MSCE
PHYSICAL SCIENCE PASS-WORD
(FORM 3 &4) NEW EDITION

DAUD M.ADAM, Bed. (Science)(University Of Malawi, Chancellor College):
Physical Science/Maths Teacher, Ndirande Hill Secondary School, BT
Cell: O999 156 027, 0888 456 027, 0881 577975
Email: adauadam@yahoo.com , **WhatsApp: 0888 456 027**

Acknowledgements:

Thanks to Almighty **Allah.**

Special thanks should go to **Mr. K. A. Adini** of LISS for his inspirational and academic support. I also owe huge debt of gratitude to relatives, friends (GodwinZimba) and colleagues whose encouragement provided impetus needed in this kind of work.

Introduction:

This "**PHYSICAL SCIENCE PASS-WORD**" is aimed at providing teachers and secondary school learners with science information that is in tandem with the Malawi School Certificate of Education P/science syllabus.

It is rich in content with well spelt out objectives. Plenty of examples have been given with quality diagrams to deepen your understanding of scientific concepts.

In addition, the copy provides Maneb questions with suggested solutions for the past three years.The last topic nuclear physics has several challenging questions and their suggested solutions.

Buy your "**Fizo pass-word**" copy and you will appreciate!

TABLE OF CONTENTS:

1.PROPERTIES OF MATTER.

OBJECTIVES:

By the end of this chapter learners should be able to:

- Describe the Kinetic theory of matter.
- Explain the cause of gas pressure.
- Explain the relationship between the speed of molecules and the temperature.
- Explain the meaning of absolute temperature.
- Convert temperature from one unit to the other.
- State the evidence for molecular motion.
- Discuss the gas laws.
- Apply the gas laws in problem solving.
- Explain how a manometer works.
- Derive a formula for liquid pressure.
- Relate liquid pressure to everyday activities.
- Explain the application of expansion and contraction in our every day.

MATTER.

- Matter refers to anything that possesses mass and occupies space (has volume).
- Matter comprises tiny (minute) particles unseen by naked eyes.
- There are three types of particles namely, molecules, atoms and ions.
- A molecule is the smallest particle of a pure substance that can exist on its own (can exist independently).
- Molecules in a substance are held together by **Inter-Molecular Forces** (IMF). The IMF is also known as **Van Deel Waal's forces**.
- Further study reveals presence of other particles within molecules. Theses are atoms.
- An atom is the smallest particle that gets involved in chemical reaction. During formation of new things, molecules break down to form atoms and the atoms get rearranged to give rise to new species.
- It is also defined as a basic unit of matter.
- Atoms are held together by inter-atomic force (IAF) or chemical bonds.
- The Inter-atomic forces are much stronger than the inter-molecular forces. I.e. the force of attraction among atoms is stronger than the force of attraction among molecules. Breaking of chemical bonds (IAF) entails occurrence of a chemical reaction while breaking of IMF suggests change of states of matter.

BASIC ASSUMPTIONS OF KINETIC MOLECULAR THEORY OF GASES:

1. Gases contain tiny (submicroscopic) particles.
2. The distance between the molecules is larger compared to the size of the molecules.
3. Gas molecules have no force of attraction for each other.

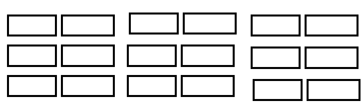
4. Gas molecules move in a straight line and in all direction, colliding frequently with each other and with the walls of the container.

KINETIC THEORY OF MATTER

- It states that matter is made up of tiny particles which are constantly moving.
- These particles attract each other when close.
- The word 'kinetic' means moving.
- Matter exists as solid, liquid or gas.

Properties of Solids:

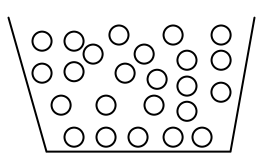
- Solids have a definite shape due to a close arrangement of particles.
- Particles in solids do not move but just vibrate in the fixed positions. However, the effects of such vibrations can be disastrous.
- The IMF is very large in solids. This is why most solids have a high Mpt and Bpt.
- They are incompressible due to absence of spaces among particles.
- They do not flow (do not take shape of container) due to strong force of attraction (IMF) that restricts particle movement.
- Examples of solids include bricks, wall, metal ball, stones, chalk etc.



Arrangement of Particles in solids

Properties of Liquids:

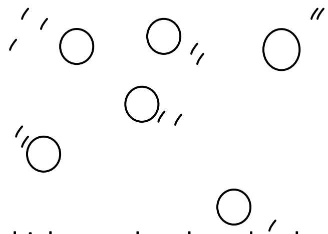
- Particles are slightly far apart.
- Particles move by sliding over each other.
- Liquids take the shape of the container in which they are poured.
- Liquids have a less IMF as compared to IMF in solids.
- Examples include Paraffin, oil etc



Particle arrangement in liquids

Properties of Gases:

- Particles are far apart.
- Particles move randomly in all direction. This random movement of particles is called Brownian motion.
- Gases do take the shape of the container. They spread to all parts of environment.
- The IMF is almost negligible (almost zero). This makes the particles always on the move.



Gas particles moving at high speed and randomly

MOLECULAR MOTION AND GAS PRESSSURE

- The continuous collisions of gas molecules with one another and with the walls of the container cause pressure on the walls of the containing vessels.
- Thus, a gas pressure is the pressure due to a continuous heating of the gas molecules with the walls of the container.
- An increase in temperature causes an increase in pressure. This is so, because gas particle gain extra energy for movement.

TEMPERATURE SCALES:

- Temperature refers to degree of hotness or coldness of an environment.
- Temperature scales refer to the range of numbers measuring level of hotness or coldness. We shall describe two temperature scales namely: **Celsius scale** and **absolute temperature scale.**

A. CELSIUS/CENTIGRADE SCALE:

- On this scale, temperature is measured in degrees Celsius, °C.
- The numbers are chosen specifically so that pure ice melts at 0°C and pure water boils at 100°C under standard temperature and pressure.
- This scale can have positive and negative values.

B. ABSOLUTE TEMPERATURE SCALE:

- It also called absolute scale.
- It is a scale that measures temperature in **Kelvin.**
- It only registers positive values.
- The lowest value on this scale is **absolute zero**.
- Absolute temperature is the temperature measured or calculated on the absolute scale in Kelvin.
- Absolute zero is the temperature at which molecular motion stops or particles have a lowest kinetic energy possible.
- The absolute scale is also called thermodynamic scale.

CONVERSION OF UNITS

- To change from degrees Celsius to absolute temperature you need to add **273.**
- Thus, $T_k = T_{0_C} + 273$.
- Example: change the following to absolute temperature
    - **a)** 20°C
    - **b)** 0°C

c) -127°C

d) 77°C

a. T_k= 20+273 = 293K

b. T_k= 0+273 = 273K

c. T_k = -127 + 273 = 146K

d. T_k = 77+273 = 350K.

- To change from absolute temperature to degrees Celsius just subtract 273.

$$T_{0_C} = T_k - 273.$$

- Change the following to degrees Celsius.
  - **a.** 500K
  - **b.** 200K.

a) $T_{0_C} = T_k - 273 = 500 - 273 = 227^0 C$

b) $T_{0_C} = T_k - 273 = 200 - 273 = -73^0 C$

Exercise

a. Convert the following temperatures to degrees Celsius

i. 120K

ii. 400K

iii. 0K

b. Convert the following temperatures to kelvins

i. 300^{o}C

ii. -153 ^{o}C

iii. 0 ^{o}C

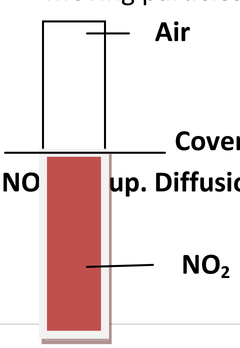
EVIDENCE FOR MOLECULAR MOTION

a) Occurrence of chemical reaction:

- Exchange of atoms which takes place during chemical reaction implies movement.
- If reacting particles were not moving they would not come to contact with each other and no reaction would take place.

b) Diffusion:

- This is the movement of particles from regions of higher concentration to regions of lower concentration.
- Fig below shows what happens when a jar with a dense brown gas, nitrogen dioxide is put underneath a jar of air.
- Moving particles of air and NO_2 spread themselves between the two jars.



Five minutes after the cover is removed, air and NO up. Diffusion takes place.

- Diffusion also occurs in liquids where some colored crystals of soluble solids dissolve in water. One can see the particles splitting off from the crystal and spread out in the water.
- Examples of such kind of crystals are Copper sulphate and potassium permanganate.
- Diffusion is faster in gases than in liquids.
- Lighter particles diffuse faster and cover a larger distance than the heavier ones.
- The **rate of diffusion** is affected by the following:
    - Temperature.
    - Mass (size) of the particle.
    - Concentration.
    - Surface area.

c) Brownian motion:

- This, as already defined, is the random movement of particles. It acts as evidence of molecular motion. Usually a microscope is used to trace a path moved by one particle of smoke enclosed in a glass box. A pattern that clearly describes the random movement of the particles is drawn.

