TOPIC 1 : INTRODUCTION TO CHEMISTRY

MEANING OF CHEMISTRY

Chemistry is the branch of science dealing with elements and the compounds they form and the reactions they undergo.

BRANCHES OF CHEMISTRY

The braches of chemistry include physical, environmental, analytical, industrial, organic and inorganic chemistry.

a. PHYSICAL CHEMISTRY

It is the study of how chemical compounds and their constituents react with each other.

b. ENVIRONMENTAL CHEMISTRY

It is the study of how chemicals react naturally in the environment and human impact on natural systems.

c. ANALYTICAL CHEMISTRY

It is the study of separation, identification, and quantification of the chemical components of natural and artificial materials.

d. INDUSTRIAL CHEMISTRY

It is the study of the application of physical and chemical processes towards the change of raw materials into beneficial products.

e. ORGANIC CHEMISTRY

It is the study of compounds that contain carbon except oxides of carbon and carbonates.

f. INORGANIC CHEMISTRY

It is the study of compounds that do not contain carbon and non-living things.

IMPORTANCE OF CHEMISTRY IN EVERYDAY LIFE

Chemistry is important in everyday life and it is applied in different ways. Some of the applications of chemistry are:

- Water treatment. Different chemical processes are used to purify water so that it is safe for drinking.
- Cooking *nsima*. Mixing of the ingredients applies concepts in chemistry.
- Making a cup of tea.
- Pharmaceuticals.
- Food industries. Chemistry is involved in the processing of the food. For example, lime is added to brown sugar so that it becomes white.
- Manufacture of soap and detergents also applies knowledge of chemistry.
- Manufacture of pesticides.

AREAS WHERE CHEMISTRY IS APPLIED

- Pharmaceutical companies that manufacture medical drugs.
- Companies that make food and drinks (soft and alcoholic).
- Companies that manufacture oil products.
- Companies that manufacture fertilizers and pesticides.
- Water purification and supply companies.
- The mining industries.

CAREERS IN CHEMISTRY AND THEIR IMPORTANCE

Most careers in modern society require the application of the knowledge in chemistry.

a. Medicine and nursing

Doctors and nurses need chemistry as part of their training.

b. Pharmacist

Pharmacists require chemistry as part of their training in order to understand the chemicals they are providing.

c. **Food chemist**

Food chemists help test manufactured food to ensure that it is safe to eat.

d. **Teacher chemist**

Chemistry teachers prepare students for different careers by teaching them chemistry in schools.

e. **Environmental chemist**

Environmental chemists are involved in managing the environment by making sure rivers and lakes do not becomes polluted, waste materials are properly disposed among others.

LABORATORY

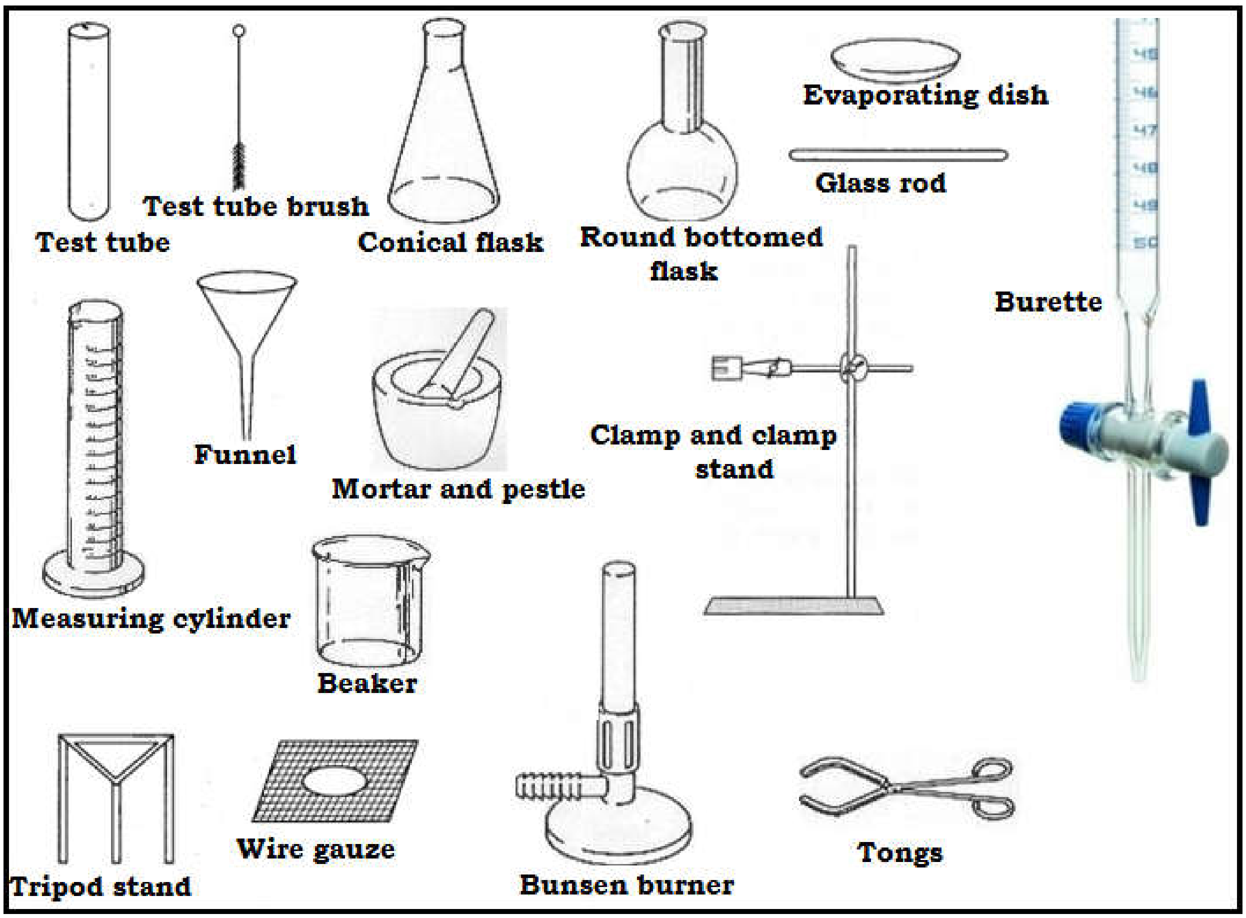
A laboratory is a special room equipped for conducting scientific research and experimentation.

SAFETY RULES IN THE LABORATORY

- Do not drink, taste nor eat anything in the laboratory. Any chemical is never tasted in the laboratory but can be tested.
- Handle all materials in the laboratory carefully. Glassware must be held with both hands.
- Never run or play in the laboratory.
- Wear protective materials such as lab coat, an apron, and safety goggles.
- Never work in the laboratory barefooted.
- Avoid disturbing or pushing a colleague who is busy working in the laboratory.
- Clean all equipment and workplaces after each laboratory period.
- Tie up long hair and avoid wearing loose clothing which could be caught in equipment.
- Follow experimental procedures and do not take short cuts.
- Avoid carrying out any other experiments other than the one given by the teacher.
- Turn off water, gas and electricity outlets when not in use.
- Keep flame and flammable solutions apart.
- Keep electrical equipment away from water and keep areas around electrical equipment dry.
- Always clean glassware before using them.
- Always work in a well ventilated area.

- Keep hands away from face, eyes, mouth and body while using chemicals or laboratory equipment.
- Work areas should be kept clean.
- When first entering a laboratory, do not touch any equipment or other materials in the laboratory until you are instructed to do so.

COMMON LABORATORY APPARATUS

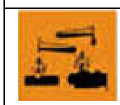


PROTECTIVE EQUIPMENT IN THE LABORATORY

In the chemistry, some of the protective equipment includes goggles, gloves, lab coats, respiratory/gas mask, eye wash station and fire extinguisher

HAZARD SYMBOLS

A hazard symbol tells you the dangers associated with handling laboratory chemical and apparatus. Some of them are shown below.

Hazard symbol	**Meaning**
	Harmful or irritant substance
	Toxic substance
	Highly flammable
	Corrosive
	Dangerous to the environment

THE SI UNIT SYSTEM OF MEASUREMENT

The system of measurement used nowadays is known as the SI system of units. SI stands for International System.

BASIC UNITS

Basic units are a set of unrelated units that form the basis of the SI system of units. These quantities cannot be expressed in terms of other quantities.

Quantity	**Unit name**	**Unit Symbol**
Length	Metre	M
Mass	Kilogram	Kg
Time	Second	S
Temperature	Kelvin	K

DERIVED UNITS

These are units obtained from combination of basic units through multiplication and division. Some of them are shown below.

Quantity	Name of unit	Unit symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Speed	metre per second	m/s
Density	kilogram per cubic metre	kg/m^3

SI PREFIXES FOR UNITS OF MEASUREMENTS

The SI prefix is an affix that is added to the name of a basic unit. It tells you whether the unit is a multiple or a fraction of the basic unit. Examples of SI prefixes are shown in the table.

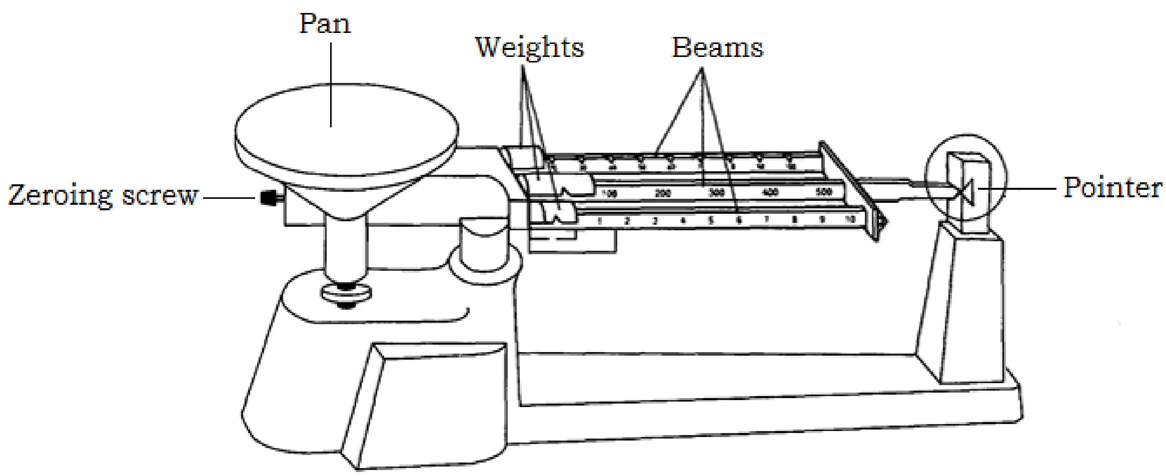
Prefix	Fraction or multiple
nano	10^{-9}
micro	10^{-6}
mili	10^{-3}
kilo	10^{3}
mega	10^{6}
giga	10^{9}

MEASURING PHYSICAL QUANTITIES

Physical quantities must be measured as accurately as possible. Different measuring instruments are used to measure the physical quantities.

