Ghada omar
chemistry tutor

O LEVEL CHEMISTRY

0971 0620 NOTES (2024 Edition)

CAMBRDIGE IGCSE O-LEVEL

For more infomation
00966567038607
01002776949

Ghada omar
chemistry tutor

For More Info:

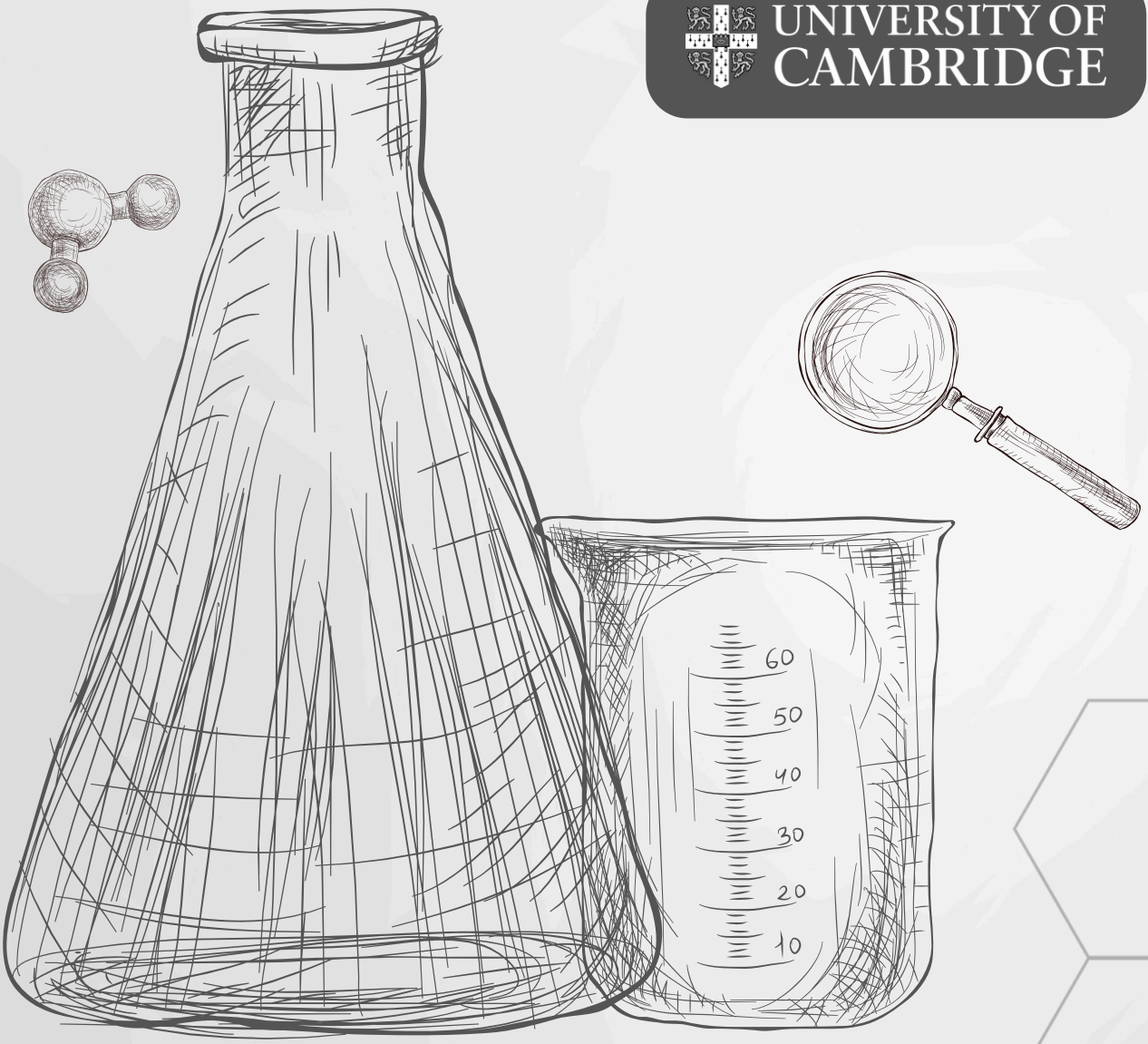
0096567038607
01002776949

@mrs.ghadaomar

O Level Cambridge
Chemistry Notes

Syllabus Of

UNIVERSITY OF CAMBRIDGE



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Ghada omar
chemistry tutor

For More Info:

0096567038607
01002776949

@mrs.ghadaomar

Ghada omar
chemistry tutor

Topic 2

Atomic Structure

Atoms: It is the smallest particle of substance that cannot be broken down further by chemical means, and it shows the chemical characteristics of particular elements.

Element: It is a substance made up of atoms with the same atomic number and cannot be split up into anything simpler by chemical means.

Molecule: A group of two or more atoms chemically joined together.

Compound: A substance made of two or more elements chemically combined together.

Compound	Formula	Elements	No. of Atoms
Water	H_2O	H & O	3
Calcium Nitrate	$Ca(NO_3)_2$	Ca, N, O	9
Sulfuric Acid	H_2SO_4	H, S, O	7
Ammonium Carbonate	$(NH_4)_2CO_3$	N, H, C, O	14

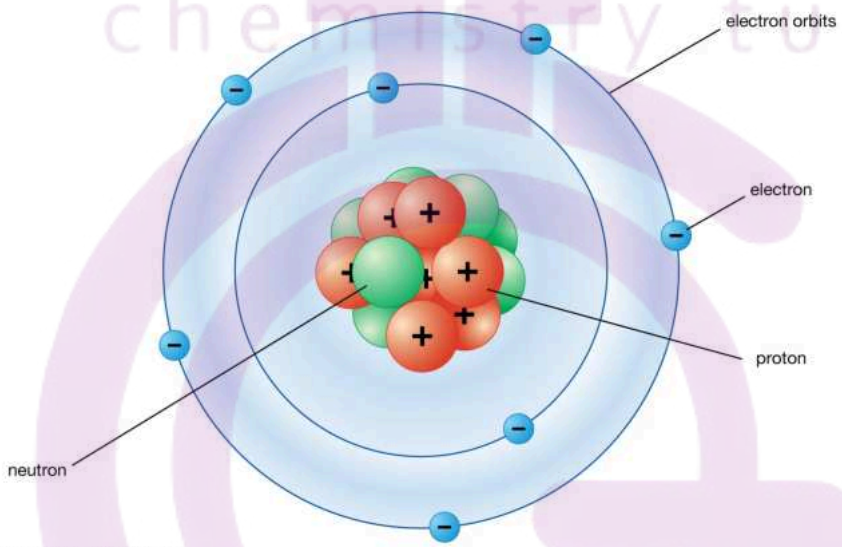
Dalton Atomic Theory

- Pure element is composed of atoms.
- Atoms of different elements are different in size and mass.
- Atoms of the same element have identical mass and size.
- Atoms of different elements combine in simple whole number ratio to form a compound.

Atomic Structure

Atomic Structure

- Atoms are made up of 3 subatomic particles: **Protons, Neutrons and Electrons.**
- **Protons and Neutrons** in the center of the atom in the nucleus.
- **Electrons** in energy shells around the nucleus.