++

GAS LAWS

- ✓ All gases have pressure. Pressure of gases is due to molecules hitting the sides of container.
- ✓ The magnitude (size) of the pressure is affected by the rate of collisions.
- ✓ The interdependence of pressure, temperature and volume of gas was investigated in the 17th and 18th century.
- ✓ The relationship among these three quantities together with the laws of mechanics forms the foundations of the Kinetic Theory of Matter.

CHARLES LAW.

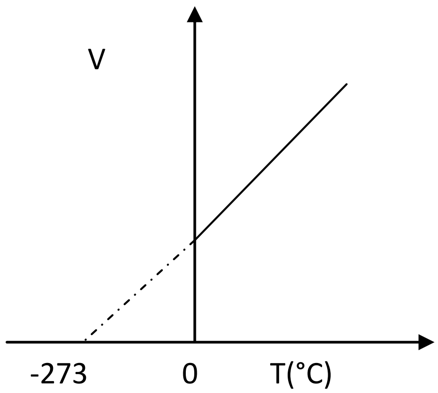
- ✓ **It states that for a constant amount of gas the volume is directly proportional to the absolute temperature if the pressure is constant.**
- ✓ Thus, an increase in volume leads to an increase in temperature
- ✓ Symbolically, $V \propto T \Rightarrow V = KT$ where K is constant. Making K subject of the formula we have $\frac{V}{T} = K$.
- ✓ Dividing the volume by temperature one always get a constant number even if conditions change to new ones. Thus,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \text{ or } \frac{T_1}{V_1} = \frac{T_2}{V_2}$$

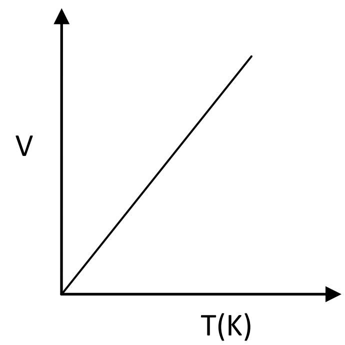
SYMBOL	**MEANING**
$\mathbf{V_1}$	Initial volume
$\mathbf{T_1}$	Initial temperature
$\mathbf{V_2}$	Final volume

T_2	Final temperature

✓ Graphically,



Or



✓ Example:

A helium sample at 25°C has a volume of 1.82 liters. If pressure and amount of gas are unchanged determine what the volume will be when temperature is 50°C.

solution:

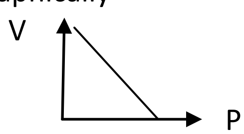
T_1= 25+273 = 298K, T_2= 50+273 = 323K, V_1 = 1.82L, V_2=?

$$\frac{1.82}{298} = \frac{V_2}{323} \Rightarrow V_2 = \frac{1.83}{298} x323 = 1.97L$$

BOYLE'S LAW

✓ **It states that for a constant amount of gas, the pressure is inversely proportional to volume if the temperature is constant. I.e.** $P \propto \frac{1}{V}$ **for constant, T.**

Graphically



- Boyle's law with constant temperature becomes $P_1V_1 = P_2 V_2$ e.g. A700ml sample of gas at 500mmHg pressure is compressed at constant temperature until its final pressure is 800mmHg. What is the final volume?

	Initial state	Final state
Pressure	500mmHg	800mmHg
Volume	700ml	?

$P_1, V_1 = P_2, V_2$

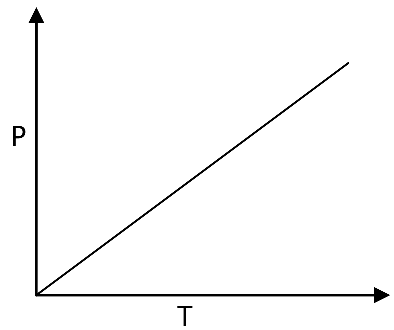
500mmHg × 700ml = 800mmHg × V_2

$V_2 = \frac{500mmHg \times 700ml}{800mmHg}$

V_2 = 438ml

PRESSURE LAW

- **It states that for a constant amount of gas pressure is directly proportional to the Kelvin temperature if the volume remains constant.**
- P α T for constant V. Graphically



E.g. A gas in a fixed container is at a pressure of 4atm and a temperature of 24^0c if the temperature is changed to 127^0c, what would be the pressure?

P_1 = 4atm, P_2=? T_1 = (27 + 273) K = 300K

T_2 = (127 + 273) K = 400K

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{4atm}{300k} = \frac{P_2}{400k} \Rightarrow P_2 = \frac{4atm x 400k}{300k} = 5.33atm$$

IDEAL GAS LAWS

- If all the gas laws are combined we would obtain a general form as follows:

PV = n RT where n R is constant.

- The ideal gas law can also be written as $\dfrac{P_1V_1}{T_1} = \dfrac{P_2V_2}{T_2}$
- The standard atmospheric pressure and temperature (S. T. P.) are 1.01×10^5Pascals and 0^0C (273K), 1atm = 1.01×10^5pa = 760mmHg.
- Ideal gas is the gas where pressure, volume and temperature behavior can be completely described by the ideal gas equation. E.g. Hydrogen gas is contained in a $360cm^3$ of glass and at standard temperature and pressure 0^0C and 760mmHg. Calculate the new pressure if it is carefully transferred into a glass bulb of volume $340cm^3$ at 40^0C?

  $V_1 = 360cm^3$, V_2= $340cm^3$, T_1= 0+273= 273K, T_2=40+273= 313K, P_1= 760mmHg,

  Using: $$\frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$$

$$\frac{360x760}{273}=\frac{340xP_2}{313}\Rightarrow P_2=\frac{760x360x313}{273x340}=922.6mmHg$$

Exercise

a. 6ml of fluorine gas F_2 at temperature of 27 °C is heated at constant pressure to 132°C. find its new volume ***Ans8.1ml***

b. $20cm^3$ of gas sample at a pressure of 1.5 atmospheres is transferred (at constant temperature) to a container of volume $120cm^3$. Find its new volume

Ans 2.5 atmospheres

c. 0.5 liters of helium gas at STP (0°C, 1atm) is heated. Its new volume and pressure become 1.4liters and 0.75atm respectively. Work out its new temperature

Ans 573.3K

d. Table below shows values obtained through experiment on gas law.

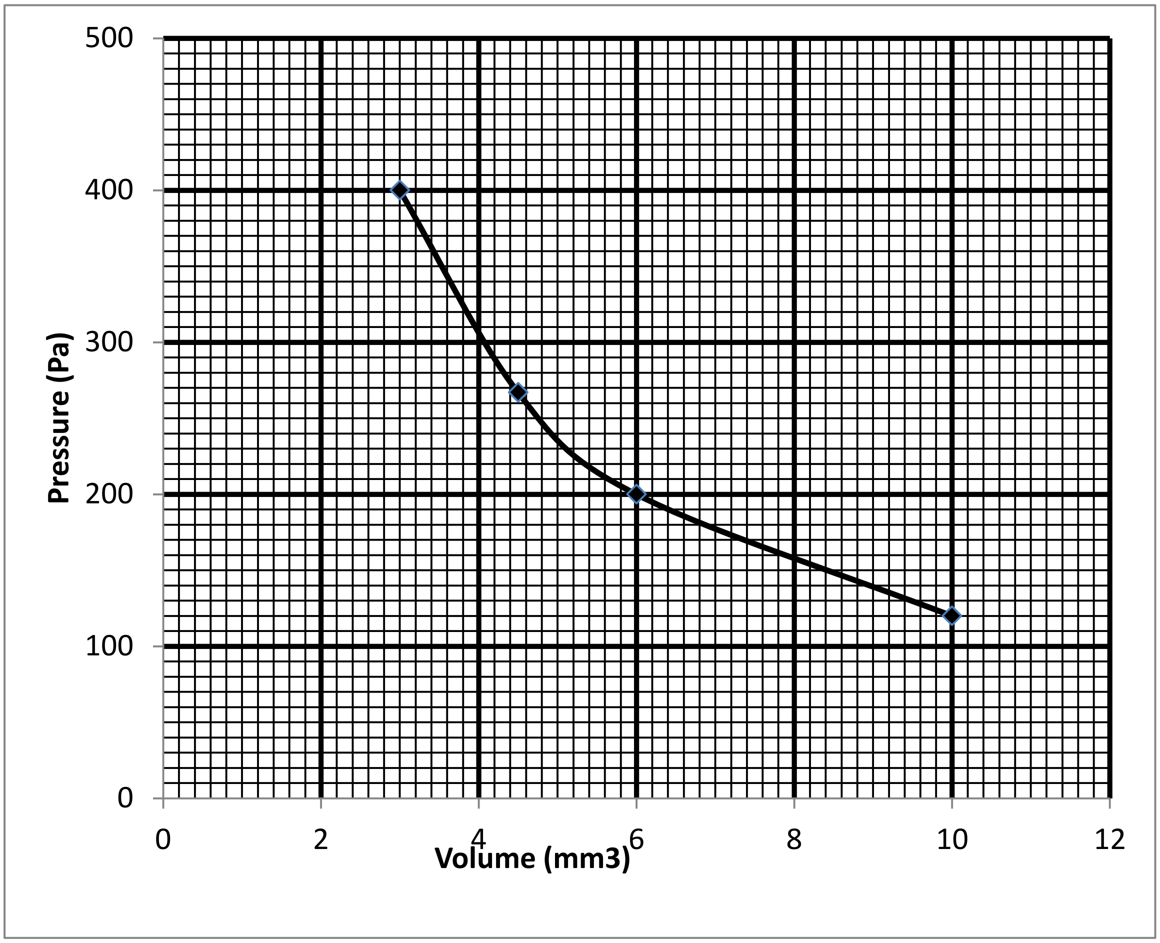
Volume (mm^3)	**3.0**	**4.5**	**6.0**	**10.0**
Pressure (Pa)	**400**	**267**	**200**	**120**

i. Plot a graph of pressure against volume

ii. Which gas law was being investigated in the experiment?

iii. Which two factors were made constant?