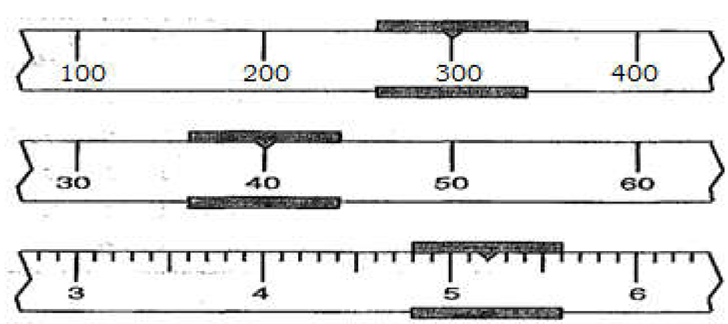
a. MEASURING MASS

The mass of an object is measured using a balance. The triple beam balance is the commonly used balance in the chemistry laboratory. It is shown in the figure below.



HOW TO USE THE TRIPPLE BEAM BALANCE

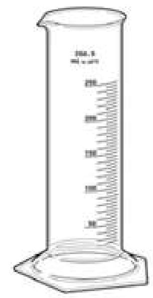
- Put the balance on a flat hard surface where no wind is blowing.
- Put all the masses to zero marks.
- Adjust the zeroing screw until the pointer is at zero.
- Place the object whose mass you want to measure on the pan carefully.
- Move the big mass (100g) first, gradually until the beam balance topples over. Then push the mass one step back.
- Move the second mass (10g) gradually until the beam balance topples over again and push it one step back.
- Move the smaller mass (1g) gradually until the pointer is at zero mark again.
- Read the mass by adding the numerical values of positions of all the three masses. An example is shown.



The mass of the object = (300 + 40 + 5) = 345 g

b. MEASURING VOLUME

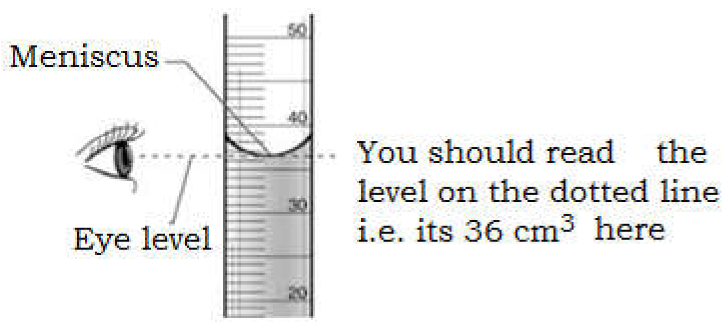
The instrument for measuring volume of a liquid is the measuring cylinder. The measuring cylinders are in different sizes such as 25 ml, 50 ml, 100 ml, 500 ml, and 1000 ml.



Measuring cylinder

HOW TO READ THE VOLUME

The volume of the liquid in the measuring cylinder must be taken from the bottom of meniscus. The meniscus is the curve on the liquid caused by the liquid being slightly attracted to the glass. The meniscus must be viewed at eye level and not from an angle as shown below.



c. MEASURING TEMPERATURE

Temperature is measured using an instrument called thermometer. There are different kinds of thermometers but the commonly used in the chemistry laboratory is the **liquid–in–glass thermometer**.

Thermometer

This kind of thermometer has a glass tube sealed at both ends and is partly filled with liquid like mercury or alcohol. When the liquid in the bulb is heated, it expands and the top of the liquid moves up the tube.

To measure the temperature of a liquid, suspend the tip of the thermometer below the surface of the liquid. Allow the liquid in the thermometer to expand. When it has finished expanding and it is no longer moving up the column, you can read the thermometer.

d. MEASURING TIME

Time is measured using an instrument called stopwatch. A stopwatch is handheld and come in different versions. The most commonly used in the chemistry laboratory is the digital stop watch.

Stop watch

Timing functions are controlled by two buttons; **start/stop button** and the **reset button**. Pressing the start/stop button starts the timer running, and pressing it a second time stops it. Pressing the reset button resets the stopwatch to zero.

When you begin a task, you press the start/stop button to begin recording your time. When you finish working on that task, press the button again to stop recording time.

When the stop watch is set to zero, five zeroes will be displayed on the screen. The first two zeroes on the left represent the "minutes", the middle zeroes represent "seconds" and the last zero "hundredths of a second".

To read the time taken for the task, combine the numbers for your full time used. For example, 11:14:01 would be 11 minutes, 14 seconds and 01 hundredths of a second.

SCIENTIFIC METHOD OF INVESTIGATION

Like other subjects, chemistry is a practical subject. It follows the scientific method or enquiry.

STEPS OF SCIENTIFIC INQUIRY

1. **Identify a problem**

Identifying a problem involves asking questions about the natural world. Examples of scientific questions are:

- What causes rusting?
- Why do plastics not decompose easily?

2. **Formulating a hypothesis**

A hypothesis is a guessed answer to a problem. A hypothesis is formulated from the scientist's experiences and knowledge.

3. **Testing the hypothesis**

To test, the hypothesis, an experiment is carried out. An experiment is a series of investigations intended to accept, modify or reject a hypothesis.

4. **Analyse the results**

This involves looking at the collected date and making sense of it.

5. **Conclusion**

The conclusion is drawn based upon the collected data. It is either a conformation or the rejection of the hypothesis under investigation. If the hypothesis is correct, it is confirmed and adopted and if false it is declared null and void hence rejected. When the hypothesis is rejected another one is formulated and tested.

TOPIC 2 : ESSENTIAL MATHEMATICAL SKILLS IN CHEMISTRY

EXPRESSING NUMBERS IN STANDARD FORM

The standard form or the scientific notation is a special way of writing very large number or very small numbers. When a number is expressed in standard form, its meaning or value does not change.

The number is written in two parts which give the original number when multiplied. One of the numbers must be between 1 and 10 and the other is a power of ten.

EXPRESSING VERY BIG NUMBERS IN STANDARD NOTATION

Place a decimal point just after the first digit, followed by $\times 10$ to the power the number of places moved from the decimal point to the last digit. The movement is from the left to the right. The power of ten must be positive.

Example

Write down each of the following numbers in standard form.

a. 4 500
b. 67 413
c. 300 000 000

Solution

a. 4.5×10^{3}
b. 6.7413×10^{4}
c. 3.0×10^{8}

EXPRESSING VERY SMALL NUMBERS IN STANDARD FORM

Place the decimal point just after the first non-zero digit, followed by $\times 10$ to the power the number of places moved from the decimal point. The movement is from the right to the left. The power of ten is negative.

Example

Write the following numbers in scientific form.

a. 0.00067
b. 0.00145
c. 0.335

Solution

a. 6.7×10^{-4}
b. 1.45×10^{-3}
c. 3.35×10^{-1}

SIGNIFICANT FIGURES

Significant figures of a number are those digits that carry meaning contributing to its precision.

GUIDELINES FOR WRTING SIGNIFICANT FIGURES

1. All non-zero digits are significant. For example in the number 6753 there are 4 significant figures.
2. Zeroes between non-zero digits are significant. For example, the number 40072 has 5 significant figures.
3. Zeroes to the left of non-zero digits are not significant. For example the number:
   0.89 has 2 significant figures
   0.089 has 2 significant figures
   0.0089 has 2 significant figures
4. If a number ends in zeroes to the right of a decimal point, the zeroes are significant. For example the number 9.0 has 2 significant figures.
5. In a figure without a decimal point, the right most non-zero digit is the least significant figure. For example in 7900 the least significant is 9.
6. If the next digit after the last significant figure is 4 or less, the number is rounded down. If it is 5 or more, it is rounded up. For example 14.628 to 4 significant figures is 14.63 while 15.473 to 4 significant figures is 15. 47.

EXPRESSING NUMERICAL RESULTS TO CORRECT NUMBER OF SIGNIFICANT FIGURES

a. Addition and subtraction

The result obtained from adding or subtracting and multiplying or dividing numbers must be quoted based on the number that has the least number of significant figures.

Example 1

Add the following number: 2 345, 7 800 and 934 456.

Solution

The answer is 940 000 and not 944 601 because 7 800 has the least number of significant figures (which is 2).

Example 2

Work out $\frac{2.467 \times 465}{2.7}$.

Solution

424.872222222 to 2 significant figures is 420.

ACCURACY AND PRECISION

Accuracy is how close a measured value is to the actual value. Precision is how close the measured values are to each other.

Example

Consider the three measurements 30.01g, 30.02 and 30.03. If the actual value is 30.0g, then all the three measurements are accurate because they are very close to the actual value. They are also precise because they are close to each other.

GRAPHS

Graphs are pictorial representations of data values measured in an experiment.

TYPES OF GRAPHS

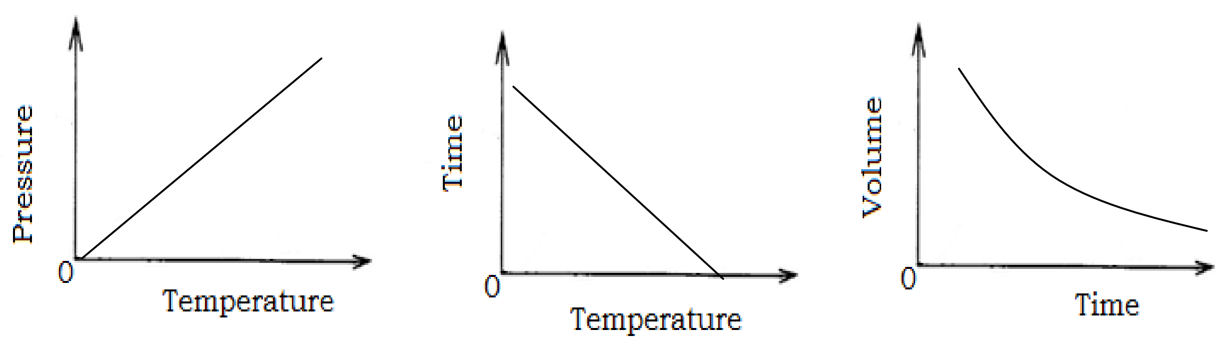
Graphs can be in form of line graphs, bar graphs or pie charts.

a. LINE GRAPHS

Line graphs uses points connected by a line to show data. The line graph must have the following components:

- Title. For example "A graph of temperature against time"
- Axes. These are fixed reference lines for the measurement of coordinates. There are two axes on the graph. The horizontal axis, a straight line drawn from the left to the right and the vertical axis, a straight line drawn from bottom to the top. From any statement, "a graph of A against B", A must be on the vertical axis while B must be on the horizontal axis.
- Scale. A range of numbers that show the units used on the graph.
- Origin. It is a point where the vertical and horizontal axes meet.