Subatomic Particle	Symbol	Mass	Charge	Location in atom
Proton	P	1	+1	in nucleus
Neutron	n	1	0	in nucleus
Electron	e^-	1/1840	-1	outside nucleus

Note!

- *Atoms are electrically **neutral** (have overall charge = zero) because **number of positive protons = no. of negative electrons***
- ***Protons and electrons** are the **only** charge particles in an atom*

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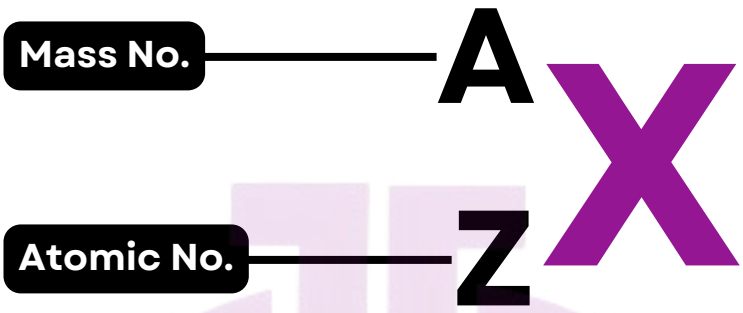
Atomic Number & Mass Number



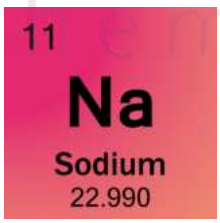
Mass Number (Nucleon Number): it is the number of proton and neutrons inside the nucleus of an atom.

Atomic Number (Proton Number): it is the number of protons inside the nucleus of an atom.

The larger number is the mass number

No. of Protons = 1
No. of Electrons = 1
No. of Neutrons = 1-1 = 0
No. of Charged Particles = 2

No. of Protons = 8
No. of Electrons = 8
No. of Neutrons = 16-8 = 8
No. of Charged Particles = 16



No. of Protons = 11
No. of Electrons = 11
No. of Neutrons = 23-11 = 12
No. of Charged Particles = 22

No. of Protons = 17
No. of Electrons = 17
No. of Neutrons = 35-17 = 18
No. of Charged Particles = 34

State

What is meant by an ion?

It is an electrically charged atom that loses or gains electrons to become stable.

Cation: A positively charged ion that has more protons than electrons.

Anion: A negatively charged ion that has more electrons than protons.

$^{24}_{12}Mg - 2e^- \Rightarrow ^{24}_{12}Mg^{2+}$

P = 12	***P = 12***
n = 12	***n = 12***
e = 12	***e = 10***

lost 2 electrons

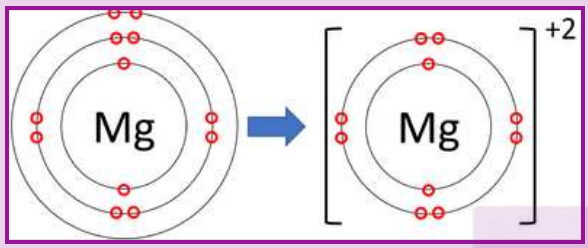
$^{16}_{8}O + 2e^- \Rightarrow ^{16}_{8}O^{2-}$

P = 8	***P = 8***
n = 8	***n = 8***
e = 8	***e = 10***

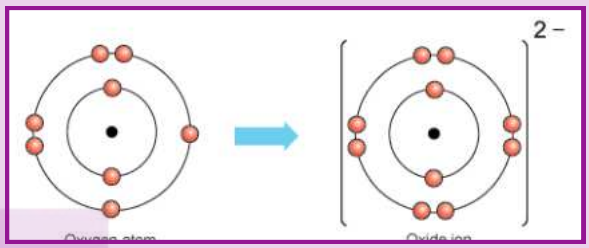
gained 2 electrons

Atoms of most elements undergo chemical reactions. They lose or gain or share electrons to have a full outer shell of electrons & become stable. (have the electronic configuration of the nearest noble gas)

How do atoms form ions?



- Magnesium is an element in group 2; it has an electronic configuration of 2,8,2.
- To obtain a full outer shell of electrons, it loses 2 electrons to another atom and forms a positively charged ion (Mg^{+2}) with a charge +2



- Oxygen is an element in group 6; it has an electron configuration 2,6.
- To obtain a full outer shell of electrons, it gains 2 electrons from another atom and forms a negatively charged ion (O^{-2}) with a charge of -2

Important Terms:

Valency Electrons: Electrons in the outer shell of an atom.
Example: Sodium has 1 valency electron & chlorine has 7.

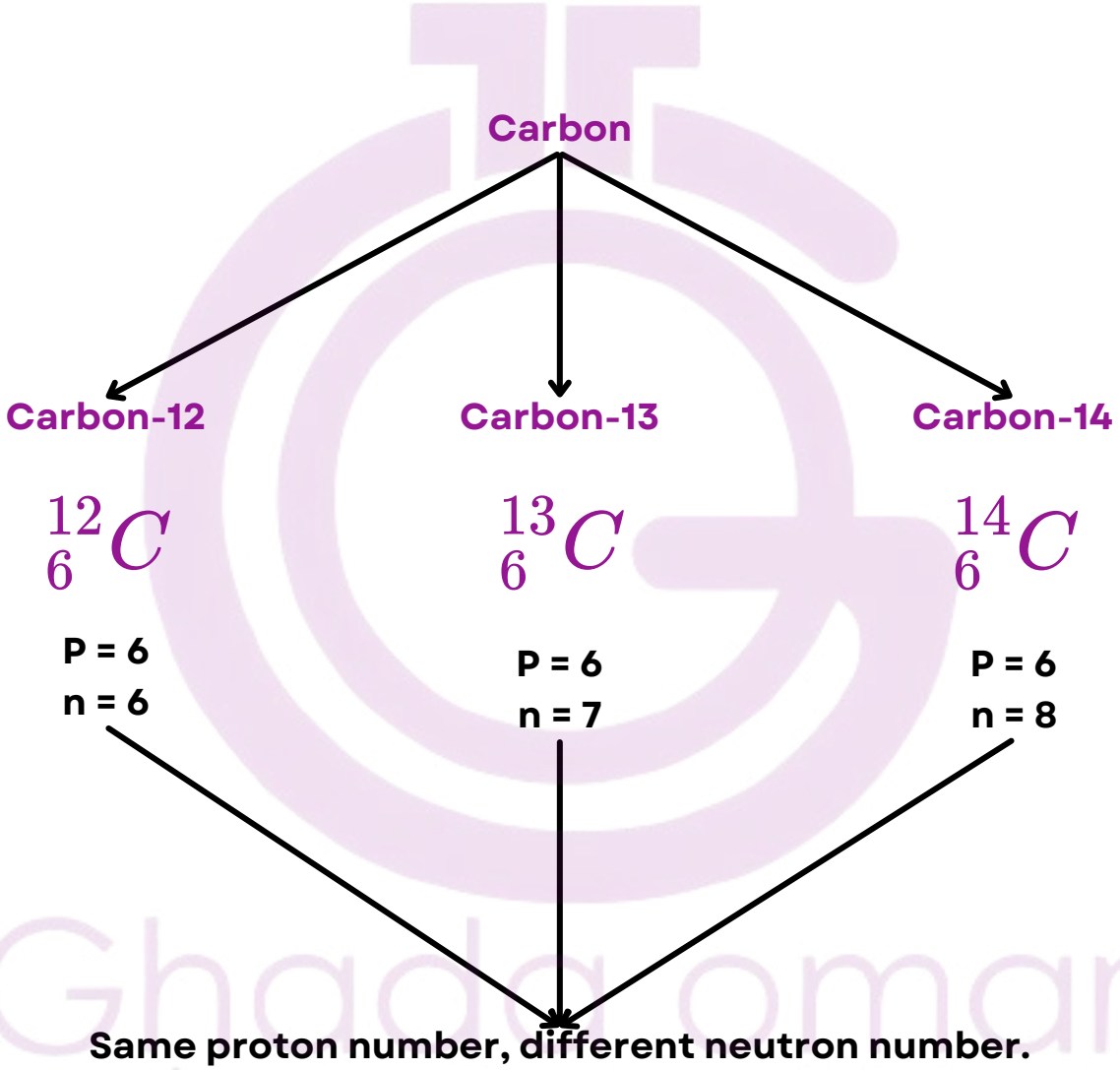
Valency: No. of electrons lost or gained by an atom to become stable.
Example: Sodium loses 1 electron, its valency is 1 & Chlorine gains 1 electron, its valency is also 1.