Solution



ii. Boyle’s law

iii. Temperature and amount of gas

FACTORS THAT AFFECT GAS PRESSURE:

a) Number of moles:
The greater the number of molecules the bigger the pressure. This is so because there are more molecules hitting the walls of the container.

b) Volume of Container:
- Decreasing the volume cause the gas molecules to bump into each sides and the lid of container more often so that pressure increases.
- With constant number of molecules at constant temperature decreasing the volume increases pressure.

c) Temperature:
With constant volume and constant number of molecules increasing the temperature increases the pressure.

PRESSURE:

- It is defined as force per unit area.

- Mathematically $P = \frac{Force(N)}{Area(m^2)}$
- **(N/m^2)** is Newton per square meter $1N/m^2$ = 1 Pascal.
- **E.g.** Calculate pressure exerted by 200N force acting on the ground of area $40m^2$.
- $P = \frac{200N}{40m^2} = 5N/m^2$

<u>FACTORS THAT AFFECT PRESSURE</u>

1. Force;
   - The higher the force the higher the value of pressure.
2. Area;
   - An increase in the area leads to a decrease in the value of pressure.

<u>LIQUID PRESSURE</u>

- ✓ This is the pressure due to continuous hitting of liquid molecules with the walls of the container.
- ✓ The liquid pressure is affected by; **height (depth) and density.**
- ✓ The higher the value of height or the density, the higher the value of liquid pressure.

<u>PROPERTIES OF LIQUID PRESSURE</u>

- ✓ **The liquid pressure is the same in all direction at the same depth**
- ✓ **The liquid pressure increases with increase with depth (height)**
- ✓ **The liquid pressure is perpendicular to the surface of the *container***
- ✓ **The liquid pressure increases with increase in density**

EQUATION FOR LIQUID PRESSURE

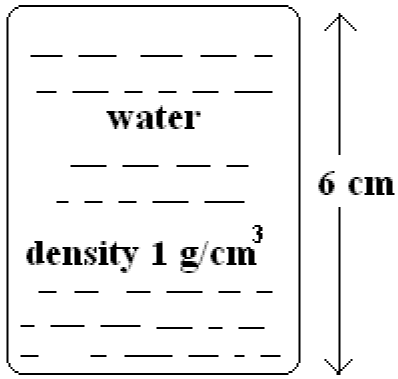
- ✓ It is given as: Liquid pressure= density x height x g where is g is the acceleration due to gravity. Its value is 10N/Kg or $10m/s^2$.
- ✓ Thus, P = dhg where P is the liquid pressure, d is density in Kg/m^3, h is the height of the liquid column in meters.

  Examples

  1. A container with water, density $1000Kg/m^3$ supports a column of water of height 20 meters. Taking g = 10N/Kg calculate the value of liquid pressure at the bottom.

  Solution: P = dhg = 1000 x 20 x 10 N/m^2 = 200000 Pa = 2×10^5 Pa.

  2. find the liquid pressure in Pascals that is exerted by water at the bottom of a container (g = 10N/Kg)



Solution

1g/cm^3 = 1000Kg/m^3 h = 6cm = 6/100cm = 0.06m

$$P = dhg = 1000 \times 0.06 \times 10 = 600Pa$$

Given Volume (Capacity) of the container and cross-sectional area:

$$height = \frac{volume}{area}$$

Eg.A container with cross-sectional area of 15cm^2 is filled with 60cm^3 of paraffin of density 0.8g/cm^3. Calculate the pressure exerted by the paraffin at the bottom of the container. Acceleration due to gravity, g = 10m/s^2.

$$d = 0.8g/cm^3 = 0.8 \times 1000 = 800kg/m^3$$

$$h = \frac{volume}{height} = \frac{60cm^3}{15cm^2} = 4cm = 0.04m$$

see also Maneb (2013) #1c

$$P = dhg = 800 \times 0.04 \times 10 = 320Pa$$

DERIVING THE FORMULA FOR LIQUID PRESSURE:

Volume of Liquid = A x h

M = V x d

F = mg = v x d x g

$\therefore$ **F = A x h x d x g**

$P = \frac{F}{A} = \frac{Axdxhxg}{A} = dhg$ **hence** $P = dhg$

USES OF LIQUID PRESSURE:

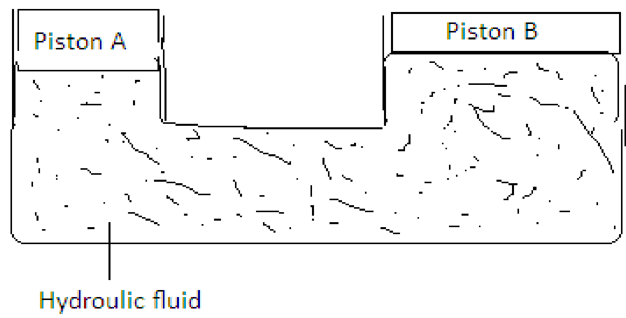
A. Hydraulic Systems:

- Hydraulic machines make use of the following properties:
  - **Liquids are incompressible**

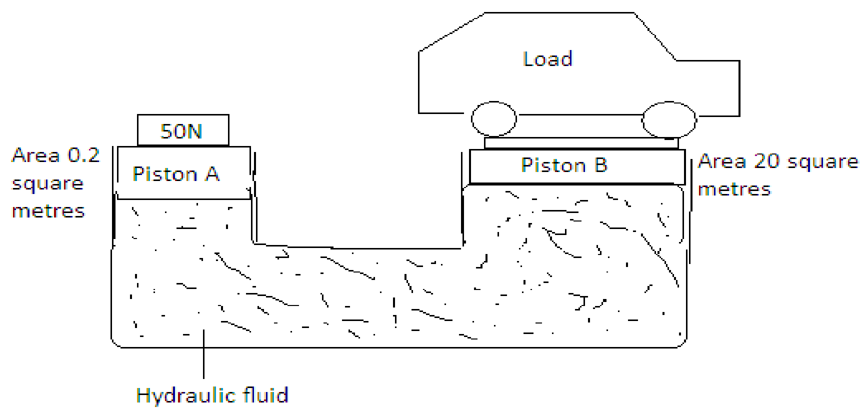
-**The pressure of a trapped liquid is transmitted to all other parts of the system.**

- The fluid can be used to transfer forces from one place to the other.
- The basic principle is that the fluid transfers equal pressure throughout the system.
- Examples of hydraulic machines include **hydraulic brakes, hydraulic jacks, hydraulic fork lifts** etc**.**

Refer to the following diagram:



For example:



Work out:

I. the pressure piston A exerts on the fluid
II. The pressure the liquid exert on the piston B
III. The up-thrust (lift or the upward force) on the load.

Solutions:

I. $P = \frac{Force}{Area} = \frac{50N}{0.2m^2} = 250N/m^2 = 250Pa$.

II. The pressure the piston A exerts on the liquid = the pressure the liquid exerts on the piston B = 250 Pa.

III. $F = PxA = 250N/m^2 x 20m^2 = 5000N$

The hydraulic jacks are force multipliers because they increase the amount of force applied. In the example above, force has being increased from 50 N to 5000N.

B. **Construction of dams**:
The dams are made thicker at the bottom in order to make them withstand huge pressure at large depth.

C. Designing of outlet and in-let pipes:
The out-let pipes are located at the bottom since pressure is high hence liquid could come out easily.

D. Location of water supply systems:
Reservoirs for water supply or hydraulic power stations are often made in hilly or mountainous regions. This is to increase pressure.

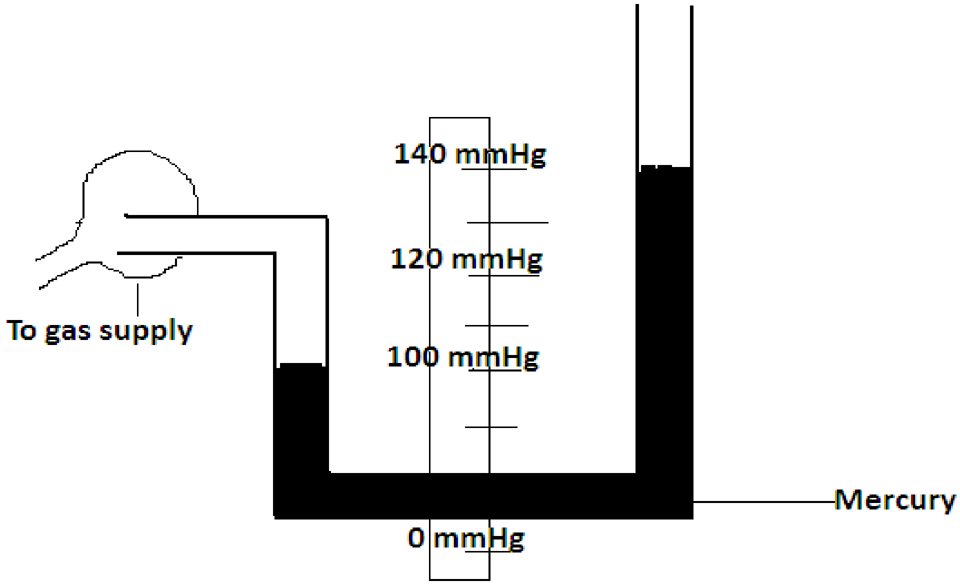
E. **Designing of sub-marines**:
They are made of a tough and strong metallic and glass materials in order to prevent a collapse due to high liquid pressure at the large depth of sea bodies.

