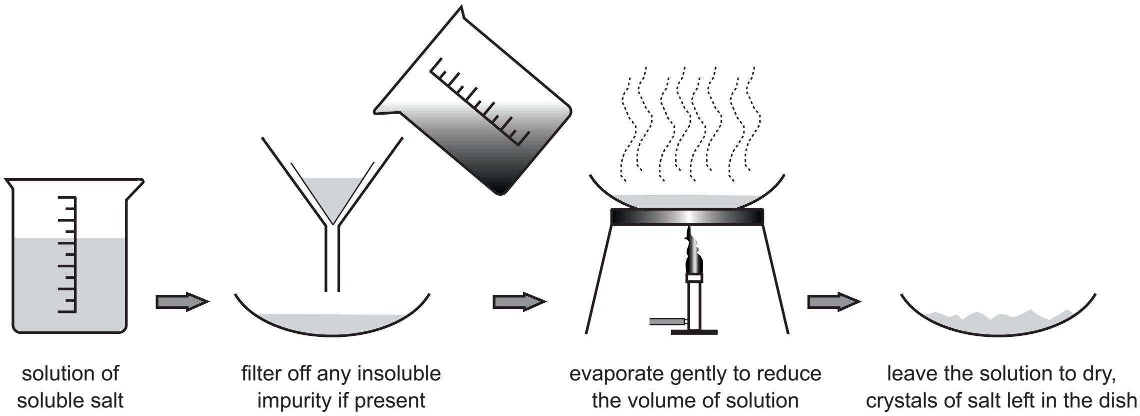


fig. 1.2.7

- Sometime a gentle heat is required to increase the rate of evaporation.
- Slow evaporation produces large crystals while using heat produces small crystals.
- Strong heating is not recommended as many substances decompose when they are heated strongly. For example, sugar decomposes to water and carbon when its solution is heated strongly. Similarly, strong heat may release water of crystallization from crystals and leave them in powder form. Another drawback of using this method is that soluble impurities present in the solution may contaminate the solid to be recovered. For such substances, crystalization is a better technique.
- This method is also used in some countries to get salt from sea water.

Desalination (*optional*)

- **Desalination** is a process of removing salt from sea water by **distillation** or by **reverse osmosis.**
- In **reverse osmosis**, sea water is passed through a specially designed container with a semipermeable membrane. An external pressure forces the water to pass through the semipermeable membrane but leaves behind the dissolved salts.

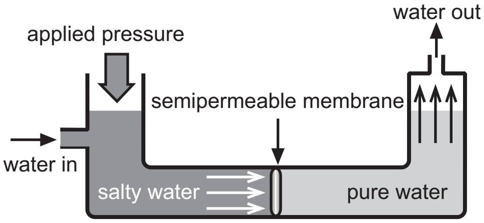


fig. 1.2.8

Crystalization

- **Crystalization** is used to separate soluble salts from a liquid by cooling their saturated solutions.
- This technique is suitable for substances that decompose on heating.
- In order to separate a soluble solid from its solution, first evaporate some of the solvent by heating the solution to saturation point and get a hot saturated solution. Now allow this solution to cool to room temperature. This makes the dissolved solid to reappear as pure crystals.
- The following diagram shows the various steps to obtain pure crystals from a salt solution.