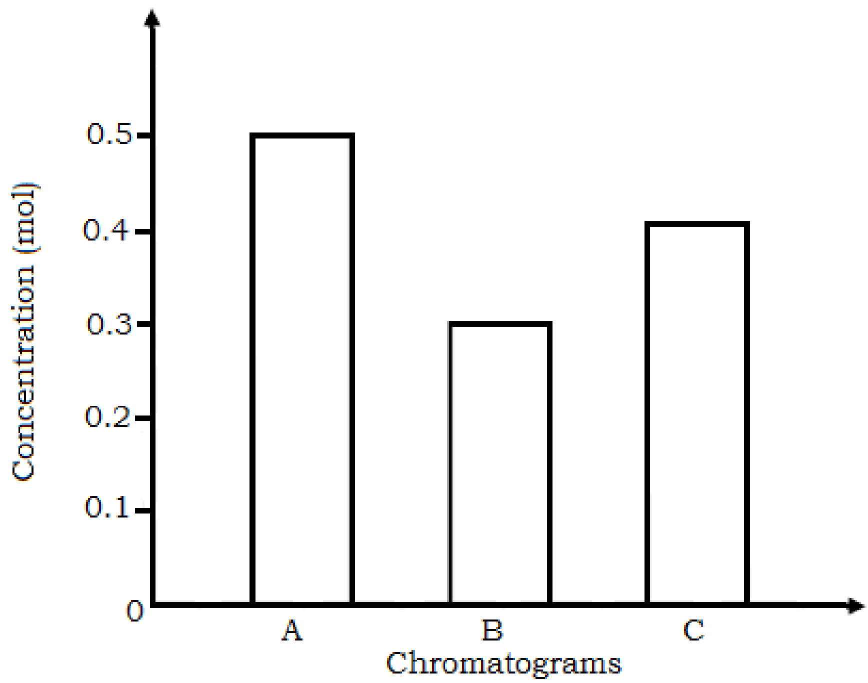
An example of a line graph is shown below



b. BAR GRAPHS

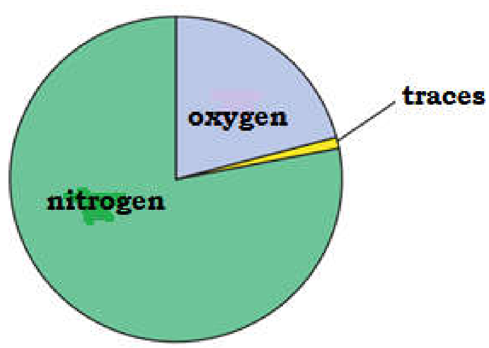
A bar graph displays data using bars or rectangles to show comparisons between categories of data. The bars can either be vertical or horizontal. On the bar graph, one axis will describe the types of categories being compared; and another will have numerical values that represent the values of data.

Just like the line graph, the bar graph includes a title, scale, axes among other things. For example, the figure below is a bar graph showing concentration of solute of three chromatograms, A, B and C.



c. PIE CHARTS

A pie chart display data in the form of a circle. In the pie chart, a circle is divided into various sections or segments. Each segment represents a certain proportion or percentage of the total. In such a diagram, the total of all the given items is equated to 360º. The degrees of angles, representing different items are calculated proportionately. An example of a pie chart is shown below.



TOPIC 3: COMPOSITION AND CLASSIFICATION OF MATTER

MATTER

Matter is defined as anything that has mass and occupies space.

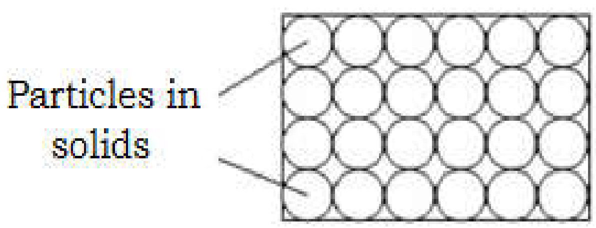
STATES OF MATTER

There are three states of matter. These are solids, liquids and gases

PROPERTIES OF MATTER

1. **SOLIDS**

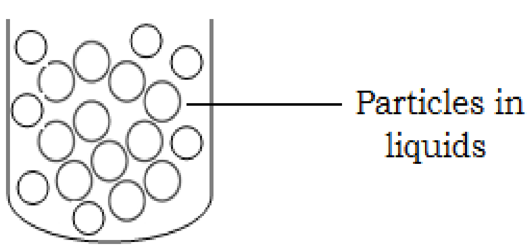
- Particles in solids are tightly packed, usually in a regular pattern.



- They do not flow. This is because particles are not free to move. But they vibrate in fixed positions.
- They have a definite shape.
- They have a definite volume.
- They are difficult to compress.

2. **LIQUIDS**

- Particles in liquids are close together, but with no regular arrangement.

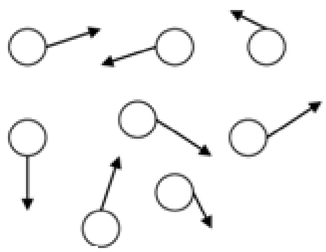


- Liquids flow. This is because their particles are free to move while sticking together.

- They have indefinite shape. In other words, they take the shape of the container in which they are put.
- They have a definite volume.
- They are difficult to compress.

3. GASES

- Particles are very far apart from each other with no regular arrangement.



- Particles move randomly at very high speeds in all directions.
- They have an indefinite shape.
- They an indefinite volume.
- They can be compressed.
- They flow and particles can move past one another.

THE PARTICULATE NATURE OF MATTER

The particulate nature of matter is an idea that explains how matter is put together.

Matter is made up small particles called molecules. The molecules are in turn made up of indivisible and invisible particles called **atoms**.

ATOM

An atom is defined as the smallest particle of matter.

EVIDENCE OF THE PARTICULATE NATURE OF MATTER

The particulate nature of matter can be proved using the concept of diffusion.

DIFFUSION

Diffusion is defined as the movement of particles from a region of a higher concentration to a region of a lower concentration.

Diffusion takes place mainly in liquids and gases, but it occurs most quickly in gases because the particles in gases are very far apart and move more randomly at very high speeds.

It does not take place in solids because particles in solids are not free to move.

INVESTIGATING DIFFUSIONS IN LIQUIDS

Materials:

- A beaker
- Water
- Potassium permanganate crystals
- Thistle funnel.

Procedure

a. Put the thistle funnel into the beaker.
b. Slide a few crystals of potassium permanganate into the beaker through the thistle funnel.
c. Pour water into the beaker with the thistle funnel in the same position as shown in the **Figure 3.1**.

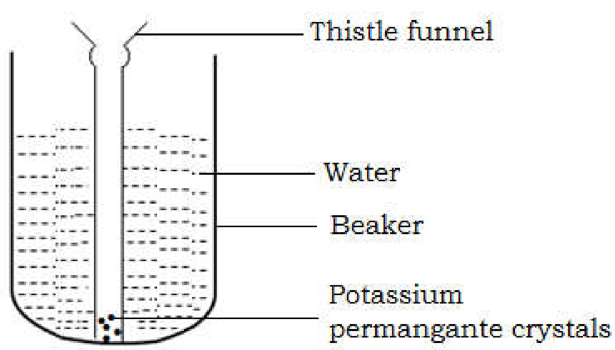


Figure 3.1

d. Carefully, remove the thistle funnel.
e. Leave the set up for 5 minutes and observe what happens. Do not shake or swirl the beaker.

Observations

After five minutes, the purple colour of potassium permanganate is distributed throughout the water in the beaker.

Explanations

The purple colour of potassium permanganate spreads because the particles leave the crystals and mix with water. The solute particles move throughout the water as they keep colliding with water particles as they move, eventually becoming evenly distributed and the colour of water turns purple. In simple words, the particles of potassium permanganate have diffused.

This demonstration proves that matter is made up of tiny particles which are in constant motion.

COMMON EXAMPLES OF DIFFUSION IN EVERYDAY LIFE

- When you enter a restaurant, you smell food being cooked.
- Sugar diffuses in water when it dissolves.
- Coffee grains spread in water.
- A person wearing perfumed clothes

ELEMENTS

An element is a substance which cannot be split into simpler substances by chemical means. Elements are made up of atoms. Some elements exist as separate atoms, while others comprise groups of atoms combined together.

The groups of atoms that result from combination of two or more atoms are called **molecules**. However, it is worth noting that elements are made form only one kind of atoms.

EXAMPLES OF ELEMENTS

There are about 115 elements which have been discovered. Ninety–nine of the elements occur naturally, while twenty–four of these have been made artificially by scientists. The table shows is a list of the first twenty elements.

Hydrogen	Sodium
Helium	Magnesium

Lithium	Aluminum
Beryllium	Silicon
Boron	Phosphorous
Carbon	Sulphur
Nitrogen	Chlorine
Oxygen	Argon
Fluorine	Potassium
Neon	Calcium

CHEMICAL SYMBOLS OF ATOMS OF ELEMENTS

The chemical symbol is a shorthand form for writing the names of the elements. The system of writing symbols uses the letter taken from the name of the element. This could be the English or Latin name of the element.

RULES FOR WRITING CHEMICAL SYMBOLS OF ELEMENTS

- All chemical symbols consist of one or two letters.
- The second letter is added where some elements have the same initial letter.
- The first letter of the chemical symbols must always be **capital**.

Name of element	Chemical symbol	Name of element	Chemical symbol
Hydrogen	H	Sodium	Na
Helium	He	Magnesium	Mg
Lithium	Li	Aluminium	Al
Beryllium	Be	Silicon	Si
Boron	B	Phosphorous	P
Carbon	C	Sulphur	S
Nitrogen	N	Chlorine	C*l*
Oxygen	O	Argon	Ar
Fluorine	F	Potassium	K
Neon	Ne	Calcium	Ca

The table below shows chemical symbols of elements which are derived from Latin names of the elements.

Element	Latin name	Chemical symbol
Sodium	Natrium	Na
Potassium	Kalium	K
Copper	Cuprum	Cu
Iron	Ferrum	Fe
Silver	Argentum	Ag
Lead	Plumbum	Pb
Gold	Aurum	Au
Mercury	Hydrargyrum	Hg

MOLECULES

A molecule is the smallest particle of an element or a compound which can exist in a free and separate state.

TYPES OF MOLECULES

There are three main types of molecules. These are:

a. MONOATOMIC MOLECULES

These are molecules composed of one atom. Examples are helium (He), Neon (Ne), Argon (Ar), Xenon (Xe) and Radon (Rn).

b. DIATOMIC MOLECULES

These are molecules composed of two atoms. Examples are Hydrogen (H_2), Oxygen (O_2), Nitrogen (N_2), Fluorine (F_2), Chlorine (Cl_2), Bromine (Br_2) and Iodine (I_2).

c. POLYATOMIC MOLECULES

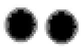
These are molecules composed of many atoms. The e amples are Sulphur (S_8) and Phosphorous (P_4).