Isotopes

Isotopes

They are atoms of the same element which have the same no. of protons but different no. of neutrons.
OR same atomic number but different mass no.

Isotopes are referred to the mass no.; for example:



Note

Carbon-14 is a radioactive isotope because its nucleus is unstable.

Explain Why?

Isotopes of the same element have the same chemical properties

⇨ Because they have the same number of electrons, therefore same electronic configuration.

Suggest Why?

The relative atomic mass of Chlorine is not a whole number

⇨ Because Chlorine has isotopes, its the average mass of its isotopes.

Important Notes

- Isotopes of an element have the same chemical properties because they have the same number of electrons.
- Some physical properties of isotopes are different such as density and rate of diffusion.

Calculating relative atomic mass of isotopes of an element

- The relative atomic mass of an element is the average mass of its atoms.
- The relative atomic mass of an element is calculated from its **mass number** and **relative abundances** of all its isotopes.

$$\text{Ar} = \frac{\text{(mass of isotope x its abundance) + (mass of isotope x its abundance)}}{\text{total}}$$

Example 1

Calculate the relative atomic mass (Ar) of the isotopes in a sample of Chlorine with 75% ^{35}Cl and 25% ^{37}Cl

⇨ The abundance of Chlorine-35 is 75% and the abundance pf Chlorine-37 is 25%.

$$Ar = \frac{(75 \times 35) + (25 \times 37)}{100}$$

Example 2

Calculate the relative atomic mass (Ar) of the isotopes in a sample of Rubidium with 72% ^{85}Rb and 28% ^{87}Rb.

⇨ $$Ar = \frac{(72 \times 85) + (28 \times 87)}{100} = 85.6$$

Electronic Configuration

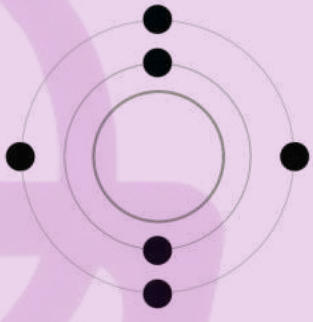
Electronic Configuration

- Electronic Configuration means arrangements of electrons in shells.
- The first shell is the closest to the nucleus; it is filled by 2 electrons.
- The 2nd, 3rd and 4th shells are filled by 8 electrons each.
- A shell must be filled before starting on the next one.

How to draw the electronic configuration of elements?

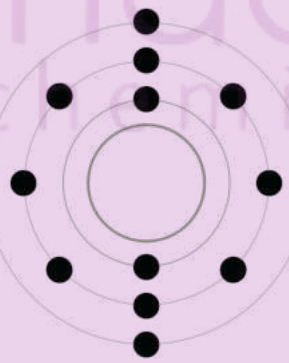
Example 1

$_6C \rightarrow$ will be distributed into 2 in the first shell and 4 in the second.



Example 2

$_{12}Mg \rightarrow 2, 8, 2$



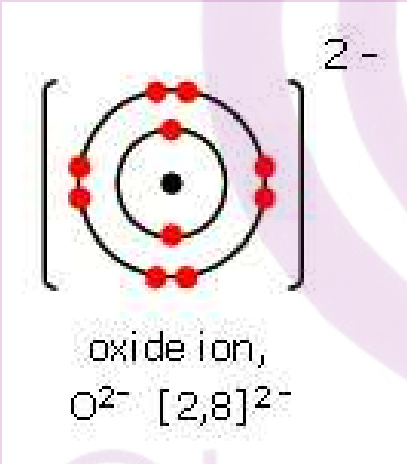
How to draw the electronic configuration of ions?

Example 1

$_{12}Mg^{2+} \rightarrow$ no of electrons 12-2=10
lost 2 electrons

2,8

Example 2



$^{16}_{8}O^{2-} \rightarrow$ no of electrons 8 + 2 = 10
gained 2 electrons

2,8

Relationship between electronic configuration of an element & its position in the periodic table

- There is a direct relationship between the electronic configuration of an element & its position in the periodic table.
- The periodic table has vertical columns called “Groups” & horizontal rows called “Periods”.

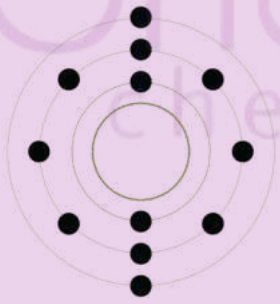
Periods	Groups
7 horizontal periods	8 vertical groups
elements of the same period have the same no. of energy levels (shells)	elements of the same group have the same no. of valency electrons (outer shell electrons)
no. of shells = period no.	so they have the same chemical property

In conclusion...

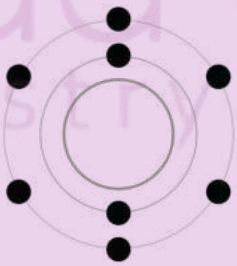
Group no. = No of outer shell electrons (valency electrons)
Period no. = No of occupied electron shells.

"group 1 elements have 1 valency electrons, group 2 have 2 valency electrons, etc."

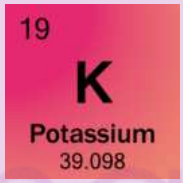
Examples

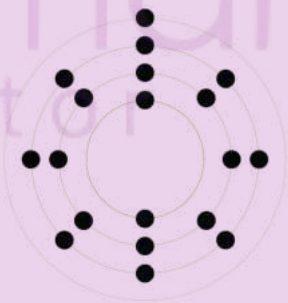


No. of electrons = 12
Electronic Structure = 2,8,2
Group no. = 2
Period no. = 3



No. of electrons = 8
Electronic Structure = 2,6
Group no. = 6
Period no. = 2





No. of electrons = 19
Electronic Structure = 2,8,8,1
Group no. = 1
Period no. = 4

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Electronic Configuration of Noble Gases

- Noble gases have full outer shell (8e- except He has 2e-) so they are chemically unreactive, so they don't make chemical bonds with atoms of other elements.