LUNG PRESSURE:

- ✓ This is the pressure exerted by the lungs on the air inside it.
- ✓ It can be measured by a manometer e.g. a **U-tube manometer**

HOW A MONOMITER WORKS:

- ✓ Air pressure from the lungs or a gas supply system forces the manometer liquid to rise up in the open side of the u-tube until it remains steady when difference in level balances with the lung pressure or gas pressure.
- ✓ In general when end is connected to any supply of gas
  Pressure of gas = atmospheric pressure + pressure due to liquid column
  I.e. Gas pressure = atm pressure + hdg.
- ✓ A manometer measures pressure difference.
- ✓ The height difference shows the extra pressure that the gas supply has in addition to the atmospheric pressure.
- ✓ The extra pressure is called excess pressure of gas supply system.
- ✓ To find pressure of gas supply one has to add the atmospheric pressure to its excess pressure.
- ✓ The following is an example:



U-tube manometer

I. Work out the pressure difference on the U-tube manometer.
   Pressure difference = 140 mmHg – 100 mmHg = 40 mmHg.

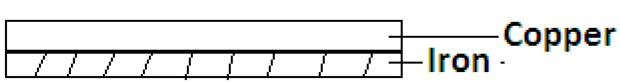
II. If the atmospheric pressure is 760 mmHg work out the pressure of the gas.
   Gas pressure = atmospheric pressure + gas pressure =
   (760+40) mmHg= 800 mmHg.

ATMOSPHERIC PRESSURE:

- ✓ This is the pressure air molecules exert on the ground. There is a blanket of various gas particles in the atmosphere. It acts in all direction.
- ✓ It can best be measured by barometer or a manometer.
- ✓ It is highest at sea level and its value is about 100000N/m^2= 100000Pa.
- ✓ 100000N/m^2= 1 atm = 760 mmHg
- ✓ The 100000 Pa is called **the standard atmospheric pressure**.
- ✓ Atmospheric pressure decreases with height above sea level.

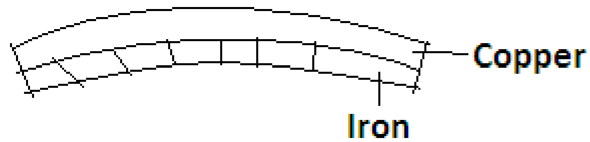
EXPANSION AND CONTRACTION

- ✓ Expansion is an increase in volume (size) while contraction is the decrease in volume or size.
- ✓ Metals expand differently when heated equally.
- ✓ Consider a bi-metallic strip which is also called a compound bar. Two different metals are juxtaposed side by side as shown below.



Bimetallic strip

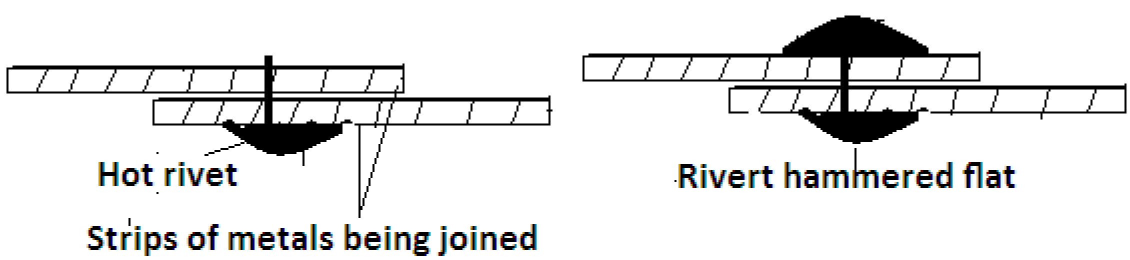
- ✓ During heating, the metal that expands more bends towards the metal that expand less.
- ✓ In the above strip copper expands more than iron hence when heated above room temperature, the strip will bend as follows:



- ✓ The metal that expands more also contracts more.

USES OF EXPANSION AND CONTRACTION IN OUR EVERYDAY DAY:

1. **Construction of thermostats**:
   It is a device that regulates temperature in a circuit.
   It is a compound bar made of metals that expand and contract differently.
2. **Separating stuck tumblers**:
   This is done by passing hot water over the top tumbler. The top tumbler expands faster than the inner one hence reducing the degree of stickiness.
3. **Separating tightly screwed bottle tops**:
   It is done by pouring hot water on the bottle top. It expands before the glass does hence removed with ease.
4. **Shrink-fitting**:
   An example is the axle of gear wheel. There is a metal too big to enter into hole. It is dipped in liquid nitrogen to cool it and make it contract. It becomes sizable to be inserted into the wheel. Upon regaining normal temperature it expands to give a tight fit.
5. **Reverting of metals**:
   A hot revert (small metal) is placed into revert hole and its ends are hammered under intensive heating. On cooling it contracts and pulls the plates being joined, together



6. **Weathering**:
   It is the breaking down of rocks to form soil. It happens when a rock is subjected to frequent contraction and expansion. It becomes loose, develops cracks and later disintegrates into small fragments.

7. **Construction of brick fences:**
   Gaps are left at intervals when constructing brick fences in order to provide room for expansion and construction otherwise it may collapse.

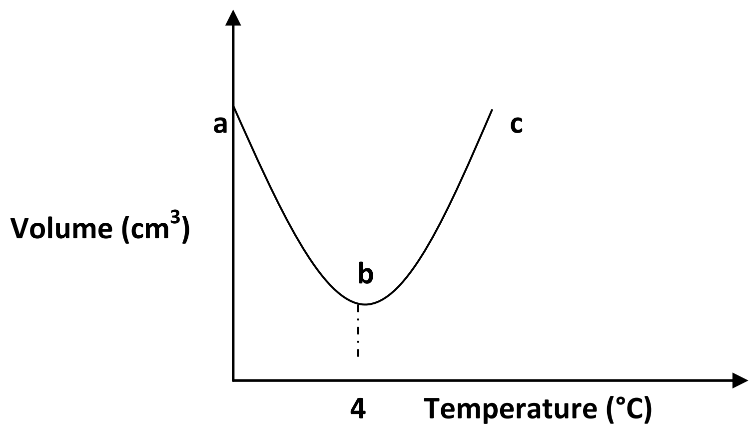
Other uses include designing of fire alarms, and construction of railway lines.

8. **Functioning of liquid-in –glass thermometer**

   Rapid expansion and contraction of the liquid assist in reading temperatures scales.

<u>ANOMALOUS EXPANSION & CONTRACTION OF WATER</u>:

- ✓ Water expands and contracts abnormally.
- ✓ Heating the water from 0°C to 4°C it contracts instead of expanding. From 4 to 0°C it expands when factors suggest it has to contract.



From a to b, volume of water is reducing and is minimum at b. Then volume increases as temperature changes from 4°C onwards. It implies that water has largest density of **1g/cm^3** at 4°C.This abnormal expansion of water explains why pipes and bottles containing water burst during cold days.

HOW THE TOPIC HAS BEEN FEATURED BY MANEB IN THE RECENT 4 YEARS:

2015

1. a state the pressure law

Answer: it states that for a fixed amount of gas at constant volume, the pressure is directly proportional to the absolute temperature

b. The initial pressure of a fixed volume of a gas is 120mmHg. Calculate the final pressure in mm Hg if the temperature of the gas is raised from $27°C$ **to** $327°C$

$$T_1 = 27 + 273 = 300K$$

$$T_2 = 327 + 273 = 600K$$

$$P_1 = 120mmHg$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow \frac{120}{300} = \frac{P_2}{600} \Rightarrow P_2 = \frac{120 \times 600}{300} = 240mmHg$$

8c Explain how a bimetallic strip maintains the temperature of an electric iron at the required level

The bimetallic strip acts as a thermostat. It is made of two metals with different rates of expansion reverted together. When the iron overheats, the bimetallic strip bends towards the metal that expands less there by breaking contacts (current no longer flows). When it cools, the strip regains normal shape there by reconnecting the circuit. The heating cycle gets repeated as long as the switch is on