USING MODELS OR DIAGRAMS TO ILLUSTRATE FORMATION OF MOLECULES

Example 1: Oxygen molecule (O_2)

Let  repressent one oxygen atom.

Since oxygen molecule is diatomic, it will be shown as:

 oxygen molecule

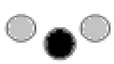
Example 2: Water molecule (H_2O)

A water molecule consists of two hydrogen atoms and one oxygen atom.

Let  represent oxygen atom

and  represent hydrogen atom

The water molecule is shown as

 water molecule

COMPOUNDS

A compound is a pure substance made up of two or more different chemical elements. In a compound, elements are present in definite proportion. A compound has different chemical and physical properties from those elements of which it is composed of.

The table below shows examples of compounds and elements which are present in each compound.

Name of compound	**Elements present in the compound**
Water	Hydrogen, Oxygen
Carbon dioxide	Carbon, oxygen

Sodium chloride	Sodium, Chlorine
Copper carbonate	Copper, Carbon, Nitrogen
Glucose	Carbon, Hydrogen , Oxygen
Ammonia	Hydrogen, Nitrogen
Potassium nitrate	Potassium, Nitrogen, Oxygen
Methane	Carbon, Hydrogen

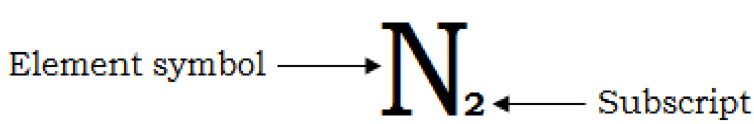
DIFFERENCES BETWEEN AN ELEMENT AND A COMPOUND

Element	**Compound**
Is made up of only one kind of atoms	Is made up of two or more elements
Cannot be split into simpler substances by chemical means	Can be split into individual elements using chemical reactions
Are represented by chemical symbols of their atoms	Are represented by chemical formula

CHEMICAL FORMULAE OF SUSBTANCES

This is a formula that shows what types of atoms present and how many there are for each type, in a given compound.

- The types of atoms present in the compound are indicated by the chemical symbols of the elements.
- The numbers for each type of atoms is are indicated by a **subscript**. A subscript is a lowered small digit. It is written slightly below the element symbol.



For example, the chemical formula of glucose is $C_6H_{12}O_6$. This formula tells us that:

- In glucose molecule, there are three types of atoms that combine. These are Carbon (C), Hydrogen (H) and Oxygen (O).

- There are 6 carbon (C) atoms, 12 Hydrogen (H) atoms and 6 Oxygen (O) atoms in the compound.

The chemical formulae of some common substances are shown below.

Name of substance	Chemical formulae
Carbon dioxide	CO_2
Water	H_2O
Ethanol	C_2H_5OH
Sodium chloride (common salt)	$NaCl$
Copper (II) sulphate	$CuSO_4$

DETERMINING THE TYPE AND NUMBER OF ATOMS IN THE CHEMICAL FORMULA OF A GIVEN SUBSTANCE

Example 1:

The molecule of sucrose consists of 12 carbon atoms, 22 hydrogen atoms and 11 oxygen atoms. Write down the molecular formula of sucrose.

Solution:

The molecular formula of sucrose is $C_{12}H_{22}O_{11}$.

Example 2:

The chemical formula of sodium sulphate is given as Na_2SO_4.

a. Determine the types and number of atoms in sodium sulphate.
b. Work out the total number of atoms in sodium sulphate.

Solution:

a. The types and number of atoms are:
   Sodium (Na) = 2 atoms , Sulphur (S) = 1 atom, Oxygen (O) = 4 atoms

b. Total number of atoms = 2 + 1 + 4 = 7 atoms

Example 3:

Work out the total number of atoms present in one molecule of copper nitrate, $Cu(NO_3)_2$.

Solution:

$(NO_3)_2$ means that everything inside the brackets is multiplied by 2.

Copper (Cu)	=	1 atom
Nitrogen (N)	=	2 atoms
Oxygen (O)	=	6 atoms
Total number of atoms	=	1 + 2 + 6
	=	9 atoms

PURE SUBSTANCES AND MIXTURES

A **pure substance** is a substance that has definite and constant properties throughout the sample. It can either be an element or a compound. Examples of pure substances are rain water, salt, ethanol, sugar etc.

A **mixture** is a substance that contains two or more kinds of substances that are not chemically joined together.

TYPES OF MIXTURES

There are two types of mixtures. These are homogeneous and heterogeneous mixtures.

a. HOMOGENEOUS MIXTURE

It is a mixture in which the particles are uniformly distributed throughout the mixture. Examples are sugar solution, salt solution, blood, air, milk etc.

b. HETEROGENOUS MIXTURE

It is a mixture in which the particles are not evenly distributed within the sample. Examples are rock, soup, water, crude oil, a mixture of slat and sand.

SOLUTIONS

A solution is a homogeneous mixture of two or more components. It is a mixture of a **solute** and **solvent**.

A **solute** is substance that dissolves in another substance. A substance in which another substance dissolves is called the **solvent**. For example, in a sugar solution, sugar is the solute while water is the solvent.

AQUEOUS SOLUTION AND NON-AQUEOUS SOLUTIONS

An **aqueous solution** is the one in which the solvent is water. Examples are sugar solution, salt solution etc. A **non-aqueous solution** is the one in which the solvent is not water. Examples are iodine in water, acetone in benzene.

TYPES OF SOLUTIONS

a. Solid–in–solid

This is a solution in which a solid is dissolved in another solid.

This is done when both metals are melted so that they can uniformly form a single solution. For example, galvanized iron is a solution of zinc in iron, and brass is a solution of zinc in copper.

b. Liquid–in–liquid

This is a solution in which a liquid is dissolved in another liquid. For example, vinegar is a solution of acetic acid in water.

c. Solid–in–liquid

This is a solution in which a solid dissolves in a liquid. The best example is a solution of sugar in water.

d. Gas–in–liquid

This is a solution in which a gas is dissolved in a liquid. Fizzy drinks are solutions of a gas in a liquid. For example, in soda water, coca-cola, cocopina, and cherry plum carbon dioxide is dissolved in water.

SATURATED AND UNSATURATED SOLUTIONS

A **saturated solution** is the one in which no more solute can dissolve. If more solute is added to a saturated solution, undissolved crystals of the solute will rest at the bottom of the container without dissolving. An **unsaturated solution** is the one in which more solute can dissolve.

WAYS OF MAKING A SATURATED SOLUTION UNSATURATED

- Adding more solvent to the solution.
- Increasing the temperature of the solution i.e. by heating

WAYS OF MAKING UNSATURATED SOLUTION SATURED

- Add more solute to a liquid.
- Evaporate the solvent from an unsaturated solution.
- Lowering the temperature of the solution.

FACTORS AFFECTING SOLUBILITY

a. TEMPERATURE

The solubility of solids in liquids increases as the temperature increases, and decreases as the temperature decreases. When temperature increases, solvent particles gain kinetic energy and collide frequently with solute particles, hence speeding up the solubility.

b. SIZE OF PARTCILES

Solubility of solids increases with an increase in surface area and decreases with a decrease in surface area. Thus, powders dissolve more quickly than lumps in the same volume of solvent. This is because; small particles can easily come into contact with solvent molecules, while it is difficult for solvent molecules to surround large particles.

c. POLARITY

Polar solutes dissolve best in polar solvents. Non–polar solutes dissolve best in non–polar solvents.

WAYS OF INCREASING SOLUBILITY OF SOLUTES IN SOLVENTS

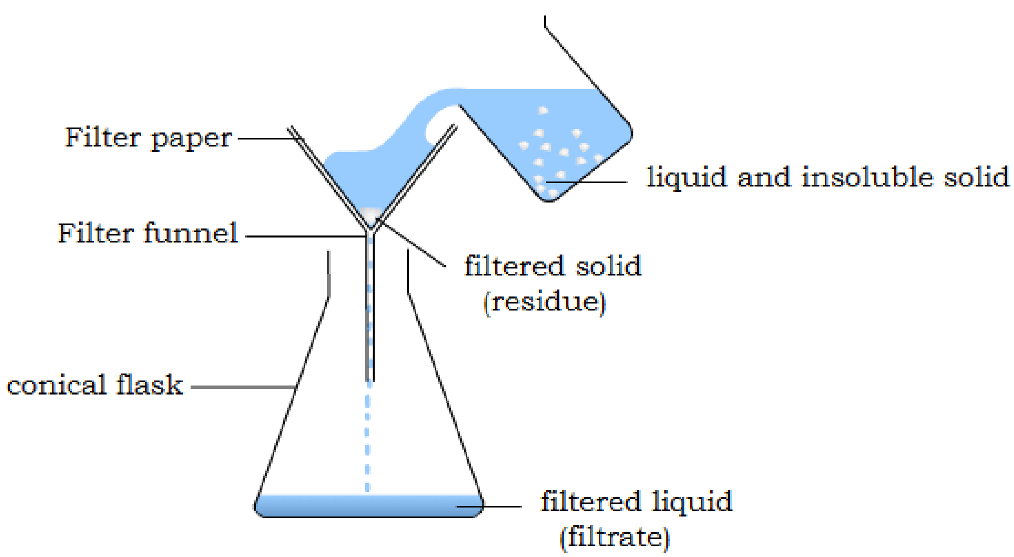
- Stirring the solution.
- Crushing the solute to powder.
- Heating the solution.

METHODS OF SEPARATING MIXTURES

The methods include filtration, decantation, evaporation, distillation (simple and fractional), chromatography and magnetism.

a. FILTRATION

Filtration is a method used to separate an insoluble solid from a liquid. During filtration, the mixture is passed through a filter paper which acts like a sieve. The filter paper has millions of tiny holes in it, allowing the liquid to pass but retaining the solid particles.



The liquid that passes through the filter paper is called the filtrate and the solid that remains on the filter paper is called the residue.

Examples of mixtures that can be separated by filtration include a mixture of sand water, and a mixture of salt and a salt.

b. DECANTATION

This method is used to separate mixtures of immiscible liquids or of a solid and a liquid in a suspension.

Immiscible liquids are liquids that do not mix and form two distinct layers in a container e.g. water and paraffin, vinegar and oil etc.

To separate two immiscible liquids, the top layer is carefully poured out into another container. The middle portion is rejected since it is a mixture of the two unseparated liquids. The other liquid remains behind.