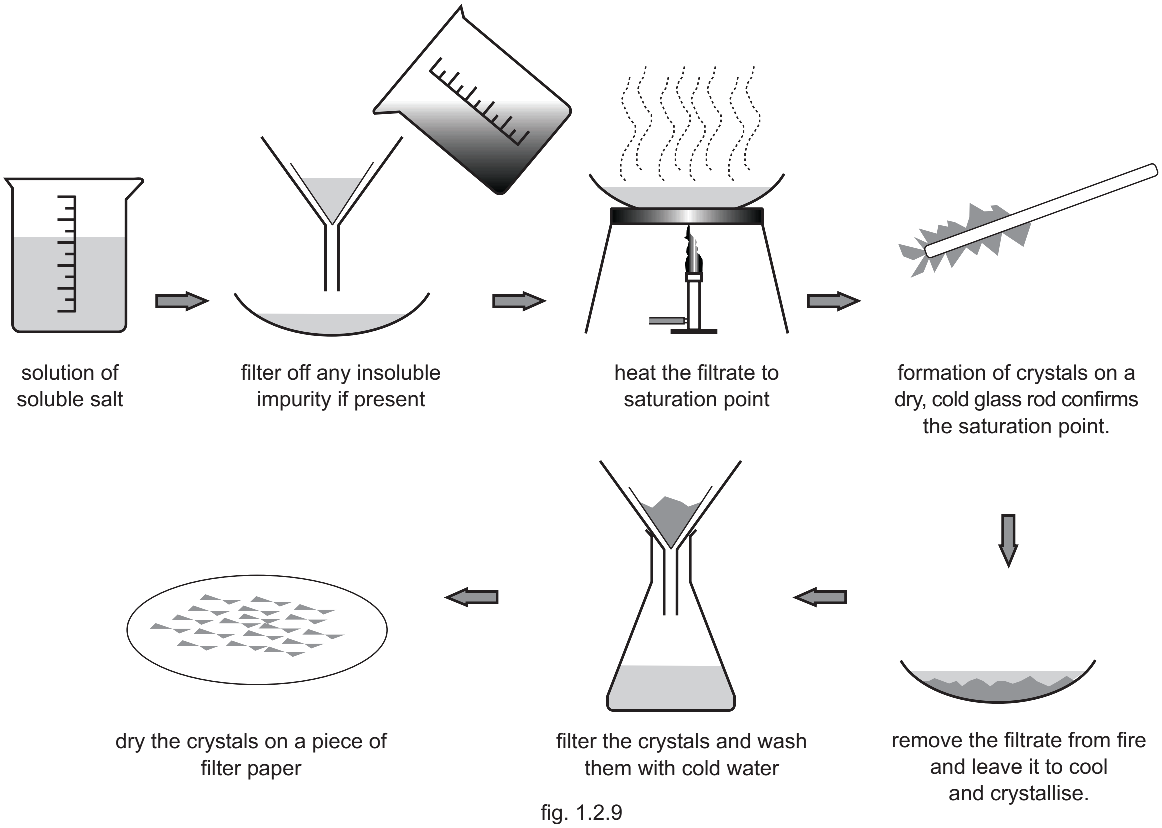


fig. 1.2.9

- If other soluble impurities are present in the solution, they remain there as soluble during cooling process while the pure crystals can be separated by filtration.

Simple Distillation

- **Simple distillation** is used to separate a pure liquid (solvent) from its solution by heating the mixture upto its boiling point and then condensing the vapour.
- This technique is used to obtain pure water from a salt solution.

- The following diagram shows the various steps to obtain pure liquid from a salt solution.
    i. Heat the solution in a distillation flask.
    ii. The vapour rises and enters the condenser where they are cooled and change back to liquid.
    iii. Pure liquid is collected as distillate in the flask.
    iv. The salt solution in the distillation flask becomes more and more concentrated as distillation proceeds. If distillation continues, a solid residue of salt is left behind.

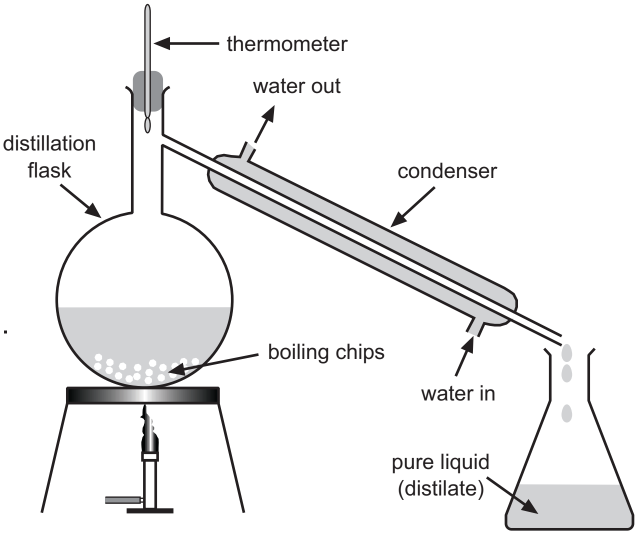


fig. 1.2.10

- While carrying out simple distillation, keep the following points in mind:
    i. The bulb of thermometer should not be dipped into the solution, rather it should be placed just beside the side arm of the distillation flask. This ensures that the thermometer measures the boiling point of the liquid that is being distilled.
    ii. Add boiling chips to the solution before heating. Boiling chips are small, insoluble stones made of calcium carbonate or silicon carbide. They allow the solution to boil smoothly and save the distillation flask from overheating and cracking.
    iii. The condenser should be placed in a downward sloping position so that the distillate can run into the flask easily.
    iv. Cold water should run in the condenser from bottom to top for better cooling of the vapour.