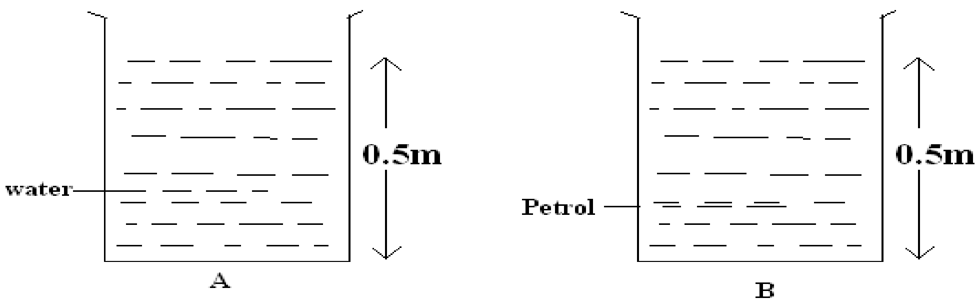
2014

1

a. State any three uses of expansion of solids in everyday life
Answers:

Bimetallic strip, weathering of rocks, construction of brick fences, metal reverting etc

b. figure below is a diagram showing two similar tins A and B containing water of density 1000kg/m^3 and petrol of density 800Kg/m^3



(i) Which liquid exerts a greater pressure at the bottom of the tin? Ans: ***Water***

(ii) Give a reason for the answer in 1b(i***) water has a higher density and the higher the density the higher the pressure (the other factor, height is the same)***

(iii) Calculate the pressure at the bottom of tin B

$$P = dhg = 800kg/m^3 \times 0.5m \times 10N/Kg$$
$$= 4000Pa$$

8b Explain how a bimetallic strip maintains the temperature of an electric iron at the required level

The bimetallic strip acts as a thermostat. It is made of two metals with different rates of expansion reverted together. When the iron overheats, the bimetallic strip bends towards the metal that expands less there by breaking contacts (current no longer flows). When it cools, the strip regains normal shape there by reconnecting the circuit. The heating cycle gets repeated as long as the switch is on

2013

1

a. Mention any two properties of liquid pressure

- ***The liquid pressure is the same in all direction at the same depth***
- ***The liquid pressure increases with increase with depth (height)***
- ***The liquid pressure is perpendicular to the surface of the container***

b. In terms of the kinetic theory of matter, explain why liquid evaporates
Answer: when liquid is heated, the motion of its particles increases due to gain in kinetic energy. Further heating causes the particles to overcome the attraction force among them (IMF) hence they start escaping from the surface of the liquid as gas or vapor (evaporate).

c. A container with a cross-section area of $9cm^2$ is filled with $36cm^3$ of petrol. Calculate the pressure exerted by the petrol at the bottom of the container. (density of petrol = $0.7g/cm^3$ and acceleration due to gravity (g) = $10m/s^s$)

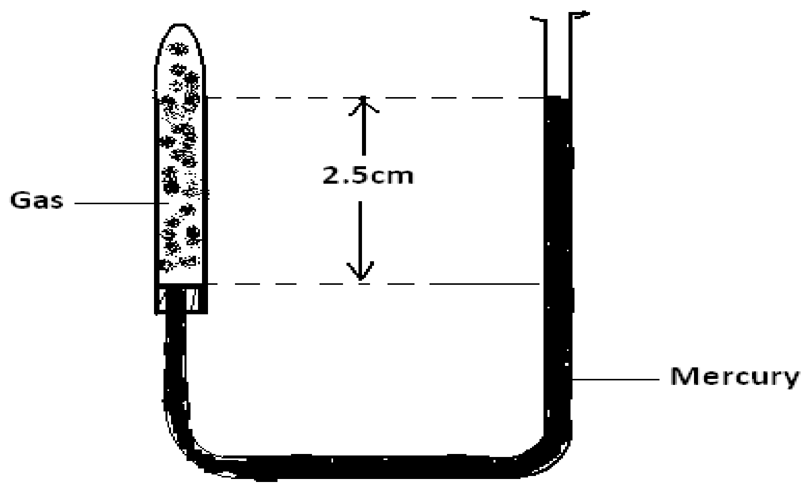
$$d = 0.7g/cm^3 = 0.7 \times 1000 = 700kg/m^3$$

$$h = \frac{volume}{height} = \frac{36cm^3}{9cm^2} = 4cm = 0.04m$$

$$P = dhg = 700 \times 0.04 \times 10 = 280Pa$$

2012 a. State the kinetic theory of matter
Answer*: **It states that matter is made up of tiny particles which are always in motion***

b Figure below shows an instrument used to measure pressure exerted by a gas



Calculate the pressure exerted by the gas if the atmospheric pressure is 765mm Hg
Answer: ***the excess pressure = 2.5cmHg = 25mm Hg***
Gas pressure = excess pressure + atmospheric pressure
Hence Gas pressure = 25mm Hg + 765mm Hg = 790mm Hg

8cIn terms of kinetic theory of matter, explain why ice melts when put in the sun
Answer: ***Ice melts when put in the sun due to increase in heat energy which weakens the IMF that holds the water particles together as the particles tend to vibrate more.***

2.ELEMENTS AND CHEMICAL BONDING

Topic Objectives

By the end of this topic learners should be able to:

- write the structure of an atom
- Explain how elements differ from each other.
- Analyze the arrangement of elements in the periodic table.
- Predict the group and the period of an element given the atomic number.
- Describe how atoms attain stability.
- Distinguish between the ionic and covalent compound.
- Represent bond formation with dot and cross diagrams.
- Work out formula of compounds given valences.
- Differentiate polar from non-polar covalent bonds.
- Provide description of metallic bonds.
- Describe properties of metals.
- Draw relationship between properties and use of metals.
- Describe physical and chemical properties of halogens.
- Discuss uses of halogens.
- State sources of sulphur.
- Explain physical and chemical properties of sulfur.
- Highlight uses of sulfur.
- Discuss importance of sulfuric acid.
- State uses of sulphates.

ATOMIC STRUCTURE

- An atom is the basic unit of matter. It gets involved during formation of new species (Chemical reaction).
- Atoms contain other small particles referred to as 'sub-atomic particles'. These are protons, electrons and neutrons.
- Protons and neutrons together are referred to as nucleons.
- The number of protons and neutrons together gives the atomic mass number of an element (nucleon number).

Protons.

- Are positively charged particles.
- Are found in the nucleus. (Nucleus is the central part of the atom).

- Have a mass of 1 amu. (1 atomic mass unit) which is the same as 1.6725×10^{-27}kg.

Electrons

- Are negatively charged.
- They are located in the shells or energy levels.
- An electron has a mass of 9.1095×10^{-31}kg.
- Are held in their positions by the positively charged nucleus.

Neutrons

- They are electrically neutral. Have a zero charge.
- Found in the nucleus.
- Have a mass of 1 amu or 1.6749×10^{-27}kg.

Nuclide

In any atomic species of which the proton number is specified. i.e. ${}^{A}_{Z}X$ A is the nucleon number and Z is the atomic number.

Number of neutrons = Atomic mass – Atomic number = A –Z

E.g. given the following ${}^{27}_{13}Al$. State the number of

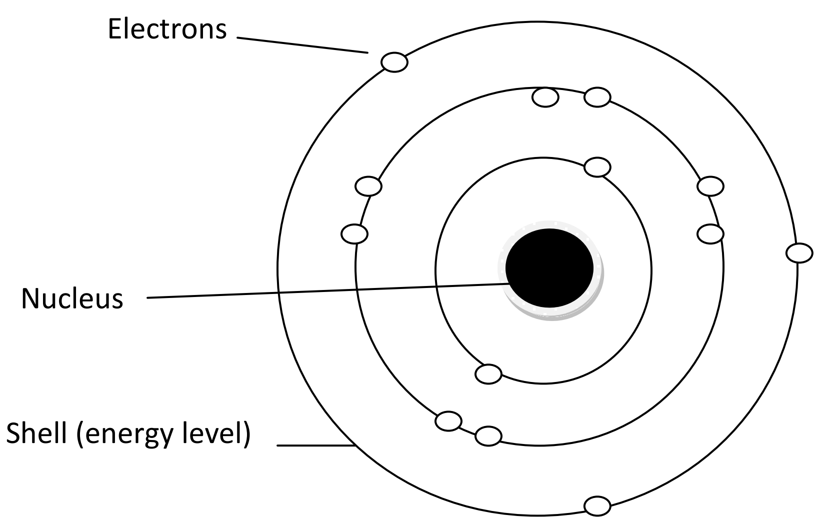
1. Protons
2. Electrons.
3. Neutrons.

Solution

1. 13
2. 13
3. 27 – 13 = 14

Draw the structure of the given element.

Ans:



ELECTRON STRUCTURE, ARRANGEMENT OR CONFIGURATION

- Electron configuration refers to the number and arrangement of electrons in the energy levels.
- Atoms with full outer energy levels are stable and show little chemical activity.
- First electron shell holds **up to 2** electrons.
- The second shell holds a **maximum of 8**, so too with the third shell.
- The forth shell holds **up to 18.**

E.g. Chlorine has the atomic number of 17. What is its electron configuration? It means it has 17 electrons hence its electron configuration is 2, 8, 7

THE PERIODIC TABLE OF ELEMENTS.