When separating a mixture of a solid and a liquid, the mixture is allowed to stand in a beaker until all the solid settles at the bottom of the container. Then, the liquid is carefully poured off to leave the insoluble solid behind.

c. EVAPORATION

This is a method of separating a soluble solid substance from its solvent. For example, salt could be recovered from salt solution using this method. Heat is applied to an evaporating basin containing the solution and molecules of a liquid escape from it leaving behind the solid particles.

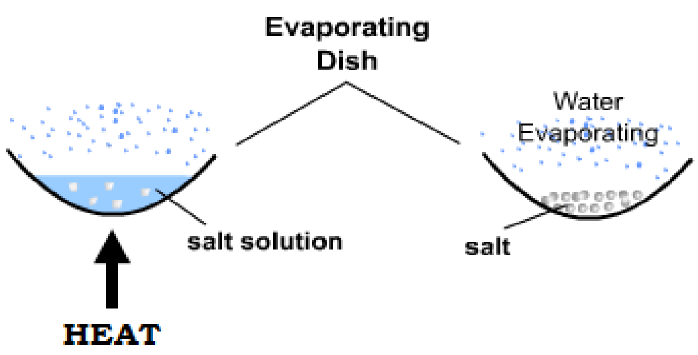


Figure 2.3

d. DISTILLATION

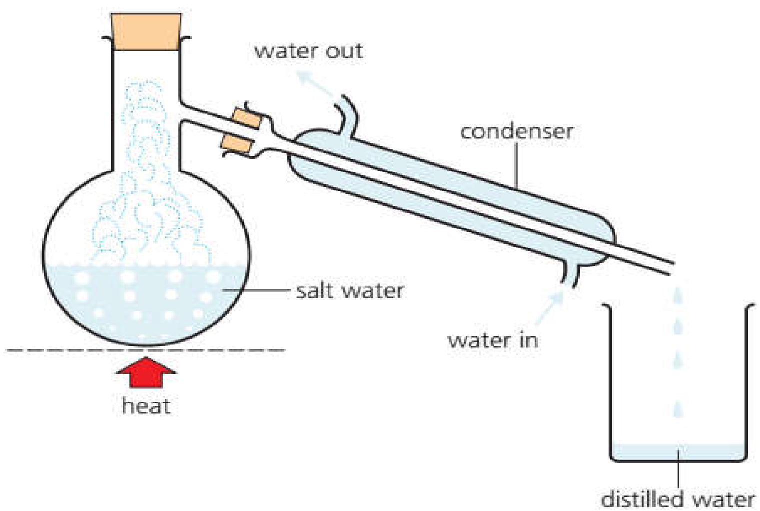
This is a chemical process of separating substances that have different boiling points by heating the mixture until it turns into gas and then cooling and collecting each substance separately.

There are two kinds of distillation; **simple distillation** and **fractional distillation**.

i. SIMPLE DISTILLATION

Simple distillation is used to separate a solvent from a solution. It is useful for producing water from salt solutions.

Simple distillation works on the principle that the dissolved solute has a much higher boiling point than the solvent. When the solution is heated, solvent vapour evaporates from the solution. The gas moves away and is cooled and condensed. The remaining solution becomes more concentrated in solute as the amount of solvent in it decreases.



ii. FRACTIONAL DISTILLATION

Fractional distillation is used to separate different liquids from a mixture of miscible liquids. It is useful for separating ethanol from a mixture of ethanol and water, and for separating different fractions from crude oil (petroleum).

Fractional distillation works on the principle that the different liquids have different boiling points. When the mixture is heated:

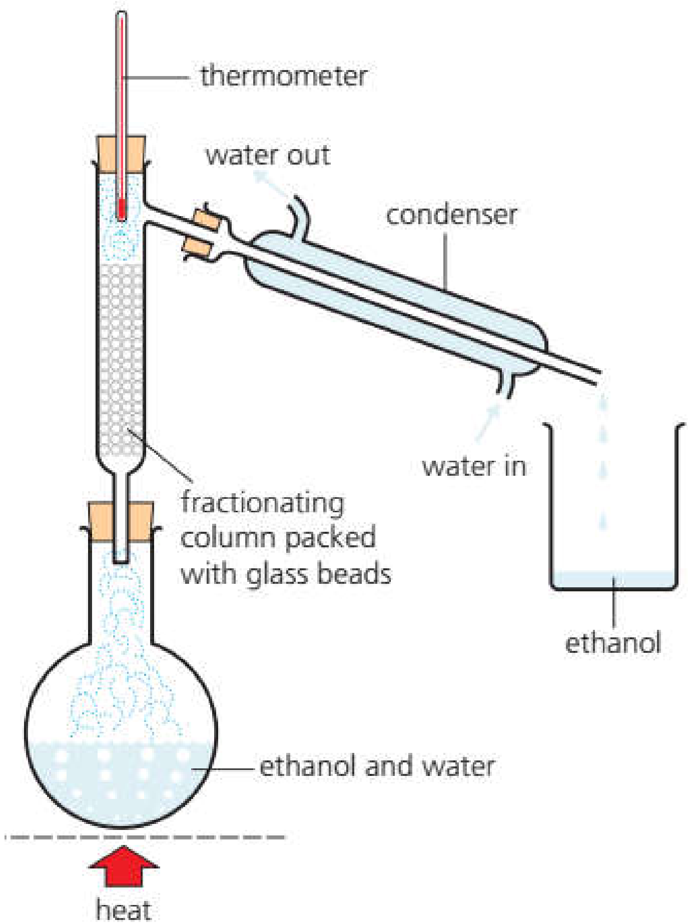
- vapours rise through a column which is hot at the bottom and cold at the top. It is called the fractionating column.

- vapours condense when they reach a part of the column that is below the temperature of their boiling point.

The different liquids are collected from different parts of the column. The substance with the lowest boiling point is collected at the top of the column.

SEPARATING ETHANOL FROM A MXITURE OF ETHANOL AND WATER

- The apparatus is set up as shown below.



- The mixture is heated and a mixture of ethanol vapour and water vapour rises up the column.
- The vapour condenses on the glass beads in the column making them hot.
- When the temperature of the beads reaches about 78ºC, ethanol vapour moves up the column into the condenser, while the water drips back into the flask.
- Eventually, the thermometer reading rises above 78ºC. This indicates that all the ethanol has been separated hence heating can be stopped.

e. CHROMATOGRAPHY

This is a method of separating a mixture of chemically similar ingredients. These are often coloured substances such as food colourings, inks, dyes or plant pigments.

Chromatography separates mixtures by taking advantage of their different rates of movement in a solvent over an absorbent material.

PAPER CHROMATOGRAPHY

In paper chromatography, the absorbent material is a filter paper and solvents such as water, ethanol, propanone and other organic solvents can be used. Substances are picked up and carried by a **mobile phase** which moves through a **stationary phase**.

The **stationary phase** is the part of the chromatography which is in solid state e.g. the filter paper.

The **mobile phase** is the part of the chromatography which is in gaseous or liquid state e.g. the solvent.

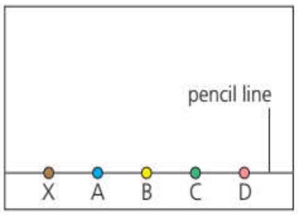
The different dissolved substances in the mixture are attracted to the two phases in different proportions. This causes them to travel at different rates through the paper.

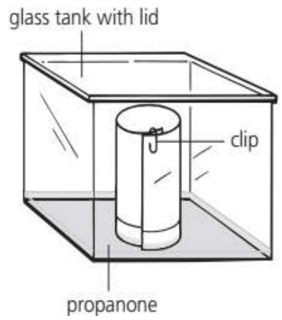
PROCEDURE

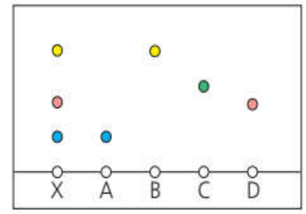
- Using a pencil, a 'start line' is drawn near the bottom of the chromatography paper.
- The mixture to be separated is spotted on the start line.
- The bottom of the chromatography paper is dipped into the solvent and the solvent travels up the paper by capillary action.
- The solvent picks up the substance being separated and carries it up the paper.
- The different components in the substance rise to different heights.
- The "solvent front" is marked.

The **solvent front** is the furthest point reached by the solvent on chromatography paper.

The pattern formed by the substances that have been separated by chromatography is called the **chromatogram**.







f. MAGNETSIM

This is a method used to separate magnetic from non-magnetic materials.

A magnet is hanged over the mixture and only magnetic materials are attracted to the magnet thereby achieving separation.

TOPIC 4 : ATOMIC STRUCTURE

ATOM

An atom is the smallest particle of matter.

COMPOSITION OF AN ATOM

An atom consists of three **sub-atomic particles**. These include protons, neutrons and lectrons. The central part of the atom is called the **nucleus**.

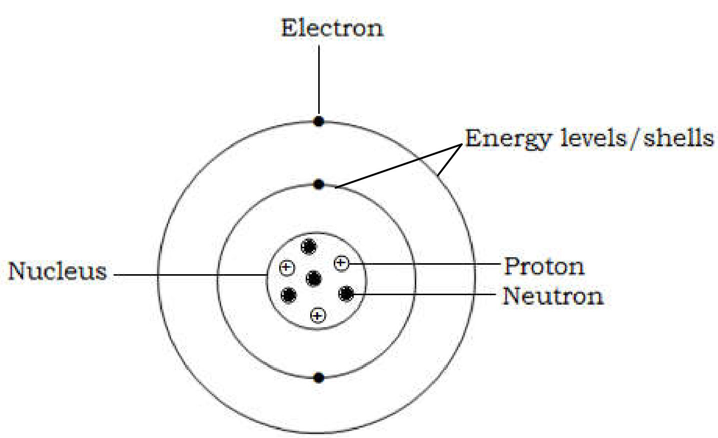
THE NUCLEUS

- It contains protons and neutrons.
- It has a positive charge because of the protons.
- The whole mass of the atom is concentrated in the nucleus.
- It is tiny compared to the size of the atom.

Outside the nucleus are regions called **energy levels**, or **shells**.

ENERGY LEVELS OR SHELLS

- These are imaginary paths through which electrons move.
- They are different distances from the nucleus.
- They are associated with a certain quantity of energy. An electron moving from one energy level to another absorbs or emits energy depending on whether it moves to a lower or a higher energy level.



CHARACTERISTICS OF PARTICLES THAT MAKE AN ATOM

1. PROTONS

- These are positively charged particles. Each proton has a charge of $+1$.
- Each proton has a mass of 1 **amu** (atomic mass unit).
- They are found inside the nucleus of an atom.

2. ELECTRONS

- These are negatively charged particles. Each electron has a charge of -1.
- Electrons have no mass.
- They move around the nucleus at very high speeds.
- They occupy the energy levels.