$_{2}H$ 2

$_{10}Ne$ 2,8

$_{18}Ar$ 2,8,8

full outer shells

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Topic Summary

Topic Summary

The elements are the basic building units of the material world – they cannot be chemically broken down into anything simpler.
The atoms of the elements are made up of different combinations of the subatomic particles (protons, neutrons and electrons) and an element is made up of atoms that all have the same number of protons.
These subatomic particles have particular electrical charges and relative masses.
In any atom, the protons and neutrons are bound together in a central nucleus, and the electrons 'orbit' the nucleus in different energy levels (or shells).
The number of protons in an atom is defined as the proton (atomic) number (Z) of the element and the total number of protons and neutrons in as atom is defined as the mass (nucleon) number (A).
Isotopes of the same element can exist and differ only in the number of neutrons in their nuclei.
The chemical properties of all the isotopes of an element are the same as they have the same electronic configuration.
The relative atomic mass of an element can be calculated from data on the abundance of the different isotopes of that element.
The electrons in atoms are arranged in different shells (or energy levels) that are at different distances from the nucleus of the atom.
Each shell (or energy level) has a maximum number of electrons that it can contain and the electrons fill the shells closest to the nucleus first.
The electronic configuration of an element determines the group number and period number of that element in the Periodic Table.

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Checklist

Checklist

I can	Needs more work	Almost there	Confident to move on
understand that matter is made up of elements and compounds			
describe the structure of the atom as a central nucleus surrounded by electrons			
define the properties of protons, neutrons and electrons, and the meaning of the proton (atomic number) number and nucleon (mass) number of an atom			
define isotopes as atoms of an element with the same proton number but different nucleon numbers			
describe isotopes of an element as having the same chemical properties as they have the same electronic configuration			
calculate the relative atomic mass of an element from the relative masses and abundancies of its isotopes			
describe the electronic configuration of an atom and the significance of it in terms of the position of the element in the periodic table			
determine the electronic configuration of atoms with proton numbers 1 to 20			

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Topic 15

Experimental Design & Separation Techniques

Experimental Design

Planning an Experimental Investigation

- Suggest a hypothesis (an idea to be tested), is it a problem worth to be tested?
- Draw up a plan of experiments to test the idea.
- Decide which variables to check and which to keep constant
- Choose the apparatus and chemicals needed
- Carry out the experiment, making notes on what happened and recording measurements
- Draw up a summary of results in tables & graphs
- Draw conclusions from results and work out what they mean
- Try to decide whether the results support the original idea
- Do they suggest further tests and idea?

Variables

There are types of variables:

- **Controlled Variables**: variables that are kept constant throughout an experiment.
- **Independent Variables**: variables that are changed during an experiment (x-axis).
- **Dependent Variables**: variables that are measured during an experiment (y-axis).

Sources of Error

- Random errors: errors that can be reduced by repeating the experiment several times, removing any anomalous data and taking an average.
- Systematic errors: mean that the data is wrong by the same amount each time. Systematic errors cannot be reduced by repeating the experiment.

Errors & their Improvements

Error	Improvement
Using measuring cylinder • **Advantages:** Quick • **Disadvantages**: Inaccurate	Use burette/pipette • **Advantages**: more accurate • **Disadvantages**: slower/ takes longer time
Doing the experiment once	Repeat the experiment, take average and compare for reliable results
Using glass beakers for temperature change experiments	Use polystyrene cups (better insulation for minimising heat loss/heat gain)

Taking Measurements

	Tool Used	Unit
Time	Stopwatch	Second (s)
Mass	Digital Balance	Grams (g)
Temperature	Thermometer	Degree Celsius (°C)
Volume of Liquid	Measuring Cylinder	Cubic Centimeter (cm^3)
Volume of Gas	Gas Syringe - Graduated Cylinder	Cubic Centimeter (cm^3)

Pay Attention!

- To the scale, is it increasing downwards (as burette or inverted measuring cylinder) or upwards as an ordinary measuring cylinder.
- To the graduations of the lab tool provided.
- All burette readings should be written to 1 decimal place. And if the reading is a whole digit, write it down as 0s (e.g. 0.0, 25.0, 20.0 etc.)
- When reading a stop watch, make sure to convert time to the unit required in the table heading (minutes or seconds, not both!)
- Burettes & Measuring Cylinders have graduations, tap funnels & gas jars don't.

Purity of Substances

Purity of substances can be checked by:

- **Measuring melting/boiling points**

Pure substances have sharp exact melting & boiling points, impure substances have lower melting points & higher boiling points.

- **By Chromatography**

Solubility

Solubility is the amount of solute that can dissolve in 100g of solvent at a specific in temperature

Explain How?

to measure solubility of Sodium Chloride in water at 40°C

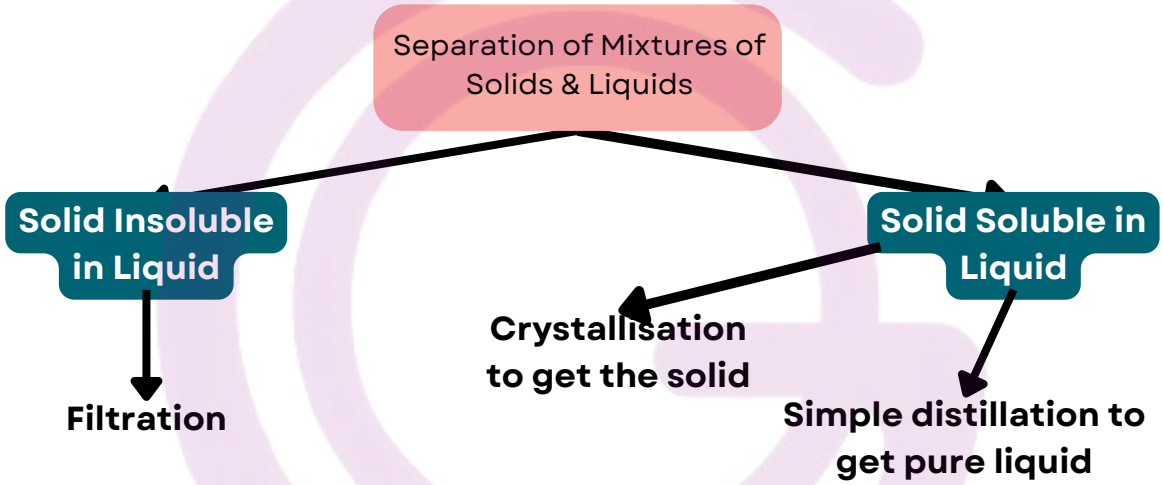
- Add 100 cm^3 of water to a beaker using a measuring cylinder.
- Heat water to 40°C using a bunsen burner
- Add sodium chloride to water & stir till no more dissolves
- Filter the undissolved solid
- Heat the saturated solution in an evaporating dish till all water evaporates
- Weigh the mass of sodium chloride salt left behind

Separation of Mixtures

Separation of a mixture depends on the difference in physical properties of its components (solubility, density, particle size, boiling point, etc.)