Separating Funnel

- Liquids which do not mix together are called **immiscible liquids**. For example, water and oil are immiscible in each other.
- When immiscible liquids are shaken, they may appear to mix. In this state, they form a mixture called **emulsion**. After some time, the emulsion separates into different layers of liquids.
- A **separating funnel** is used to separate a mixture two immiscible liquids. For this purpose, put the two liquids into a separating funnel and leave them for a short time to settle out and form two layers. The tap of the funnel is then opened and the bottom liquid is allowed to drain out leaving the top liquid in the funnel.

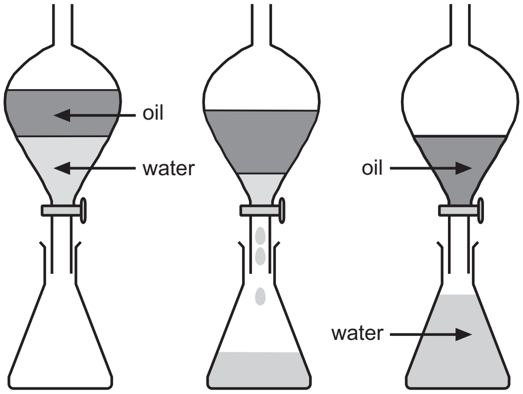


fig. 1.2.11

Fractional Distillation

- Liquids which mix together completely and form a solution are called **miscible liquids**. For example water and ethanol are miscible in each other.
- To separate a mixture miscible liquids a technique called **fractional distillation** is used.
- The following diagram shows the various steps to separate water - ethanol mixture.
    i. Heat the mixture in the flask. At about 78 °C, the ethanol begins to boil. Some water evaporates, too. So a mixture of ethanol vapour and water vapour rises up the column.
    ii. The vapour condenses on the glass beads in the fractionating column, making them hot.
    iii. When the temperature of beads reach about 78 °C, ethanol vapour no longer condenses on them. Only the water vapour does. So water drips back into the flask. The ethanol vapour goes into the condenser. At this stage, the thermometer shows a steady temperature of 78 °C which is, in fact, the boiling point of ethanol.
    iv. In the condenser, ethanol vapour condenses. Pure liquid ethanol drips into the flask as distillate.
    v. When all the ethanol has distilled over, the thermometer reading rises to 100 °C which is the boiling point of water. At this temperature, water starts distilling over and can be collected in a separate flask.