- This is a tabular arrangement of elements listed in order of increasing atomic number.
- The columns are called **groups** or **families**. There are **8 groups**.
- The horizontal rows are called **periods** or **series** and are **7** in total (if we consider the whole periodic table).
- **The number of electrons in the outermost shell corresponds to group to which a particular element belongs.**
- **The number of shells corresponds to the period to which an element belongs.**

E.g

ELEMENT	ELECTRON #	ELECTRON CONFIGURATION.	GROUP	PERIOD
Hydrogen	1	1	1	1
sodium	11	2,8,1	1	3
Nitrogen	7	2,5	5	2
Calcium	20	2,8,8,2	2	4
Argon	18	2,8,8	8	3
Chlorine	17	2,8,7	7	3
Carbon	6	2,4	4	2

- The elements of the periodic table are categorized into three parts namely: metals, metalloids and non-metals.
- Some groups have special names.
  Group 1: Alkali metals
  Group 2: Alkaline Earth metals.
  Group 7: Halogens.
  Group 8: Noble gases, Inert gases or group 0.

THE PERIODIC TABLE

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

A — Atomic mass
X — Element symbol
Z — Atomic number

METALS

They are found to the left of the periodic table.

Physical properties

- ✓ They are good conductors of heat and electricity due to free moving electrons.
- ✓ All are solids at room temperature (25°C) except mercury which is a liquid.
- ✓ Strong under tension and compression.
- ✓ Are malleable. (Capable of being shaped or bent or drawn out into shape). This is so because the layers of ions can slide over each other. This makes them suitable in making of iron sheets, cooking pots etc.
- ✓ Are ductile. (Capable of being drawn into wires) hence used in making of electricity transmission cables.
- ✓ Are sonorous (make a ringing noise when hit.) hence used in making bells.
- ✓ Have high densities due to close parking of their particles.
- ✓ Are shiny when polished hence used in making jewelry and ornaments.
- ✓ Have high melting and boiling points due to high attraction between the metal ions and the sea of mobile electrons. It takes a lot of heat to break up the lattice except of alkali metals.

Chemical properties.

- ✓ Form positive metal ions (**cations**).
- ✓ React with oxygen to form basic metal oxides.

NON-METALS:

They are found to the right of the periodic table. They are:

- ✓ Are poor conductors of heat and electricity?
- ✓ They have more varied physical properties than metals e.g. gases and liquids.
- ✓ They are brittle (easily break when hit).
- ✓ Have low melting and boiling points. Have low densities.
- ✓ Form negative ions except Hydrogen. Their ions are called **anions**.

METALLOIDS:

- ✓ They are found at the middle of the periodic table.
- ✓ They have properties that fall between those of metals and the non-metals. Examples include: boron, silicon, germanium etc.

Next part provides detailed description of the groups of the periodic table

ALKALI METALS (GROUP ONE).

Physical properties:

- ✓ Are good conductors of electricity and heat.
- ✓ Are soft metals.
- ✓ Have shinny surfaces when freshly cut.
- ✓ Are malleable (can be hammered into sheet).
- ✓ Are ductile. (Can be molded into wires.)

Chemical properties:

- ✓ They burn in air (oxygen) to produce oxides.

  e.g.: Sodium + Oxygen to form Sodium Oxide.

  $Na + O_2 \longrightarrow Na_2O$
- ✓ They react with water vigorously to give an alkali solution and hydrogen gas.

  Potassium + water to form potassium hydroxide and hydrogen gas.

  $K(s) + H_2O \longrightarrow KOH(aq) + H_2(g)$
- ✓ They react strongly with halogens to form salts (metal halides).

  E.g. Lithium + Chlorine to form Lithium Chloride.

  $Li(s) + Cl_2 \longrightarrow LiCl$
- ✓ Alkali metals have similar properties because their atoms all have 1 electron in their outer shell.
- ✓ Melting and Boiling point decrease down the group.

ELEMENT	MELTING POINT (°C)	BOIING POINT (°C)
Li	181	1342
Na	98	883
K	63	760
Rb	39	686
Cs	29	669

- ✓ Reactivity of group one elements **increases** as we go down the group.
- ✓ Group 1 metals become softer with low melting points as well as boiling point. This is so because the electron in the outer most shell is loosely held by the nucleus so it easily lost.

- ✓ Atomic radius increases down the group due to addition of shells.

ALKALINE EARTH METALS (GROUP 2).

Physical properties:

- ✓ Are harder than those in group 1.
- ✓ Are good conductors of heat and electricity.
- ✓ Have high densities.
- ✓ Generally, melting and boiling points decrease down the group.

ELEMENT	MELTING POINT (°C)	BOILING POINT (°C)
Be	1278	2970
Mg	649	1107
Ca	839	1484

Chemical properties:

- ✓ They burn in oxygen to form oxide and a bright flame.

  $Mg + O_2 \longrightarrow MgO$
- ✓ They react with water but so much less vigorously than the group 1.

  e.g. $Ca + H_2O \longrightarrow Ca(OH)_2 + H_2$
- ✓ They are less reactive because it is more difficult to lose two electrons than one because loss of electrons requires use of energy.
- ✓ Reactivity increase down the group.

TRANSITION METALS:

- ✓ Are harder and stronger.
- ✓ Have high densities.
- ✓ Are good conductors of heat and electricity
- ✓ Many are used in making metal alloys (mixture of metals).
- ✓ Are less reactive metals.
- ✓ Form a range of brightly colored compounds.
- ✓ They do not react (corrode) so quickly with oxygen. Most of them form ions with a plus two charge.
- ✓ Examples are: Copper, iron, zinc, lead, chromium, silver, gold, manganese, cobalt, nickel, cadmium, mercury etc.

HALOGENS (GROUP 7):

- ✓ These are the most reactive nonmetals.
- ✓ Their reactivity increases up the group. This is so because the incoming electron is being more strongly attracted into the outer energy level of the small atom.

- ✓ Are more reactive because their atoms are just one short of full outer shell,
- ✓ They have similar properties because their atoms have 7 electrons in their outer most shell.

Physical properties of Halogens:

- ✓ They are colored and they darken going down the group.
- ✓ They exist as diatomic molecules because two atoms can gain full shells by sharing electrons with each other.
- ✓ Their boiling points and melting points increase going down the group because of the increase in the force of attraction between the molecules

ELEMENT	FORMULA	M.Pt (°C)	B.Pt (°C)
Fluorine	F_2	-220	-187
Chlorine	Cl_2	-101	-35
Bromine	Br_2	-7.2	59
Iodine	I_2	113	188

.

- ✓ They show a gradual change in physical state from a gas (Cl_2) through a liquid (Br_2) to a solid (I_2) at room temperature.
- ✓ Their atomic radii as well as ionic radii increase down the group. This is due to addition of shells.

Chemical properties of Halogens:

- ✓ Are poisonous nonmetals.
- ✓ They form molecular compounds with other nonmetallic elements. e.g. CCl_4, PF_3, S_2Cl_3 etc.
- ✓ They react with hydrogen to form halides. E.g. HF, HCl, HI etc.
- ✓ They react with metals to form salts hence called halogens- salt formers.

  $Na(s) + Cl_2 \longrightarrow NaCl$
- ✓ They undergo displacement reaction with each other. A more reactive metal displaces a less reactive metal from solutions. e.g.: Molecular chlorine can displace bromide and iodide ions in solutions. In general, Halogen upper in the group tend to displace those below.
- ✓ They react with oxygen.
- ✓ They undergo inter –halogen reaction.

  e.g : $F_2 + Cl_2 \longrightarrow 2ClF$

USES OF HALOGENS:

a. Fluorine, F_2

- ✓ It is used in the form of fluoride in drinking water and tooth paste because it reduces tooth decay by hardening the enamel on the teeth.

- ✓ It is used to produce poly tetra fluoro ethylene, a polymer better known as Teflon.
- ✓ used to make commercial refrigerant gas which contains CCl_2F_2 etc.
- ✓ It is used as a volatile component in aerosol cans.

b. Chlorine. Cl_2

- ✓ It is a poisonous dense green gas.
- ✓ Used to make PVC pipes
- ✓ It is used in house hold bleaches.
- ✓ Used to kill microorganisms in drinking water and swimming pools.
- ✓ Used to make organic solvents e.g. CCl_4 and chloroform for removal of grease.
- ✓ Used in the manufacture of insecticides e.g. sodium chlorate.
- ✓ Used in the production of hydrochloric acid.
- ✓ Used in sewage treatment
- ✓ Used in aesthetics, antiseptics e.g. dettol and califlavin.

c. Bromine. Br_2

- ✓ It is a caustic and toxic brown volatile liquid.
- ✓ Used to make disinfectants, medicines and fire retardants.
- ✓ Used in photographic film.
- ✓ Used in manufacturing of 1,2, dibromoethane, $C_2H_4Br_2$ which is added to tetra ethyl lead used as anti-knock in petrol engines where undesirable accumulation of lead is prevented.

d. Iodine, I_2

- ✓ It is a shiny black solid which sublimes to form a violet vapor on gentle heating.
- ✓ Used in medicine as a germicide to kill bacteria in skin cuts and to flex muscles.
- ✓ Used as a photographic chemical.
- ✓ Used in making of dyes.
- ✓ Used in testing of starch.

GROUP 8 (NOBLE GASES):

- ✓ The members include helium, neon, argon, krypton, xenon and Radon.
- ✓ Are non metals.
- ✓ Are colorless gases which occur naturally in air.
- ✓ They normally don't react with anything. This is attributed to the fact that their outer most shell is completely filled with electrons. Other elements do react in order to attain a fully- electron filled outer shell.