3. NEUTRONS

- These particles have no charge. They are considered to be neutral because they contain an equal number of positive and negative charges.
- Each neutron has a mass of 1 amu.
- They are found inside the nucleus of an atom.

The table below shows the summary of characteristics of particles found in atom.

Particle	Charge	Mass	Location
Proton	+1	1 amu	nucleus
Electron	-1	Almost zero	energy levels/shells
Neutron	0 (No charge)	1 amu	nucleus

ELECTRON CONFIGURATION

Electron configuration is the number and arrangement of electrons in atom. In other words, the electron configuration shows us how electrons are distributed in the energy levels of an atom.

The first twenty elements follow the following electron configuration:

- The 1^{st} shell can hold a maximum of 2 electrons.
- The 2^{nd} shell can hold a maximum of 8 electrons.

- The 3rd shell can hold a maximum of 8 electrons.
- The 4th shell can hold a maximum of 18 electrons.

The electron configuration is shown as a pattern of numbers. For example, 2.8.8.2 or 2:8:8:2.

WORKED EXAMPLES ON ELECTRON CONFIGURATION

Example 1:

A sodium (Na) atom contains 11 atoms.

a. Write down its electron configuration.
b. Draw the atomic structure of sodium (Na)

Solution:

a. 1st shell = 2 electrons

From the 11 electrons, the remainder is 9.

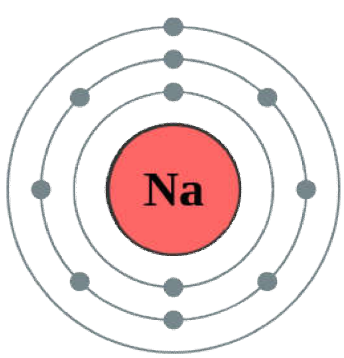
2nd shell = 8 electrons

From the 9 electrons, the remainder is 1.

3rd shell = 1

Therefore, the electron configuration of sodium is 2.8.1

b. The atomic structure of sodium is shown as



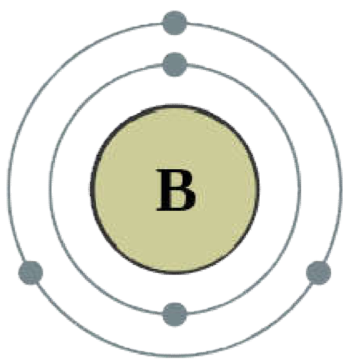
Example 2:

Boron (B) has 5 electrons.

a. Write down its electron configuration.
b. Draw the atomic structure of boron.

Solution

a. Its electron configuration is 2.3
b. Its atomic structure is shown as:



ATOMIC NUMBER AND MASS NUMBER

Atomic number is the number of **protons** in the nucleus of an atom. It is denoted by capital letter **Z**. The atomic number is like an 'identity card' of an atom. It is the property that makes atoms of different elements different.

Mass number is the number of protons and neutrons in the nucleus of an atom. It is denoted by capital letter **A**.

The number of neutrons is normally represented by capital letter **N**.

The relationship between the atomic number (Z), the mass number (A) and the number of neutrons (N) is expressed as follows:

Mass number = Number of protons + Number of neutrons

$$A = Z + N$$

The number of protons in an electrically neutral atom is equal to the number of electrons. The atomic numbers, number of neutrons and mass numbers of the first twenty elements are shown below.

Element	Symbol	Number of protons (Atomic number, Z)	Number of neutrons (N)	Mass number (A)
Hydrogen	H	1	0	1
Helium	He	2	2	4
Lithium	Li	3	4	7
Beryllium	Be	4	5	9
Boron	B	5	6	11
Carbon	C	6	6	12
Nitrogen	N	7	7	14
Oxygen	O	8	8	16
Fluorine	F	9	10	19
Neon	Ne	10	10	20
Sodium	Na	11	12	23
Magnesium	Mg	12	12	24
Aluminium	Al	13	14	27
Silicon	Si	14	14	28
Phosphorous	P	15	16	31
Sulphur	S	16	16	32
Chlorine	Cl	17	18	35
Argon	Ar	18	22	40
Potassium	K	19	20	39
Calcium	Ca	20	20	40

NUCLIDE SYMBOLS

A **nuclide** is any form of an element which is characterized by specific constitution of its nucleus.

To represent a nuclide, we write the chemical symbol of the element with the mass number on the top left and atomic number at the bottom left of the element.

$$^{A}_{Z}X$$

where **A** is the mass number, **Z** is the atomic number and **X** is the element symbol.

Example

You are given an atom **X** that has 17 protons, 20 neutrons and 17 electrons.

a. Find the atomic number of atom **X**.
b. Work out its atomic mass.
c. Write down the nuclide of **X**.
d. Write down the electron configuration of **X**.

Solution:

a. Atomic number = Number of protons = 17

b. Mass number = Number of protons + Number of neutrons

= 17 + 20

= 37 amu

c. The nuclide of **X** is $^{37}_{17}X$.

d. Since there are 17 electrons, the electron configuration of **X** is 2.8.7.

ISOTOPES

Isotopes are atoms of the same element that have the same atomic numbers but different mass numbers.

They have different mass numbers because they have different number of neutrons on their nuclei. Examples of isotopes are shown below.

Element	Name of isotope	Notation	Particles present
Hydrogen	Hydrogen – 1	$^{1}_{1}H$	1 proton, 0 neutrons
	Hydrogen – 2	$^{2}_{1}H$	1 proton, 1 neutron
	Hydrogen – 3	$^{3}_{1}H$	1 proton, 2 neutrons
Carbon	Carbon – 12	$^{12}_{6}C$	6 protons, 6 neutrons
	Carbon – 14	$^{14}_{6}C$	6 protons, 8 neutrons
Chlorine	Chlorine – 35	$^{35}_{17}Cl$	17 protons, 18 neutrons
	Chlorine – 37	$^{37}_{17}Cl$	17 protons, 20 neutrons
Uranium	Uranium – 235	$^{235}_{92}U$	92 protons, 143 neutrons
	Uranium – 238	$^{238}_{92}U$	92 protons, 146 protons

KEY POINTS ABOUT ISOTOPES

- They have the same number of protons on their nuclei.
- They have different number of neutrons on their nuclei.
- They have the same number of electrons in their outermost shell.
- They belong to the same group of the Periodic Table.
- They belong to the same period in the Periodic Table.
- They have identical (similar) chemical properties i.e. they react in the same way.

CALCULATING THE AVERAGE MASS OF AN ELEMENT GIVEN MASSES OF ISOTOPES

The average mass of atoms is also called the relative atomic mass (RAM). It is calculated from the relative percentage abundance in nature (RPA) of the isotopes and the relative isotopic mass (RIM). Thus:

RAM of element **X** = (RPA of isotope 1 $\times$ its RIM) + (RPA of isotope 2 $\times$ its RIM)

Example 1:

A sample of chlorine gas contains two isotopes, ${}^{35}_{17}Cl$ and ${}^{37}_{17}Cl$. Given that the percentage abundance of ${}^{35}_{17}Cl$ is 75% and and that of ${}^{37}_{17}Cl$ is 25%, calculate the relative atomic mass of chlorine.

Solution

Relative atomic mass of chlorine $= \frac{75}{100} \times 35 + \frac{25}{100} \times 37$

$= 26.25 + 9.25$

$= 35.5$ amu

Example 2:

A sample of neon contains 90% of atoms of ${}^{20}_{10}Ne$ and 10% of atoms of ${}^{22}_{10}Ne$. Work out the relative atomic mass of this sample of neon.

Solution

Relative atomic mass of neon $= \frac{90}{100} \times 20 + \frac{10}{100} \times 22$

$= 18 + 2.2$

$= 20.2$ amu

TOPIC 5 : THE PERIODIC TABLE

The periodic table is a table in which chemical elements are arranged according to their atomic numbers, electron configurations and recurring chemical properties.

NAMES AND SYMBOLS OF THE FIRST TWENTY ELEMENTS

Recall that there are different kinds of elements. The table below shows the names and symbols of the first twenty elements.

Name of element	Chemical symbol	Atomic number (Z)	Number of neutrons (N)	Atomic mass (Z + N)
Hydrogen	H	1	0	1
Helium	He	2	2	4
Lithium	Li	3	4	7
Beryllium	Be	4	5	9
Boron	B	5	6	11
Carbon	C	6	6	12
Nitrogen	N	7	7	14
Oxygen	O	8	8	16
Fluorine	F	9	10	19
Neon	Ne	10	10	20
Sodium	Na	11	12	23
Magnesium	Mg	12	12	24
Aluminium	Al	13	14	27
Silicon	Si	14	14	28
Phosphorous	P	15	16	31
Sulphur	S	16	16	32
Chlorine	Cl	17	18	35
Argon	Ar	18	22	40
Potassium	K	19	20	39
Calcium	Ca	20	20	40

When these elements are shown in the periodic table, their standard notations are used. For example, hydrogen (H) is shown as ${}^{1}_{1}H$, magnesium (Mg) is shown as ${}^{24}_{12}Mg$, and so on.

The Periodic Table of the first twenty elements is shown below.

	I	II	III	IV	V	VI	VII	VIII
1	${}^{1}_{1}H$							${}^{4}_{2}He$
2	${}^{7}_{3}Li$	${}^{9}_{4}Be$	${}^{11}_{5}B$	${}^{12}_{6}C$	${}^{14}_{7}N$	${}^{16}_{8}O$	${}^{19}_{9}F$	${}^{20}_{10}Ne$
3	${}^{23}_{11}Na$	${}^{24}_{12}Mg$	${}^{27}_{13}Al$	${}^{28}_{14}Si$	${}^{31}_{15}P$	${}^{32}_{16}S$	${}^{35}_{17}Cl$	${}^{40}_{18}Ar$
4	${}^{39}_{19}K$	${}^{40}_{20}Ca$						

MAIN FEATURES OF THE PERIODIC TABLE

There are two main features of the periodic table: **groups** and **periods**.

GROUPS

These are vertical columns of elements in the periodic. Groups are also called **families**. There eight groups in the periodic table. They are indicated by Roman numerals **I**, **II**, **III**, **IV**, **V**, **VI**, **VII**, **VII** and **VIII**. For example,

- Group **I** contains hydrogen (H), lithium (Li), sodium (Na) and potassium (K).
- Group **II** contains beryllium (Be), magnesium (Mg) and calcium (Ca).

Elements in the same group:

- have the same number of electrons in the outermost shell.
- have similar physical and chemical properties.
- show trends in melting and boiling points

PERIODS

These are horizontal rows of elements in the periodic table. Periods are also called **series**. There are four periods in the periodic table. They are indicated by Hindu Arabic numerals. For example,

- Period **1** has hydrogen (H) and helium (He) only.
- Period **2** has lithium (Li), beryllium (Be), boron (B), carbon (C), nitrogen (N), oxygen (O), fluorine (F) and neon (Ne).