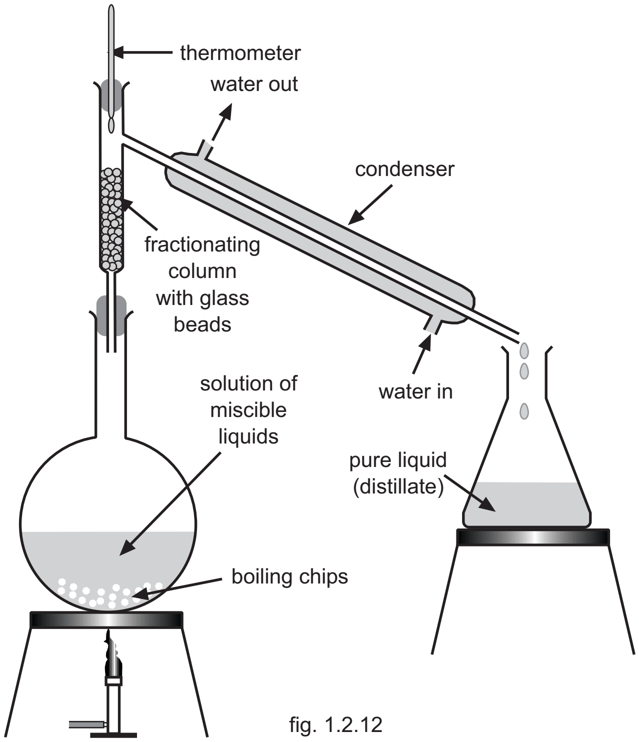


fig. 1.2.12

- Fractional distillation has some very important applications in industries.
    i. Fractional distillation is used in oil refineries to separate crude oil into useful fractions such as petrol, diesel, lubricating oil *etc*.
    ii. It is used in separating ethanol from glucose during fermentation. Ethanol is used as a solvent, and as car fuel.
    iii. It is also used to separate gases like nitrogen, oxygen and argon from air. For this purpose, the air is cooled and compressed until it is liquified. The liquid air is fractionally distilled and the gases boil off one by one.

Chromatography

- The word **chromatography** is derived from the Greek word **khromotos** which means **colour writing**.
- **Chromatography** is a technique that is used to separate the components of a mixture by passing it in a solvent along a medium in which the components move at different rates.
- With the help of chromatography, one can
    i. determine the purity of a substance,
    ii. find the number of components present in a mixture,
    iii. identify the components present in a mixture (coloured or colourless).
- Chromatography is based upon two principles:
    i. Different substances have different solubilities in the same solvent.
    ii. The more soluble the substance is, the longer distance it is carried away by the solvent.

Paper Chromatography

- Chromatography is carried out in various ways but the most popular is **paper chromatography**.
- Paper chromatography involves a piece of filter paper as medium and water or ethanol as solvent.
- Paper chromatography is used to separate dyes in inks, pigments from plant materials, amino acids obtained from proteins, to identify poisons or drugs, and to detect traces of banned substances in food.
- In ascending type of paper chromatography,
    i. Take a strip of filter paper and draw a line with a pencil about 1 cm from one end of the strip.
    ii. Put a drop of the mixture or dye on the pencil line and allow the drop to dry.
    iii. Dip the end of the paper nearer the spot of ink in a solvent *e.g.* water or ethanol.
    iv. The solvent starts moving up carrying the dyes along.
    v. After a short while, different components of the dye will separate in the form of spots.

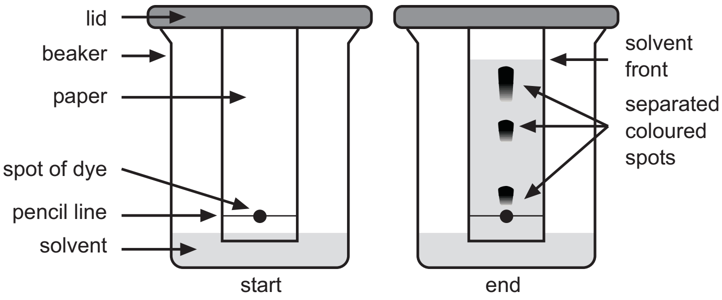


fig. 1.2.13

- The chromatography paper with separated components is called a **chromatogram**.
- A pure substance shows only one spot on a chromatogram.
- An impure substance or mixture shows two or more spots on a chromatogram.
- If the spot of a substance does not move, this means the substance is insoluble in the given solvent. To get the result, use a different solvent in which the substance is soluble.

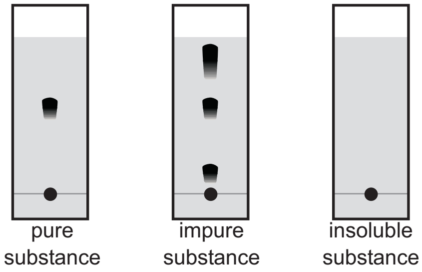


fig. 1.2.14

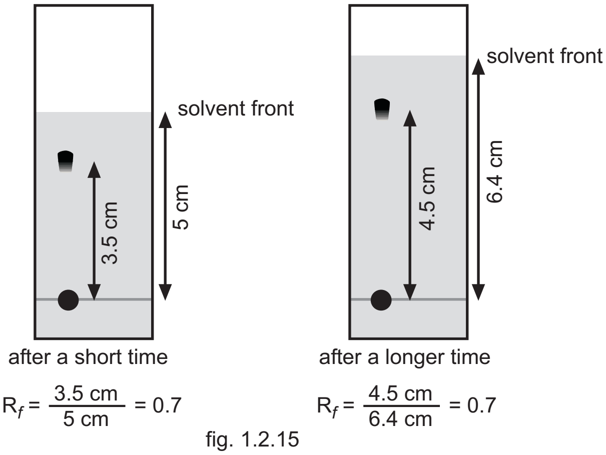
R_f value

- In chromatography the identification of components and their purity can be decided by taking their **retention factors** or **R_f values**.
- **Retention factor** or **R_f value** is, in fact, the ratio of the distance travelled by a component of a mixture on a chromatography paper to the distance travelled by the solvent.