Types of Mixtures

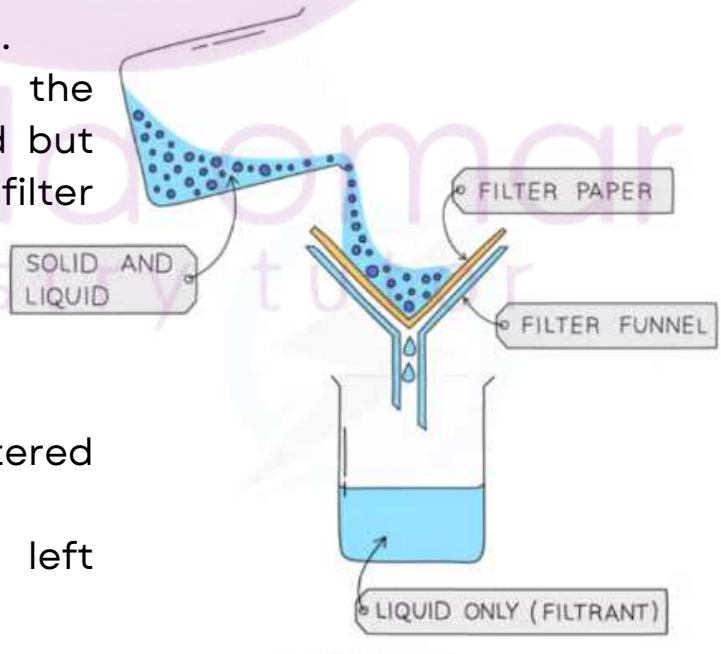
- Mixtures of Solids & Liquids
- Mixtures of Liquids
- Mixtures of Solids



Solid Insoluble in Liquid

Example: Separating a mixture of Sand & Water

- Pour the mixture over a filter paper placed on a funnel.
- Water passes through the filter paper & is filtered but sand remains on the filter paper.



Filtrate: the liquid that's filtered 'water'

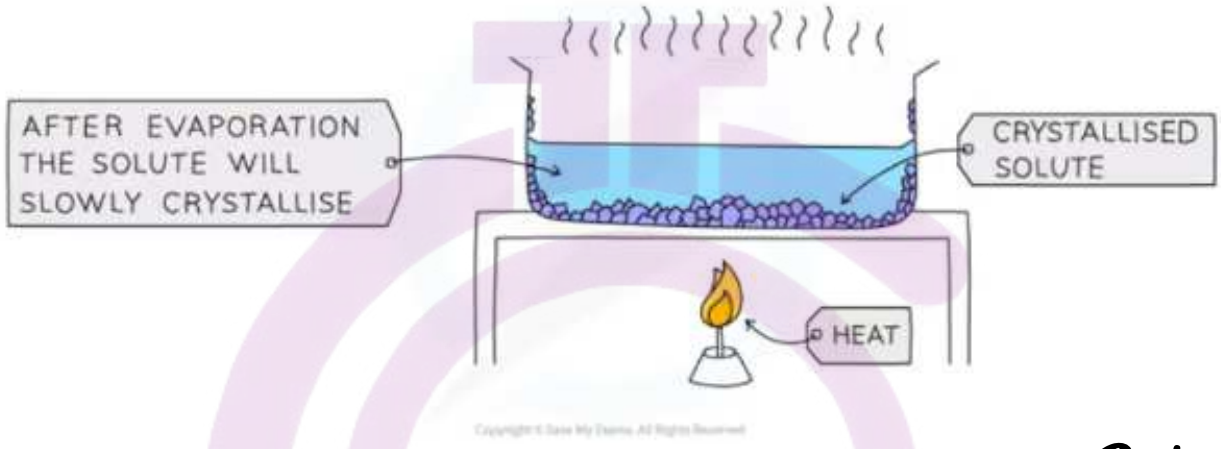
Residue: the solid that is left behind 'sand'

Solid Soluble in Liquid

Example: Separating a mixture of salty water (aqueous Sodium Chloride) or aqueous Copper Sulfate mixture

To get the solid by crystallisation,

- Heat the mixture till crystallisation point
- Leave the mixture to cool.
- Filter crystals
- Dry crystals between two filter papers



Q&A

Q1 How do we know that crystallisation point is reached?
By dipping a glass rod in the solution, crystals appear on its edge

Q2 Explain why do we leave the mixture to cool?
Because solubility decreases by cooling, so more crystals will form on cooling.

Q3 Explain why we don't dry the crystals in an oven?
To avoid losing water of crystallisation.

Simple Distillation

Steps:

- Boiling
- Condensation
- Collection

How do we know that all the first liquid is collected?

- When temperature on the thermometer starts to rise above its boiling point

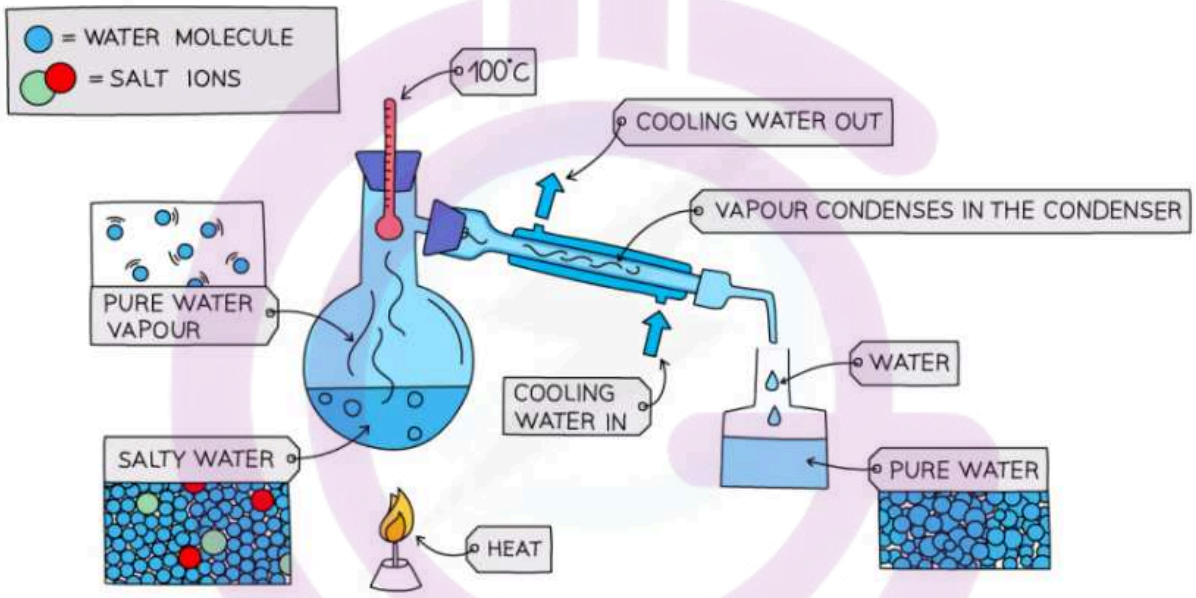
What is the purpose of the condense (or cold ice if used)?