All elements in the same period have the same number of electron shells.

GENERAL DISTRIBUTION OF ELEMENTS IN THE PERIODIC TABLE

The elements in the Periodic Table can be classified into metals, metalloids (semi-metals) and non-metals.

- Metals (groups I, II and III).
- Metalloids (groups III and IV).
- Non-metals (groups V, VI, VII and VIII).

ELECTRON CONFIGURATION OF THE FIRST TWENTY ELEMENTS

Recall that electron configuration refers to the number and arrangement of electrons in an atom.

The Periodic Table below shows the electron configurations of the first twenty elements.

H 1							**He** 2
Li 2.1	**Be** 2.2	**B** 2.3	**C** 2.4	**N** 2.5	**O** 2.6	**F** 2.7	**Ne** 2.8
Na 2.8.1	**Mg** 2.8.2	**Al** 2.8.3	**Si** 2.8.4	**P** 2.8.5	**S** 2.8.6	**Cl** 2.8.7	**Ar** 2.8.8
K 2.8.8.1	**Ca** 2.8.8.2						

RELATING THE ELECTRON CONFIGURATION TO THE PERIODS AND GROUPS OF THE PERIODIC TABLE

The electron configuration of any element can be used to predict the group number of an element as well as the period to which the element belongs in the Periodic Table.

RELATIONSHIP BETWEEN VALENCE ELECTRONS AND GROUP NUMBER OF THE ELEMENT

The number of electrons in the outermost shell (valence electrons) indicates the group number to which the element belongs.

For example, all elements in group **I** have **one** valence electron, elements in group **II** have **two** valence electrons, elements in group **III** have **three** valence electrons, and so on.

RELATIONSHIP BETWEEN PERIOD AND NUMBER OF SHELLS OF AN ATOM

The number of shells of an atom of an element indicates the period to which the element belongs.

For example all elements in period **1** have **one** electron shell only, all elements in period **2** have **two** electron shells, elements in period **3** have **three** electron shells, and so on.

Example

An element X can be represented as: $^{39}_{19}X$.

a. Write down the electron configuration of X.
b. How many neutrons does the atom of X have?
c. To which group of the Periodic Table does element X belong? Give a reason.
d. To which period of the Periodic Table does element X belong? Give a reason.

SOLUTION

a. 2.8.8.1
b. Number of neutrons = Atomic mass – Atomic number
   = 39 -19
   = 20

c. It belongs to group 1 because it has one electron in its outermost shell.
d. It belongs to period 4 because it has four electron shells.

FAMILY NAMES OF ELEMENTS IN THE PERIODIC TABLE

Some of the groups in the Periodic Table have special names. These include:

1. **Group I elements** : **Alkali metals**

The alkali metals include Lithium (Li), Sodium (Na) and Potassium (K). Hydrogen is not an alkali metal. It is a gaseous element. It is placed in group I mainly because it has one valence electron just like all the alkali metals.

2. **Group II elements** : **Alkaline earth metals**

The alkaline earth metals include Beryllium (Be), Magnesium (Mg), and Calcium (Ca)

3. **Group VII elements** : **Halogens**

Halogens include Fluorine (F), Chlorine (Cl), Bromine (Br), and Iodine (I). Bromine and Iodine are not shown in the Periodic Table of the first twenty elements but they are halogens.

4. **Group VIII elements** : **Noble gases**

Noble gases are also called **inert gases**. These include Helium (He), Neon (Ne) and Argon (Ar).

TOPIC 6 : PHYSICAL AND CHEMICAL CHANGES

A substance can be changed by heating it, mixing it with another substance, and adding water to it, among other things. The change that takes place is either **physical** or **chemical**.

PHYSICAL CHANGE

A physical change is a process in which no new substance is formed. During a physical change, only the physical properties of the substance are changed. Examples of physical changes are:

- Melting of candle wax
- Melting of ice into water
- Dissolving of sugar in water
- Changes of states of matter e.g. condensation, sublimation, freezing etc.

CHARACTERISTICS OF A PHYSICAL CHANGE

- No new substance is formed.
- No energy is either given out or absorbed in.
- The mass of the substance does not change.
- The change is usually reversible.

CHEMICAL CHANGE

A chemical change is a process in which a new substance is formed. Examples of chemical changes are:

- combustion of fuel
- burning of wood, charcoal and paper.,
- chemical reactions
- decomposition of compounds

CHARACTERISTICS OF A CHEMICAL CHANGE

- A new substance is formed.
- Energy is usually given out or absorbed.

- The mass of substances changes.
- The change is usually irreversible.

DIFFERENCES BETWEEN PHYSICAL AND CHEMICAL CHANGES

Physical change	Chemical change
No new substance is formed	A new substance is formed
No energy is either given out or absorbed	Energy is usually given out or absorbed
The mass of the substance does not change	The mass of the substance changes
The change is usually reversible	The change is usually irreversible

CHEMICAL REACTIONS

A chemical reaction is the re-arrangement of atoms to form new substances. In any chemical reaction, there are two groups of substances: **reactants** and **products**.

Reactants

These are the substances that take part in and undergo change during a chemical reaction.

Products

These are substances that are formed as a result of the chemical reaction.

WHAT HAPPENS DURING A CHEMICAL REACTION?

- the bond in the reactant breaks
- the atoms in the reactant compounds form re-arrange or forms new bonds with other atoms. This results in the formation of new substances.

CHEMICAL EQUATIONS

A chemical equation is a shorthand way of representing what happens in a chemical reaction. In a chemical reaction:

- reactants and products are separated by an arrow as follows:

  Reactants $\longrightarrow$ Products

For example:

Hydrogen + Oxygen $\longrightarrow$ Water

(Reactants) (Product)

NB: reactants are always written on the left hand side while products are written on the right hand side of the arrow.

- the plus (+) sign in chemistry when used on the left hand side of the arrow means "reacts with".
- the arrow means "to form" the products on the right.
- a double arrow ($\rightleftharpoons$) means that the reaction is reversible.

WAYS OF WRITING CHEMICAL EQUATIONS

Chemical equations can be written in two ways:

1. By using word equations
2. By using chemical symbols/formulae

WORD EQUATIONS

A word equation uses words to describe the reaction. In this equation you write the names of the reactants and products. Examples are:

Magnesium + Oxygen $\longrightarrow$ Magnesium oxide

Sodium + Chlorine $\longrightarrow$ Sodium chloride

Calcium carbonate $\xrightarrow{\text{heat}}$ Calcium oxide + Carbon dioxide

CHEMICAL SYMBOLS/FORMULAE EQUATIONS

In this equation, you write the chemical formula of elements to show the reactants and products.

Example 1

Carbon reacts with oxygen to produce carbon dioxide. Write a chemical equation for this reaction using chemical formulae.

SOLUTION

$C + O_2 \longrightarrow CO_2$

Example 2:

Magnesium reacts with chlorine to produce magnesium chloride. Write a chemical equation for this reaction using chemical symbols.

SOLUTION

$Mg + Cl_2 \longrightarrow MgCl_2$

BALANCING CHEMICAL EQUATIONS

Balancing a chemical equation is the process of ensuring that the same number of atoms of each element is on either side of the equation.

GUIDELINES FOR BALANCING CHEMICAL EQUATIONS

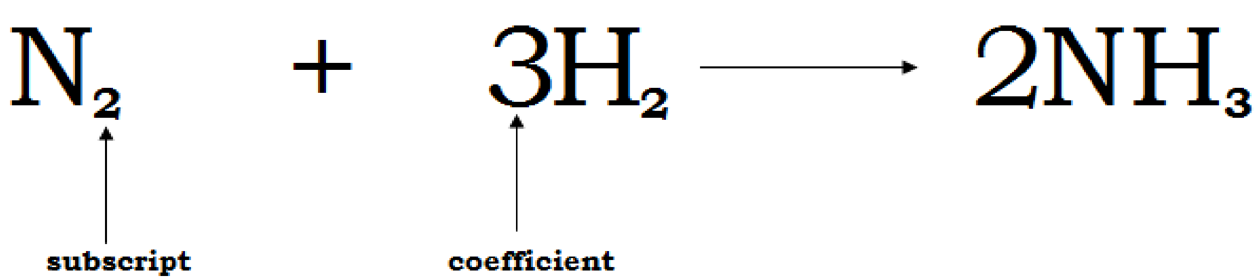
1. Write the correct formulae for reactants and products.
2. Balance by multiplication of coefficients, not addition or subtraction of subscripts.

COEFFICIENT

This is a number that is written in front of a molecular formula. This number must be a whole number, not a fraction.

SUBSCRIPT

This is a lowered small digit. It is written slightly below the symbol of the element or atom.



3. Write the physical states of the substance in the formula. The following are the short forms for different physical states which are commonly used in chemical equations.

Physical state	**State symbol**
solid state	(s)
liquid state	(l)
gaseous state	(g)
aqueous solution	(aq)

WORKED EXAMPLES ON BALANCING EQUATIONS

Example 1:

Balance the following equation: $H_2 + O_2 \longrightarrow H_2O$

SOLUTION

Step 1:

Compare the number of atoms on the left hand side (L.H.S) and the right hand side (R.H.S).

Atom	Left Hand Side	Right Hand Side
Hydrogen (H)	2	2
Oxygen (O)	2	1

Step 2:

To make oxygen atoms equal, write numbers in front of the formula (H_2). We can start with 2. If does not balance, we go to 3, 4 until the equation is balanced.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

When you have $2H_2O$, the number in front means that everything is multiplied by that number. Thus, there are two hydrogen molecules and two oxygen atoms.

Step 3:

Count the number of atoms of each element on the reactants and products, we find that the total number is the same.

Atom	Left Hand Side	Right Hand Side
Hydrogen (H)	4	4
Oxygen (O)	2	2

This means that the equation is now balanced.

Step 4:

Insert the correct state symbols for each substance.

$2H_2\ (g) + \quad O_2\ (g) \longrightarrow 2H_2O\ (l)$

CALCULATING MASSES OF REACTANTS AND PRODUCTS IN CHEMICAL REACTIONS

To calculate the masses of reactants or products of a reaction follow the following simple steps:

- Write a balanced equation for the reaction
- Use the balanced equation to come up with the relative atomic masses (RAMs) of each substance.
- Express the RAMs in grams.
- Use simple proportion to work out required masses.

Example 1:

Carbon reacts with oxygen to form carbon dioxide according to the equation below:

$C\ (s) \quad + \quad O_2\ (g) \longrightarrow CO_2\ (g)$

(RAM of C = 12, O = 16)

Re-write the equation using masses.