i.e.

$$\boxed{R_f \text{ value} = \frac{\text{distance travelled by a component of a mixture}}{\text{distance travelled by solvent}}}$$

- The R_f value of a substance is fixed as long as chromatography is carried out under the same conditions *i.e*. the same solvent and the same temperature.
- The leading or furthest edge of the solvent along the chromatography paper is called **solvent front** and its distance is measured from the pencil line.
- The R_f value of a substance is always less than 1 because the solvent front moves furthest on the chromatogram as compared with the substances it dissolves.



$R_f = \frac{3.5 \text{ cm}}{5 \text{ cm}} = 0.7$

$R_f = \frac{4.5 \text{ cm}}{6.4 \text{ cm}} = 0.7$

fig. 1.2.15

Chromatography on Colourless Substances

- Chromatography can also be used for colourless substances such as amino acids. For this purpose a **locating agent** is also applied on a chromatogram. In some cases, ultraviolet radiation can also be used instead of a locating agent.
- **Ninhydrin** is often used as a locating agent. It gives a blue colouurataion with amino acids.
- To separate and analyse various types of amino acids present in a sample, follow the steps given below:
  1. Separate the mixture of amino acids by paper chromatography using a suitable solvent.
  2. Before the solvent reaches the top of the paper, stop the process and dry the paper.
  3. Spray a locating agent onto the paper. The locating agent reacts with each of the amino acids and form coloured spots on the paper.
  4. By measuring the R_f value of each coloured spot, the different amino acids can be detected.

UNIT 1.3

Identification of Ions and Gases

O Level Chemistry (5070)
Revision Guide

Syllabus 2017 - 2019

Content

1.3 Identification of Ions and Gases

Learning Outcomes

Candidates should be able to:

(a) describe the use of aqueous sodium hydroxide and aqueous ammonia to identify the following aqueous cations:
aluminium, ammonium, calcium, chromium (III), copper (II), iron (II), iron (III) and zinc (formulae of complex ions are **not** required)

(b) describe tests to identify the following anions:
carbonate (by the addition of dilute acid and subsequent use of limewater); chloride (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate); iodide (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate); nitrate (by reduction with aluminium and aqueous sodium hydroxide to ammonia and subsequent use of litmus paper), sulfate (by reaction of an aqueous solution with nitric acid and aqueous barium nitrate), and sulfite (by warming with dilute acid)

(c) describe tests to identify the following gases:
ammonia (using damp red litmus paper); carbon dioxide (using limewater); chlorine (using damp litmus paper); hydrogen (using a burning splint); oxygen (using a glowing splint) and sulfur dioxide (using acidified potassium manganate (VII))

(d) describe a chemical test for water

Unit 1.3 Identification of Ions and Gases

1.3.1 Identification of Ions

- A soluble salt when dissolved in water dissociates into positive and negative ions. Positive ions are called **cations** while negative ions are called **anions**.
- A chemist, sometimes, has to find an unknown salt dissolved in a solution by identifying its cations and anions using chemicals called **reagents**.

Identification of Cations

- The reagents used to identify cations are aqueous sodium hydroxide ($NaOH_{(aq)}$) and aqueous ammonia ($NH_{3(aq)}$).
- To identify a cation using the reagents, follow these steps:
  i. Add a few drops of reagent in the solution and note the colour of the precipitate produced.
  ii. Add the reagent in excess and note whether the precipitate is soluble or insoluble.