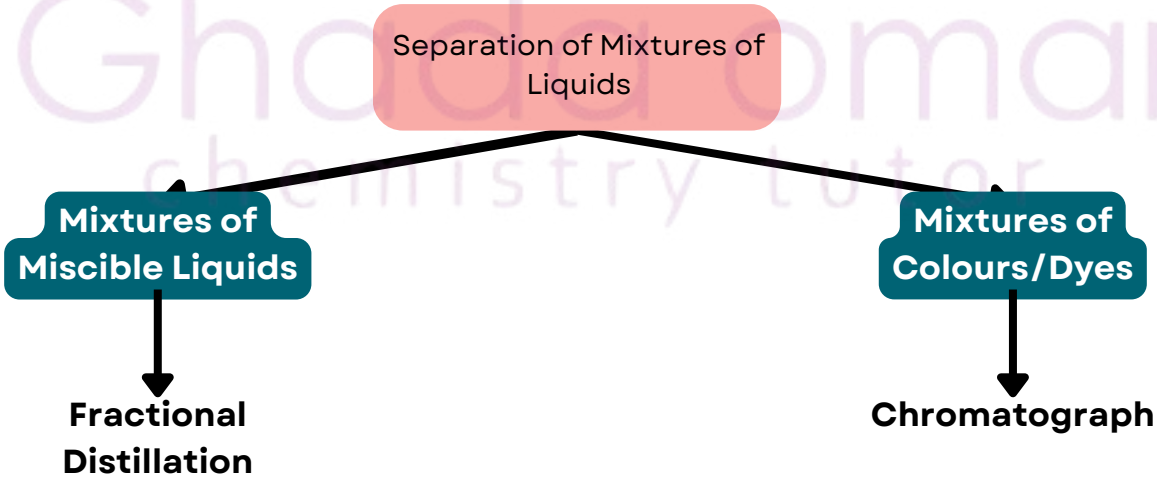
- To cool down & condense the vapor

Drawings & Labels

You may be asked to:

- Draw a condenser
- Label the condenser's water inlet and water outlet
- Draw an arrow where the heat should be applied

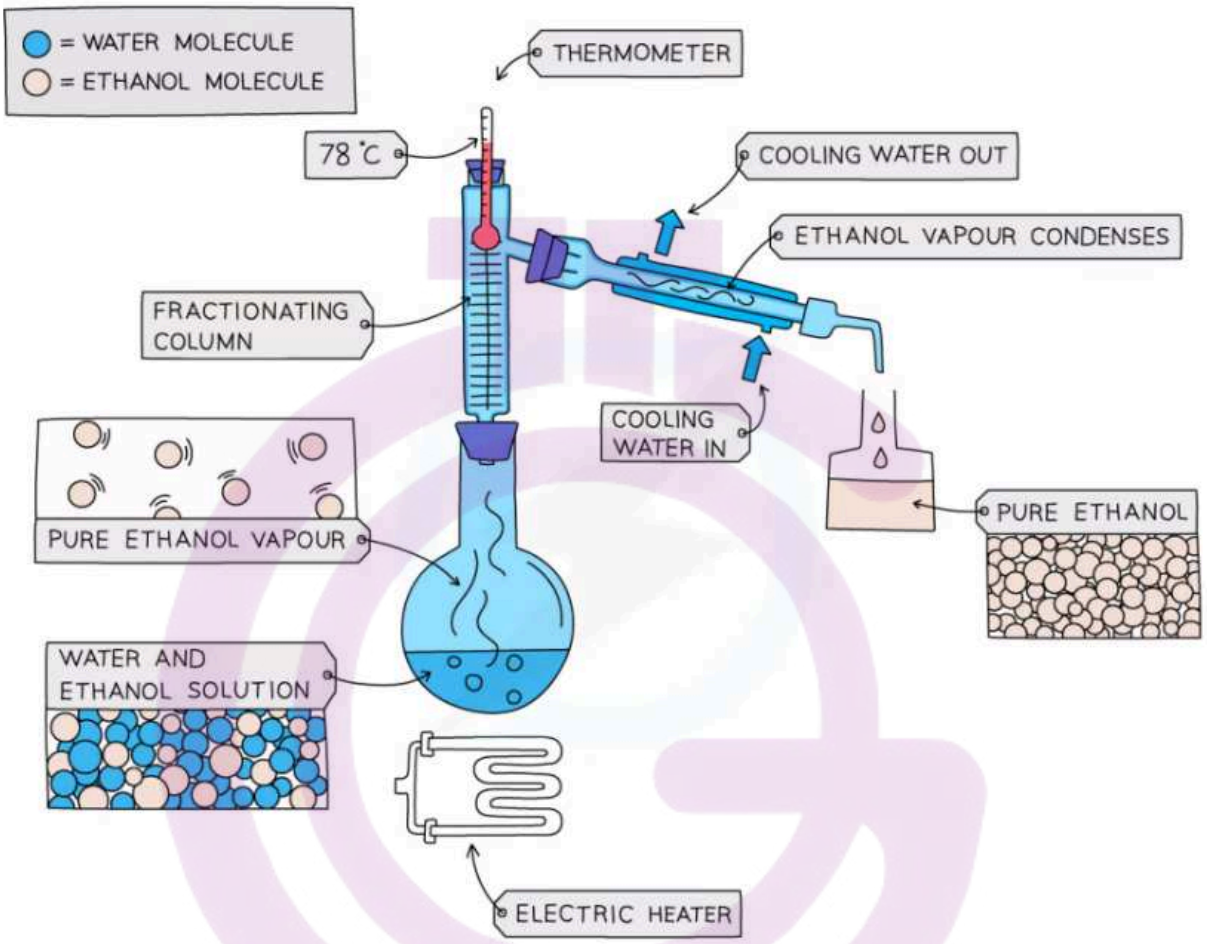




Miscible Liquids

Example: Separating a mixture of Ethanol & Water

Fractional Distillation



- An electric heater is safer to use when there are flammable liquids present.
- The separation of the components in petroleum is achieved by fractional distillation on an industrial scale.
- Fractional Distillation of crude oil is not carried out in school laboratories due to the toxic nature of some of the components of the crude oil, but it can sometimes be simulated using a synthetic crude oil made specially for the demonstration.

Take Note!

Which Liquid distills first?
The liquid with lower boiling point.

The purpose of the fractionating column?
It has a large surface area of glass beads that prevent the liquid that didn't reach the boiling point from passing through it to the condenser.

How to know that all the 1st liquid was distilled/collected?
When the temperature on the thermometer starts to rise above the 1st liquid's boiling point.

It's safer to use electric heater or water bath or sand bath than a bunsen burner. Why?
Because alcohols are flammable, they may catch fire.