BOND FORMATION:

- ✓ An atom other than hydrogen tends to form bonds until it is surrounded by eight valence electrons. This is called **Octet rule**. (Oct means eight).

- ✓ The **valence** of an atom is the number of electrons gained, lost or shared in bonding with one or more atoms. The electrons involved in bonding are the ones found in the outer most shell which is called the **valence shell**.

<u>How compounds or bonds are formed.</u>

- ✓ If the valence shell of an atom is full, the atom is said to be stable. By reacting with each other, atoms obtain full outer shells and therefore achieving stability.
- ✓ Atoms gain stability (attain a full outer shell) by:
    - **a. Loosing electrons.**
    - **b. Gaining electrons.**
    - **c. Sharing electrons.**
- ✓ Elements (metals) with 1, 2 or 3 electrons in the outer most shell tend to lose them in order to attain the inert gas configuration. Their outer most shell will be the next lower one.
- ✓ Elements (non-metals) with 5, 6, 7 electrons in the outer most shell tend to gain electrons in order to attain stability.
- ✓ Element with 4 electrons on their outer most shell generally share electrons.

<u>Dot and Cross Diagram:</u>

This is a simple way of showing bond formation. A dot and a cross are used to represent electrons contributed by each atom during bond formation.

<u>Types of Bonds:</u>

There are three types of chemical bonds namely:

1. Ionic bond.
2. Covalent bond.
3. Metallic bond.

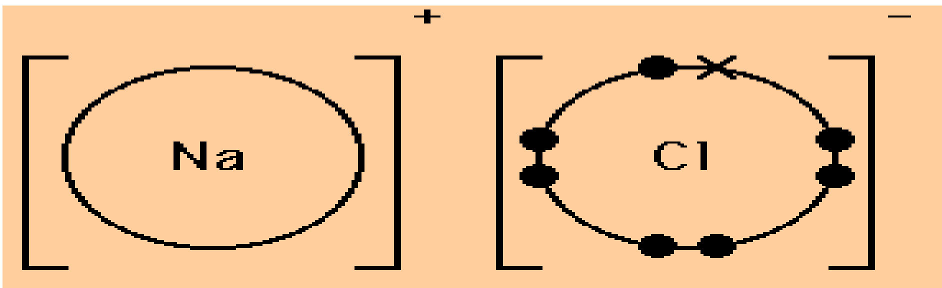
1) **<u>Ionic bond</u>**.

- It is also called electrovalent bond.
- It is a bond formed due to loss and gain of valence electrons.
- It involves a metal and a non-metal.
    - The bond involves ions of opposite charge which are held together by electrostatic force. e.g.: Na^+ and Cl^- ions.
    - The compounds formed by these cations (positive ions) and anions (negative ions) are neutral.
    - The compounds with ionic bonding are called '**ionic compounds'** or '**electrovalent compounds**.'

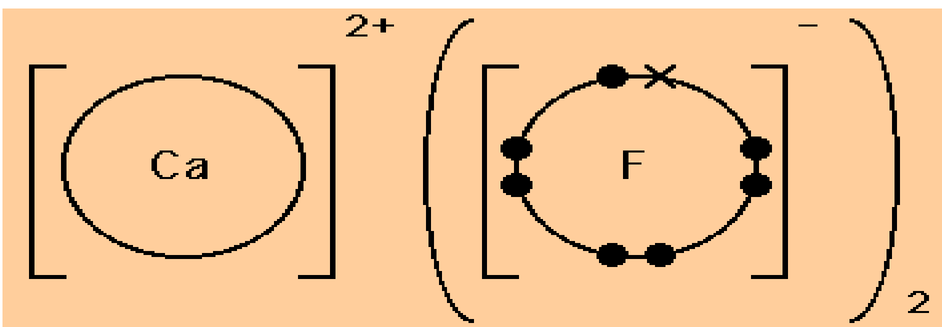
      E.g. Sodium loses an electron to become $\mathbf{Na^+}$ and chlorine gains the lost electron to become $\mathbf{Cl^-}$. The compound formed will be sodium chloride with formula **NaCl.** Consider Calcium and fluorine. Calcium is in group 2 hence it loses two electrons to become $\mathbf{Ca^{+2}}$. The fluorine atom gains a single electron to become $\mathbf{F^-}$. However, there is a single electron released from calcium atom that is remaining hence there is a need of another fluorine atom to accept it. Thus, two fluorine atoms are needed to combine with one atom of calcium. The formula of the calcium fluoride is CaF_2

The dot and cross diagram of **NaCl**and**CaF_2**will be as follows:

- NaCl



- CaF_2



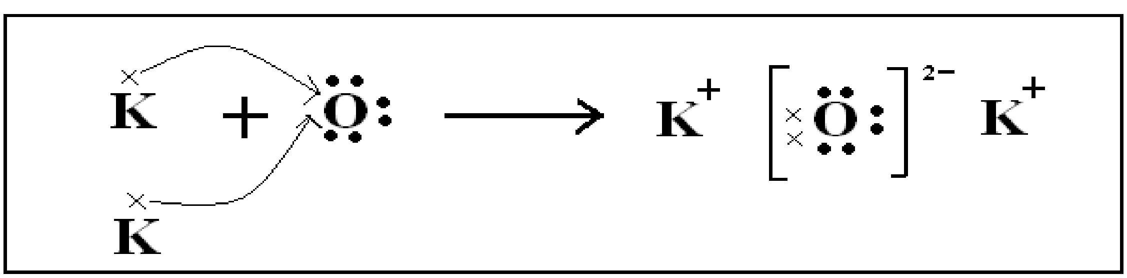
To work out formula of an ionic compound one just has to follow the following steps:

- ✓ Write down the name of the ionic compound.
- ✓ Write down the symbol for its ions.
- ✓ The compound must have no overall charge, so balance the positive and negative charges by changing the number of ions involved. The total charge has to be equal to zero.
- ✓ Write down the formula without the charges.

<u>Exercises on Dot and cross diagrams</u>

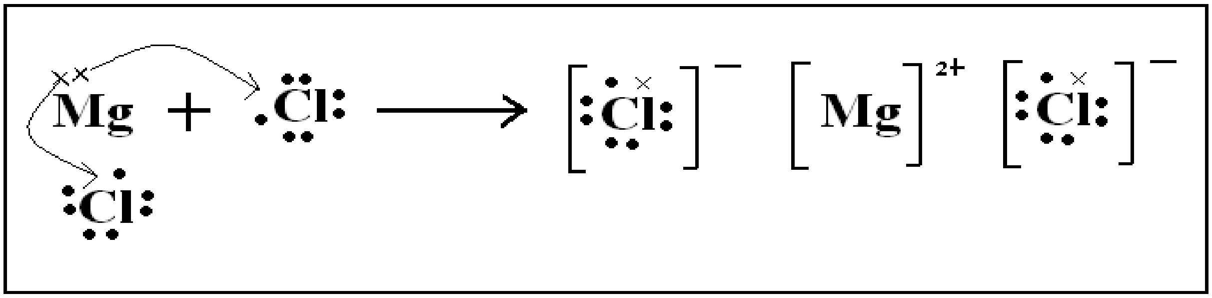
Draw dot and cross diagrams for the ionic compounds formed from the given elements. (Include the name and formula of the compounds)

a. Potassium and oxygen



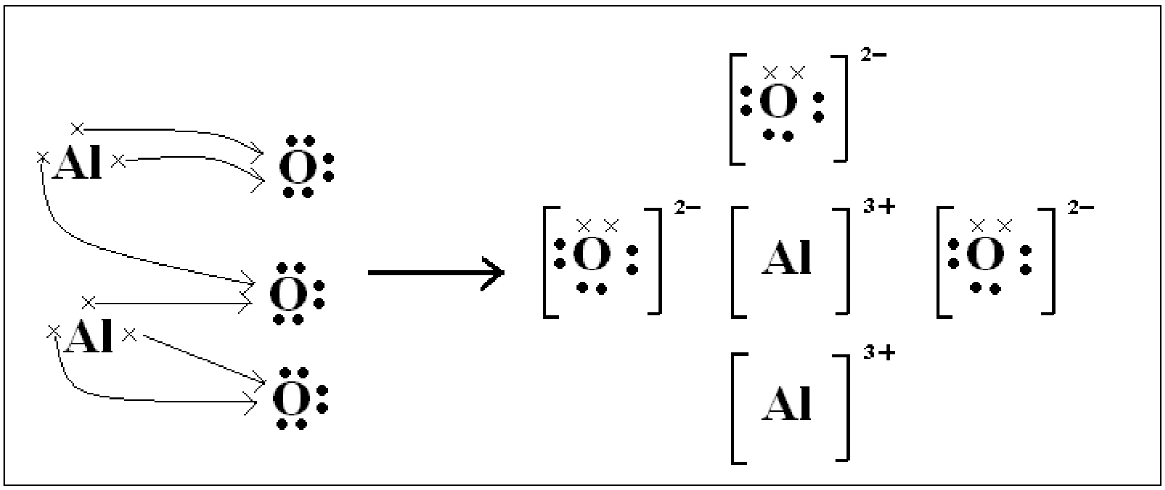
Name; Potassium oxide formula K_2O

b. Magnesium and chlorine



Name: Magnesium chloride formula $MgCl_2$

c. Aluminium and oxygen



Name:Aluminium oxide formula Al_2O_3

Listed below are some commonly used ions.