Cation	Aq. Sodium Hydroxide		Aq. Ammonia	
	on adding a few drops	on adding in excess	on adding a few drops	on adding in excess
copper (II) ion (Cu^{2+})	light blue ppt.	insoluble in excess	light blue ppt.	soluble in excess, giving a deep blue solution
iron (II) ion (Fe^{2+})	green ppt.	insoluble in excess	green ppt.	insoluble in excess
iron (III) ion (Fe^{3+})	red brown ppt.	insoluble in excess	red brown ppt.	insoluble in excess
chromium (III) ion (Cr^{3+})	green ppt.	soluble in excess, giving a green solution	green ppt.	insoluble in excess
aluminium ion (Al^{3+})	white ppt.	soluble in excess, giving a colourless solution	white ppt.	insoluble in excess
zinc ion (Zn^{2+})	white ppt.	soluble in excess, giving a colourless solution	white ppt.	soluble in excess, giving a colourless solution
calcium ion (Ca^{2+})	white ppt.	insoluble in excess	no ppt.	no ppt.
ammonium ion (NH_4^+)	no ppt.	no ppt.		

table 1.3.1

- The following schematic diagrams are easy to remember the rules for the identification of cations.

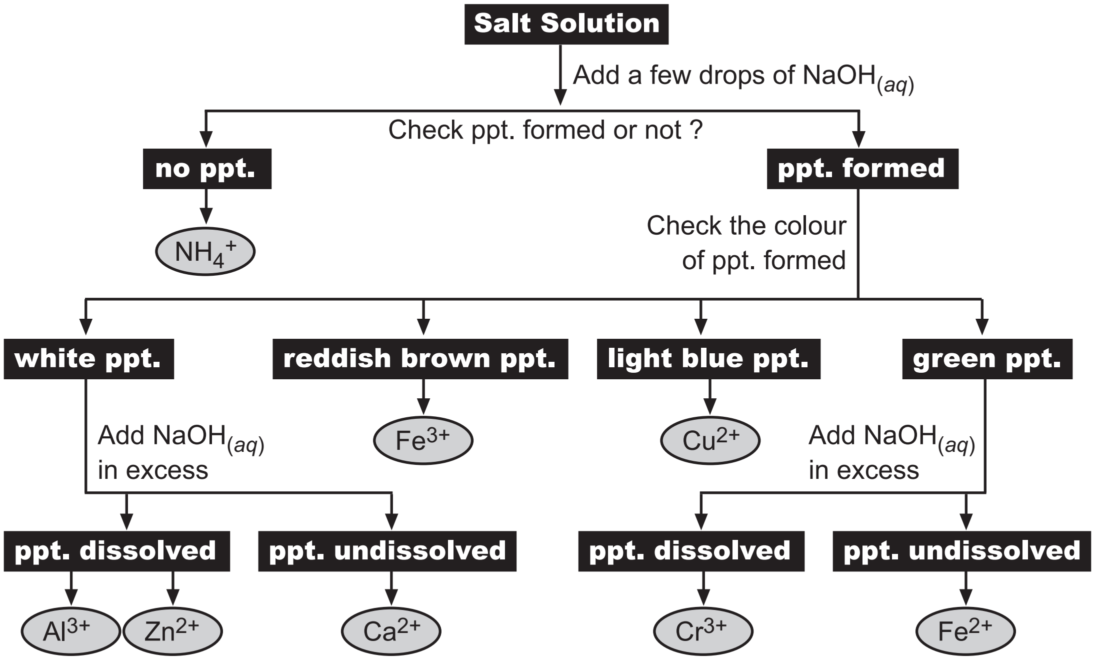


fig. 1.3.2

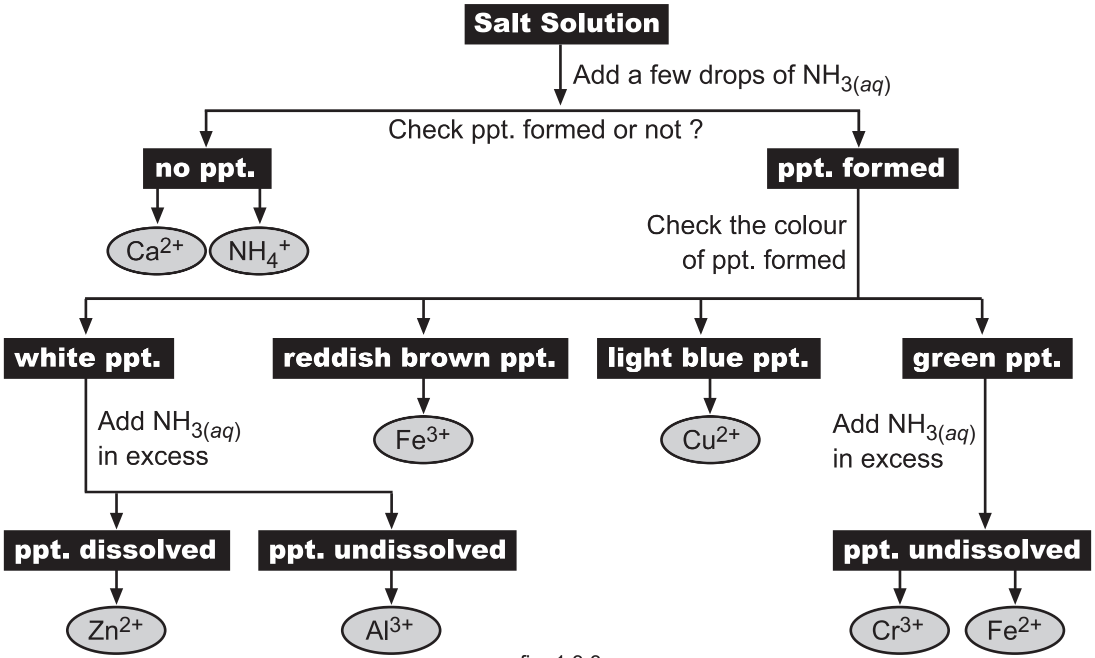


fig. 1.3.3

Identification of Anions

- There are different reagents used to identify anions present some common salt solutions.

Anion	Test	Observation & Inference
carbonate ion (CO_3^{2-})	Add dilute acid *e.g.* $HCl_{(aq)}$ or $H_2SO_{4\ (aq)}$.	Effervescence is observed.
	Pass the gas given off into lime water.	The gas given off turns lime water milky showing that the gas is CO_2.
chloride ion (Cl^-)	Add dilute nitric acid, then add aqueous silver nitrate.	White ppt. of silver chloride is formed.
ioide ion (I^-)	Add dilute nitric acid, then add aqueous silver nitrate.	Yellow ppt. of silver ioide is formed.
sulfate ion (SO_4^{2-})	Add dilute nitric acid, then add aqueous barium nitrate.	White ppt. of barium sulfate is formed.