Mixtures of Colours or Dyes

Chromatography

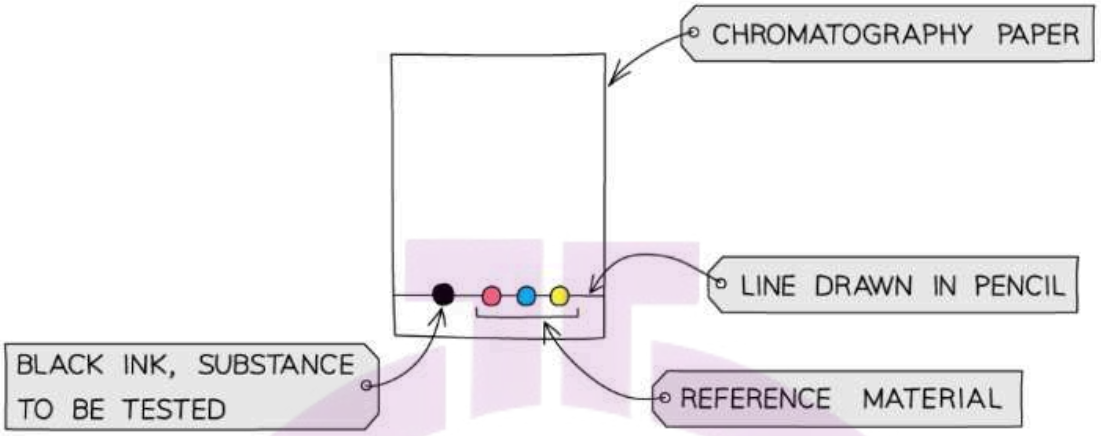
It's a method used for:

- Separation of mixtures of coloured dyes
- Checking purity of substance
- Identification of unknown dyes, pigments, amino acids and sugars

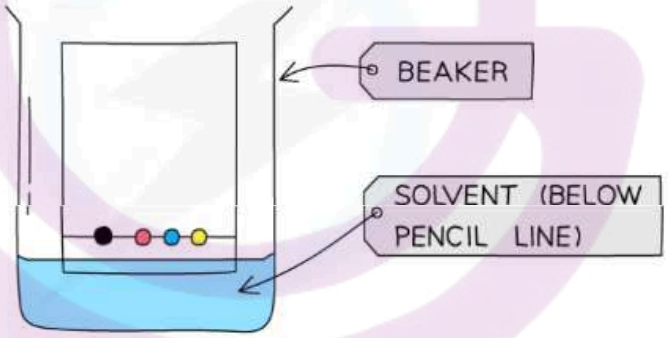
How do we set up a Chromatogram?

- Draw a line using a pencil near the bottom of the Chromatography paper called: Origin or Baseline
- Put a spot of the colour on the baseline using a teat pipette
- Dip the lower end of the level of the solvent, where the level of solvent below baseline
- Cover the beaker with a lid
- The solvent begins to move up the paper separating the colours
- Count the spots & compare / measure Rf value

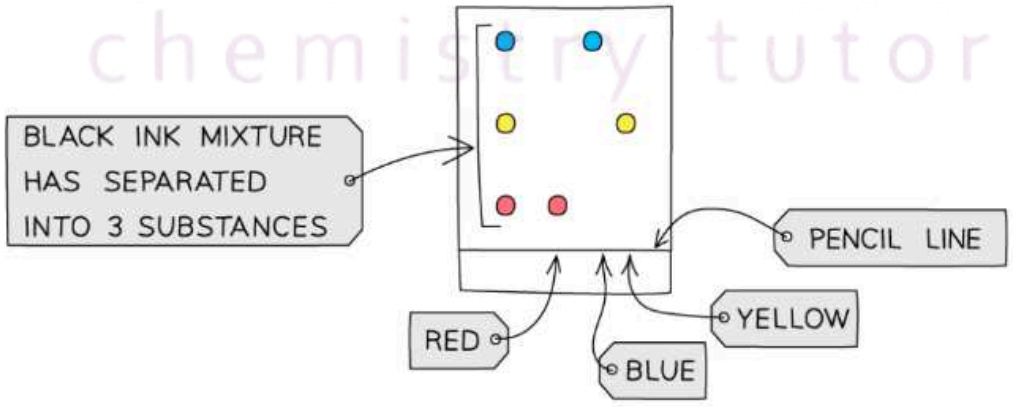
1 SET UP CHROMATOGRAPHY PAPER AS SHOWN



2 LOWER PAPER INTO A BEAKER WITH APPROPRIATE SOLVENT. WAIT FOR SOLVENT TO TRAVEL UP THE PAPER.



3 ANALYSE CHROMATAGRAM



This method of separation is based on difference in solubility & density.

- The most soluble will travel the furthest up the paper.
- The least soluble will travel the nearest to the base line.
- An insoluble substance will not move and remain on the base line.

Q&A

Q1 Why do we use a pencil not ink in drawing the base line "the origin" ?
As graphite is insoluble in water but ink chromatography paper dissolves in water and will run up the chromatograph paper

Q2 Explain why the level of the solvent must be below the baseline?
To prevent leeching of the spots or dissolving of the spots in the solvent

Q3 Solvent Choice?
If dyes are insoluble in water; we need to pick another solvent (e.g. alcohols like ethanol or butanol/esters/acetone/propanone)

Q4 What's the purpose of the lid?
To prevent escape or diffuse of the volatile solvents

Q5 How to apply out the mixture to the paper?
Using a teat pipette or capillary tube or dropper

Q6 Explain how we can use Chromatography to identify colourless substances as amino acids or Carbohydrates?
By spraying locating agent then measuring Rf value with a ruler then compare to known data

Extraction of Coloured Pigments from Plant Leaves

- Crush leaves using mortar & pestle
- Add suitable solvent: water/ethanol to extract the colours & heat
- Filter to remove leaves
- Carry out Chromatography to find no. of colours

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Separation of Mixtures of Solids

- Add water to the mixture to dissolve the salt then stir
- Filter to obtain sand
- Wash sand with distilled water then dry it between 2 filter papers
- Heat the filtrate to evapourate water
- Salt is left in the evapourating dish

Do	Do Not
Wear a lab coat, gloves & eye goggles to protect your clothes, hands and eyes.	Smell any chemicals directly as vapors may be toxic
Carry out the experiment in a fume cupboard if a toxic gas is released	Heat in a closed container as high pressure may cause an explosion
Use water bath / sand bath / electric heater instead of a bunsen burner when heating flammable substances as alcohols as they may catch fire	Heat alcohols and other organic fuels using bunsen burner as they are highly flammable & may catch fire