SOLUTION

The relative atomic mass (RAM) of carbon, C = 12 amu

The relative atomic mass of oxygen, O = 16 amu

The molecular mass of oxygen molecule, O_2 = (16 + 16) amu = 32 amu

The molecular mass of carbon dioxide, CO_2 = (12 + 32) amu

= 44 amu

Expressing the masses in grams we have

12 g of carbon reacts with 32 g of oxygen to form 44 g of carbon dioxide. Using an equation:

$$12\text{ g C} + 32\text{ g O} \longrightarrow 44\text{ g } CO_2$$

Example 2

Magnesium reacts with oxygen to form magnesium oxide according to the equation below:

$$2Mg\ (s) + O_2\ (g) \longrightarrow 2MgO\ (s)$$

If 12 g of magnesium is used:

a. how much oxygen is needed?
b. how much magnesium oxide is produced?
   (RAM of Mg = 24, and O =16)

SOLUTION

From the equation:

Mass of magnesium = (2×24) g = 48 g

Mass of oxygen = (2×16) g = 32 g

Mass of magnesium oxide = $2 \times (24 + 16)$ g = 80 g

Thus: $48\text{ g Mg} + 32\text{ g O} \longrightarrow 80\text{ g MgO}$

a. By proportion

48 g Mg = 32 g O

12 g Mg = y

$$y = \frac{12\ g \times 32\ g}{48\ g}$$

$$= 8\ g$$

Therefore, 8 g of oxygen is needed.

b. By proportion

48 g Mg = 80 g MgO

12 g Mg = x

$$x = \frac{12\ g \times 80\ g}{48\ g}$$

$$= 20\ g$$

Therefore, 20 g of magnesium oxide is produced.

THE LAW OF CONSERVATION OF MATTER

The law states that matter is neither created nor destroyed in a chemical reaction.

This statement means that in any chemical reaction, the total mass of the reactants is always equal to the total mass of the products. For example when hydrogen reacts with oxygen to produce water:

$$2H_2\ (g) \quad + \quad O_2\ (g) \longrightarrow \quad 2H_2O\ (l)$$

$$4\ g\ H \quad + \quad 32\ g\ O \quad = \quad 36\ g\ H_2O$$

$$36\ g\ (\text{reactants}) \quad = \quad 36\ g\ (\text{product})$$

PERCENTAGE COMPOSITION OF A COMPOUND

The percentage composition of a compound tells us which elements are in the compound and how much of each there is, expressed as a percentage of the total mass.

CALCULATING PERCENTAGE COMPOSITION BY MASS OF ELEMENTS IN A COMPOUND

To calculate the percentage composition by mass of an element in a compound, follow the following steps:

1. Write down the formula of the compound
2. Work out its relative formula mass (R.F.M) using the relative atomic masses (RAM) of each element
3. Write the mass of the element in question as a fraction of the total.
4. Multiply the fraction by 100.

Example 1:

Calculate the percentage composition of each element in calcium carbonate ($CaCO_3$). (RAM of Ca = 40, C =12 and O = 16).

SOLUTION

Relative Formula Mass of $CaCO_3$ = $(40 \times 1) + (12 \times 1) + (16 \times 3)$

$= (40 + 12 + 48)$ amu

$= 100$ amu

a. Percentage composition of calcium (Ca) = $\frac{\text{mass of calcium}}{\text{RFM of } CaCO_3} \times 100$

$= \frac{40\,\text{amu}}{100\,\text{amu}} \times 100$

$= 40\%$

b. Percentage composition of oxygen (O) = $\frac{\text{mass of oxygen}}{\text{RFM of } CaCO_3} \times 100$

$= \frac{(16 \times 3)\,\text{amu}}{100\,\text{amu}} \times 100$

$= \frac{48\,\text{amu}}{100\,\text{amu}} \times 100$

$$= \quad 48\%$$

c. Percentage composition of carbon (C) $= \dfrac{\text{mass of carbon}}{\text{RFM of } CaCO_3} \times 100$

$$= \frac{12\,\text{amu}}{100\,\text{amu}} \times 100$$

$$= \quad 12\%$$

Example 2:

Work out the percentage composition by mass of each element in ammonium nitrate (NH_4NO_3). (RAM of N = 14, H = 1 and O =16).

SOLUTION

Relative formula mass of NH_4NO_3 $= (14 \times 2) + (1 \times 4) + (16 \times 3)$ amu

$$= (28 + 4 + 48)\ \text{amu}$$

$$= 80\ \text{amu}$$

a. Percentage composition of nitrogen (N) $= \dfrac{\text{mass of nitrogen}}{\text{RFM of } NH_4NO_3} \times 100$

$$= \frac{(14 \times 2)\,\text{amu}}{80\,\text{amu}} \times 100$$

$$= \frac{28\,\text{amu}}{80\,\text{amu}} \times 100$$

$$= \quad 35\%$$

b. Percentage composition of hydrogen (H) $= \dfrac{\text{mass of hydrogen}}{\text{RFM of } NH_4NO_3} \times 100$

$$= \frac{(1 \times 4)\,\text{amu}}{80\,\text{amu}} \times 100$$

$$= \frac{4\,\text{amu}}{80\,\text{amu}} \times 100$$

$= 5\%$

c. Percentage composition of oxygen (O) $= \dfrac{\text{mass of oxygen}}{\text{RFM of } NH_4NO_3} \times 100$

$$= \frac{(16 \times 3)\,\text{amu}}{80\,\text{amu}} \times 100$$

$$= \frac{48\,\text{amu}}{80\,\text{amu}} \times 100$$

$= 60\%$

TOPIC 7 : ORGANIC COMPOUNDS

An organic compound is a compound that contains the element carbon in its molecule. A branch of chemistry that deals with organic compounds is called **organic chemistry**. Examples of organic compounds are proteins, carbohydrates, fats, crude oil, plastics and medical drugs made from crude oil.

Compounds such as carbon monoxide, carbon dioxide, metal carbonates and hydrogen carbonates are not considered to be organic compounds even though they contain carbon in their molecules.

HISTORY OF ORGANIC COMPOUNDS

A long time ago, scientists believed that organic compounds could only be made by natural living things. For example compounds such as Deoxyribonucleic acid (DNA) and insulin found in human bodies are examples of organic compounds made by living things. However, now it is a known fact that this is not true. Apart from organic compounds deriving from living things, they can also be made artificially by organic chemists.

SOURCES OF ORGANIC COMPOUNDS

1. **Plants and animals**
   These organisms synthesize many organic compounds. The compounds include sugar, starch, fats, dyes, drugs among other things.
2. **Fossil fuels**
   These are fuels derived from the decomposed remains of plants and animals which once lived and died in the sea.
3. **Natural gas**
   Natural gas is a hydrocarbon found underground on top of crude oil and under the sea. It is 95% methane.
4. **Coal**
   This is a fossil fuel formed from decayed plant materials that has been subjected to heat and pressure over millions of years.

ORGANIC COMPOUNDS AS FUELS

A fuel is a substance that is used to provide energy. A fuel can be in form of solid, liquid or gas.

SUBSTANCES USED AS FUELS IN HOMES

- Charcoal
- Butane
- Paraffin
- Wood
- Coal
- Petrol
- Diesel
- Ethanol
- Methylated spirit (ethanol mixed with methanol in spirit lamps and stoves)

CLASSES OF FUELS

There are two classes of fuels: bio fuels and fossil fuels.

1. BIO FUELS

These are fuels made from plants that grow around us. Bio fuels are renewable i.e. they can be replaced after we have used them by growing more plants. Examples of bio fuels are wood, biogas, biodiesel and ethanol. These fuels are made from plant materials. For example, ethanol (commonly called alcohol) and biodiesel can be made from starch and sugar.

2. FOSSIL FUELS

These are fuels formed from remains of decayed plants and animals. They are found in the ground. Examples of fossil fuels are: petroleum or crude oil, coal and natural gas.

PETROLEUM

Petroleum is a mixture of hydrocarbons. A hydrocarbon is a compound that contains carbon and hydrogen atoms in its molecule. Petroleum is also called crude oil.

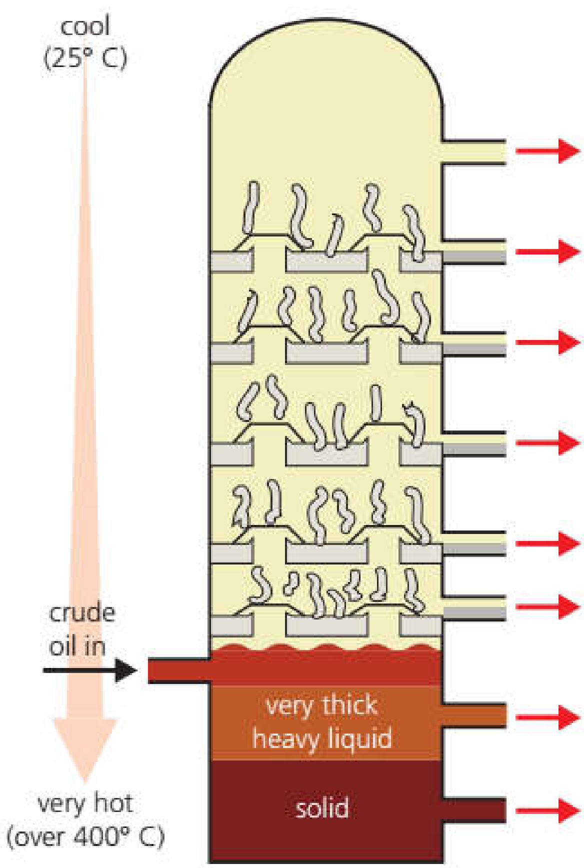
COMPOSITION OF PETROLEUM

The components of petroleum are called **fractions**. These include:

- Petrol
- Diesel
- Bitumen
- Paraffin
- Naphtha
- Lubricants

SEPARATION OF COMPONENTS OF PETROLEUM

The components are separated by fractional distillation. This is because the fractions have different boiling points. The crude oil is evaporated and its vapours allowed to condense at different temperatures in the fractionating column.



Name of fraction	Number of carbon atoms
refinery gas	C_1 to C_4
gasoline (petrol)	C_5 to C_6
naphtha	C_6 to C_{10}
paraffin (kerosene)	C_{10} to C_{15}
diesel oil (gas oil)	C_{15} to C_{20}
fuel oil	C_{20} to C_{30}
lubricating fraction	C_{30} to C_{50}
bitumen	C_{50} upwards

USES OF FRACTIONS OF PETROLEUM

The following are some of the uses of the fractions of petroleum.

Fraction	Uses
Petro (gasoline)	• It is used as a fuel for vehicles
Kerosene (paraffin)	• Used as jet fuel • Use for heating and lighting
Diesel	• Used as fuel for heavy vehicles
Bitumen	• Used for tarmacking roads • Used for repairing leaking roofs
Lubricants (e.g. lubricating oil or grease)	• Used for lubricating moving parts of machines • Used for making waxes • Used for making polishes