nitrate ion (NO_3^-)	Add aqueous sodium hydroxide, then add a piece of aluminium foil. Warm the mixture.	Effervescence is observed.
	Test the gas given off with a piece of moist red litmus paper.	The moist red litmus paper turns blue showing that the gas given off is NH_3.
sulfite ion (SO_3^{2-})	Add dilute hydrochloric acid and warm the reaction mixture.	A gas is given off which might be sulfur dioxide (SO_2).
	Pass the gas given off through pink/purple solution of acidified potassium manganate (VII).	The pink/purple colour of the solution turns colourless.

table 1.3.4

1.3.2 Identification of Gases

Gas	Colour & Odour	Test & Observation
hydrogen (H_2)	no colour no odour	Place a lighted splint in the gas. The lighted splint extinguishes with a **pop** sound.
oxygen (O_2)	no colour no odour	Introduce a glowing splint into the gas. The glowing splint rekindles.
carbon dioxide (CO_2)	no colour no odour	Bubble the gas through limewater. The limewater turns milky.
ammonia (NH_3)	colourless with a pungent smell	Introduce a piece of moist red litmus paper into the gas. The moist red litmus paper turns blue.
sulfur dioxide (SO_2)	colourless with a pungent smell	Pass the gas through acidified potassium manganate (VII) solution. The pink/purple colour of the solution turns colourless.
chlorine (Cl_2)	greenish-yellow in colour with a pungent smell	Introduce a piece of moist blue litmus paper into the gas. The moist blue litmus paper turns red, and then bleaches.

table 1.3.5

1.3.3 Chemical Test for Water

- To identify that a liquid produced in a chemical reaction is water, there are two tests:

Test	Observation
Introduce a piece of cobalt (II) chloride paper near the heated sample.	Cobalt (II) chloride paper changes from blue to pink showing that the sample contains water.
Add a few drops of the sample to anhydrous copper (II) sulfate.	Anhydrous copper (II) sulfate changes from white to blue.

table 1.3.6