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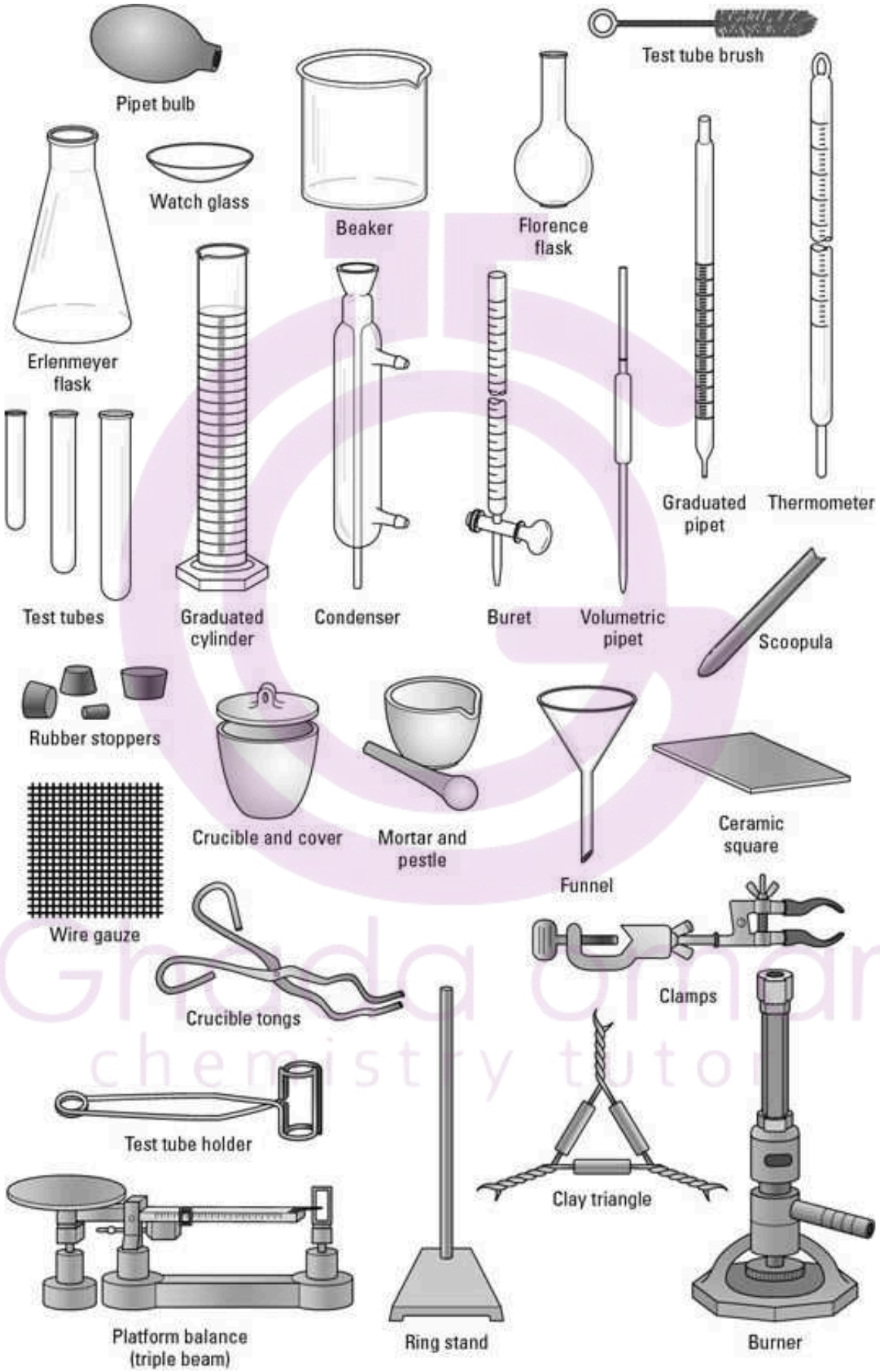
Lab Apparatus

Lab Apparatus



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Topic Summary

Topic Summary

There are different factors involved in the design and planning of an experiment, including choice of apparatus, level of accuracy, variables, sources of error and safety.
Different methods or pieces of apparatus each have advantages and disadvantages, and these should be accounted for when choosing which to use.
The correct apparatus to select when measuring time is a stopwatch or stopclock; temperature, a thermometer; mass, a balance; volume, the appropriate glassware and pH is Universal Indicator or a pH meter.
There is a range of different separation and purification techniques, including use of a solvent (to separate two solids), filtration (to separate an insoluble solid from a liquid), crystallisation (to separate an soluble solid from a solution) and simple or fractional distillation (to separate a liquid from a solution or a mixture of liquids).
The correct separation technique needs to be selected for a given mixture.
Melting point and boiling point data can be used to identify substances and assess their purity.
Paper chromatography is a simple separation technique and a chromatogram can be used to determine whether a sample is a pure substance or a mixture.
A reference sample is used to compare samples in chromatography.
An R_f value is a ratio calculated from a chromatogram and is the distance moved by the substance divided by the distance moved by the solvent front.
A locating agent can be used to highlight the position of soluble colourless substances in a chromatogram.

Flame tests can be used to identify the presence of metal cations based on the characteristic colour of the flames produced: Li^+(red), Na^+(yellow), K^+(lilac), Ca^{2+}(orange–red), Ba^{2+}(light green) and Cu^{2+}(blue–green).
Precipitation reactions with aqueous solutions of sodium hydroxide or ammonia can be used to test for the metal aqueous cations Al^{3+}, Ca^{2+}, Cu^{2+}, Fe^{2+}, Fe^{3+}, Cr^{3+} and Zn^{2}.
Sodium hydroxide can also be used to test for ammonium ions, which are reduced to ammonia.
To test for anions: carbonate ions are detected by effervescence with dilute acid, which produces carbon dioxide. Halide ions are detected by precipitation reactions with acidified silver nitrate. Sulfate ions are detected by a precipitation reaction with acidified barium nitrate. Sulfite ions are detected by a redox reaction with acidified potassium manganate(VII) which produces a visible colour change (purple to colourless). Nitrate ions are detected by a redox reaction using aluminium, which produces ammonia gas.
The tests for common gases are: hydrogen gives a squeaky pop with a lit splint, oxygen relights a glowing splint, carbon dioxide turns limewater milky, chlorine bleaches damp litmus paper. ammonia turns damp red litmus paper blue and sulfur dioxide turns acidified aqueous potassium manganate(VII) from purple to colourless.
Quantitative analysis provides information about the amount of substance present.
Acid–base titrations are a commonly used form of quantitative analysis, which use highly accurate glassware (the pipette and burette).
The end-point of a titration is detected by a colour change in an indicator: methyl orange turns from yellow to red (basic to acidic conditions), whereas thymolphthalein turns from blue to colourless (basic to acidic conditions).

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Checklist

Checklist

I can	Needs more work	Almost there	Confident to move on
understand the different factors involved in the design and planning of an experiment			
name appropriate apparatus for the measurement of time, temperature, mass, volume and pH			
state possible advantages/disadvantages for selecting a particular method or piece of apparatus			
explain the terms solvent, solute, solution, saturated solution, residue and filtrate			
describe how a mixture of solids can be separated by using different solvents			
explain how filtration can be used to separate an insoluble compound from a solvent or solution			
describe how to crystallise a soluble salt from a solution			
explain how simple and fractional distillation can be used to separate mixtures of liquids			
identify the most suitable separation technique when given information about the substances present			
describe the use of melting and boiling points to determine purity			
explain how to carry out a simple paper chromatography to separate coloured compounds			
use a chromatogram to compare an unknown to a known sample and deduce whether a substance is pure or a mixture			
recall and use the equation to calculate Rf Values			
describe how locating agents can be used to identify soluble colourless substances in chromatography			

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