Take note that the charge is equal to the number of electrons lost or gained which is the valency. There will be a positive on the ion if it loses electrons and a negative if it gains electrons.

CATIONS (POSITIVE IONS):

1	2	3
Hydrogen, H^+ Lithium, Li^+ Potassium, K^+ Sodium, Na^+ Ammonium, NH_4^+ Silver, Ag^+ Hydronium, H_3O^+	Barium, Ba^{2+} Iron (II), Fe^{2+} Lead (II), Pb^{2+} Zinc, Zn^{2+} Calcium, Ca^{2+} Copper (II), Cu^{2+}	Aluminium, Al^{3+} Iron (III), Fe^{3+} Chromium, Cr^{3+}

ANIONS (NEGATIVE IONS):

1	2	3
Fluoride, F^- Chloride, Cl^- Bromide, Br^- Iodide, I^- Hydroxide, OH^- Nitrate, NO_3^- Hydrogen carbonate, HCO_3^- Permanganate MnO_4^- Cyanide, CN^- Acetate $C_2H_3O_2^-$ or CH_3COO^-	Carbonate, CO_3^{2-} Sulphate SO_4^{2-} Sufide , S^{2-} Oxide, O^{2-} Dichromate, $C_2O_7^{2-}$ Hydrogen phosphate, HPO_4^{2-}	Phosphate, PO_4^{3-}

Physical Properties of Ionic Compounds:

- ✓ Are usually solids at room temperature with high melting points due to strong electrostatic forces of attraction holding the crystals together. A lot of energy is needed to separate the ions and melt the substance.
- ✓ Are usually hard substances.
- ✓ Do not conduct electricity when in solid form because their ions are not free to move.
- ✓ Are soluble in water because water molecules are able to bond with the positive and negative ions which cause the lattice to break up and hence keep the ions apart.
- ✓ They conduct electricity in molten or aqueous form since the ions are mobile.
- ✓ Do not dissolve in organic solvents such as petrol, carbon tetra chloride.

2) Covalent Bond (Molecular bond):

- This is the bond formed by sharing of electrons in the outer energy levels.
- It occurs between non-metal atoms.
- Compounds are called **covalent compounds** or **molecular compounds**. e.g., methane, water, sugar and ammonia.
- Covalent compounds have strong intra-molecular forces but weak inter-molecular forces.
- However, inter-molecular forces increase with an increasing size of the molecule.
- A dot and a cross in the inter-section or a dash (——) represents a shared (bonded) Pair of electrons.

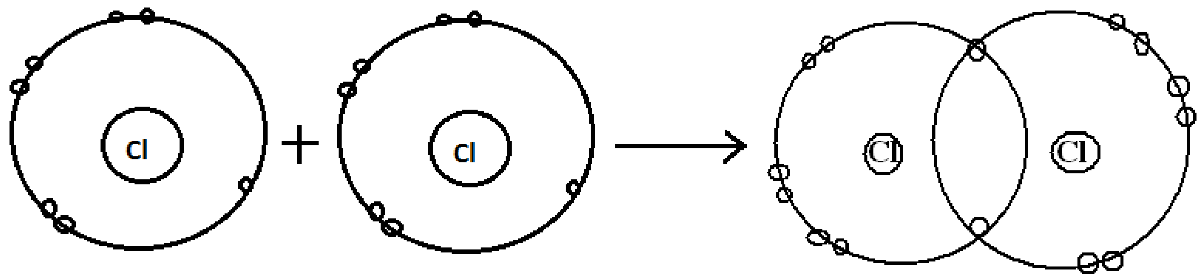
Types of Covalent bonds:

If one looks at the number of shared electrons then the covalent bonds will be categorized as:

I. Single Covalent bond.

- It normally involves sharing of a pair of electrons.
- e.g.: bonding in chlorine molecule, fluorine molecule etc.

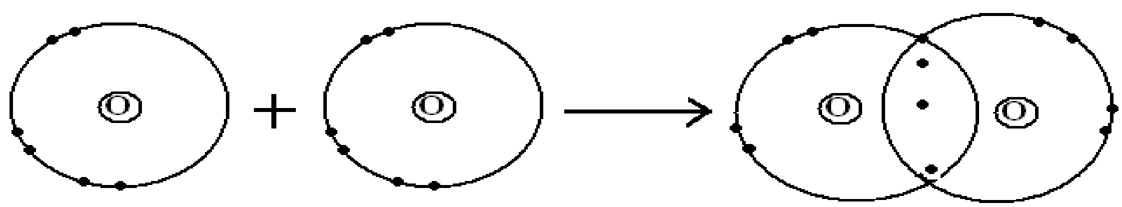
$Cl - Cl$



II. **Double- Covalent bond**

- It involves sharing of 2 pairs of electrons. Each atom contributes 2 electrons for sharing.
- E.g.: bonding in carbon dioxide, bonding in an oxygen molecule. In CO_2 its

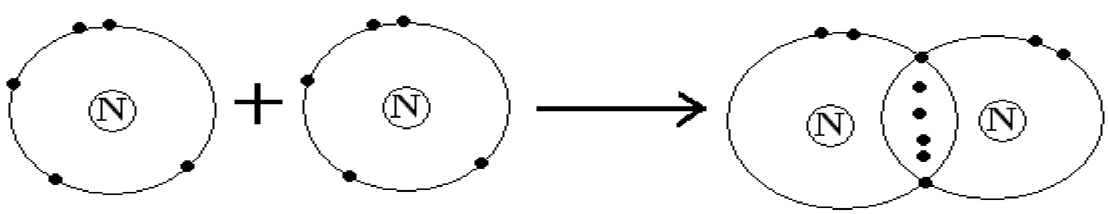
$O = C = O$



III. **Triple Covalent bond.**

- Atoms in this type of bonding share3 pairs of electrons.
- E.g.: bonding in Nitrogen and acetylene.

$N \equiv N$



The way elements share electrons can also give rise to two types of covalent bonds which are:

a) Polar covalent bond.
b) Non-polar covalent bond.

a. <u>**Polar covalent bond**</u>:

- This is a covalent bond in which electron are not shared equally.
- It happens because of differences in the electro negativity values.
- **Electro negativity** is the ability of an atom in a covalent bond to attract the bonding electron.
- For example Fluorine. This is more electronegative than hydrogen hence in the formation of hydrogen Fluoride molecule, sharing of electrons is not equal because H and F are different atom with different electro negativity. This makes

the electrons spend more time in vicinity of one atom. In this case, electrons will spend more time in the region of fluorine.

- The type of bond formed in this way is called **polar covalent bond** or simply **polar bond**.
- The compounds with polar bonds their molecules have one end positively partially charged and the other end negatively slightly charged. Thus, the bond in polar compounds has some partial ionic characters.
- In the periodic table, the electro negativity decreases as one goes down a group but it increases across the period from left to right.
- The opposite of the electro negativity is **electro positivity** which is the ability of an atom to lose its outer most electrons in order to achieve stability. Electro positivity increases down a group. Potassium is the most electro positive element.

<u>Properties of covalent compounds</u>:

- Are usually gases, liquids or solids of low melting points and boiling points.
- The melting points are low because of the weak Van der Waals forces of attraction. Giant molecular substances have higher meting points because the whole structure is held together by strong covalent bonds with the molecules.
- Generally they do not conduct electricity since when molten or dissolved in water they do not ionize save for HCl and some few acids. The HCl, when dissolved in water, it ionizes to produce H^+ and Cl^-.
- In general, they do not dissolve in water unless they react with it to form ion s. However, water is an excellent solvent and can interact with and dissolve some covalent molecules e.g. Sugars.
- They dissolve in organic solvent such as petrol, carbon tetra chloride. etc.

Examples of covalent compounds include sugar, ammonia, carbon dioxide, water etc

<u>DIFFERENCES BETWEEN IONIC AND COVALENT BONDS</u>:

When salt (ionic) e.g. sodium chloride and sugar (covalent) are heated equally, sugar takes little time to melt than the salt.

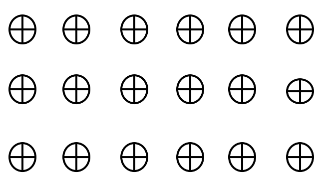
I. This indicates that ionic bonds are stronger than the covalent bonds.
II. Ionic bonds are formed by loosing or gaining valence electrons while the covalent bonds are formed by sharing of electrons.
III. Ionic bonds are because of electrostatic forces while covalent bonds are due to intermolecular forces.
IV. Ionic bonds occur between a metal and a non-metal while covalent bond involves non-metals.

<u>DIFFERENCES BETWEEN IONIC COMPOUNDS AND COVALENT COMPOUNDS:</u>

a. Ionic compounds are generally soluble in water while the covalent (molecular) compounds are insoluble in water but in organic compounds like paraffin etc.
b. Ionic compounds have high melting and boiling points hence need high heat energy to melt while covalent compounds have low melting and boiling points hence melt at a slight heating.
c. Ionic compounds conduct electricity in aqueous or liquid form while covalent compounds do not conduct electricity in either state except some few acids.

3) <u>Metallic bond.</u>

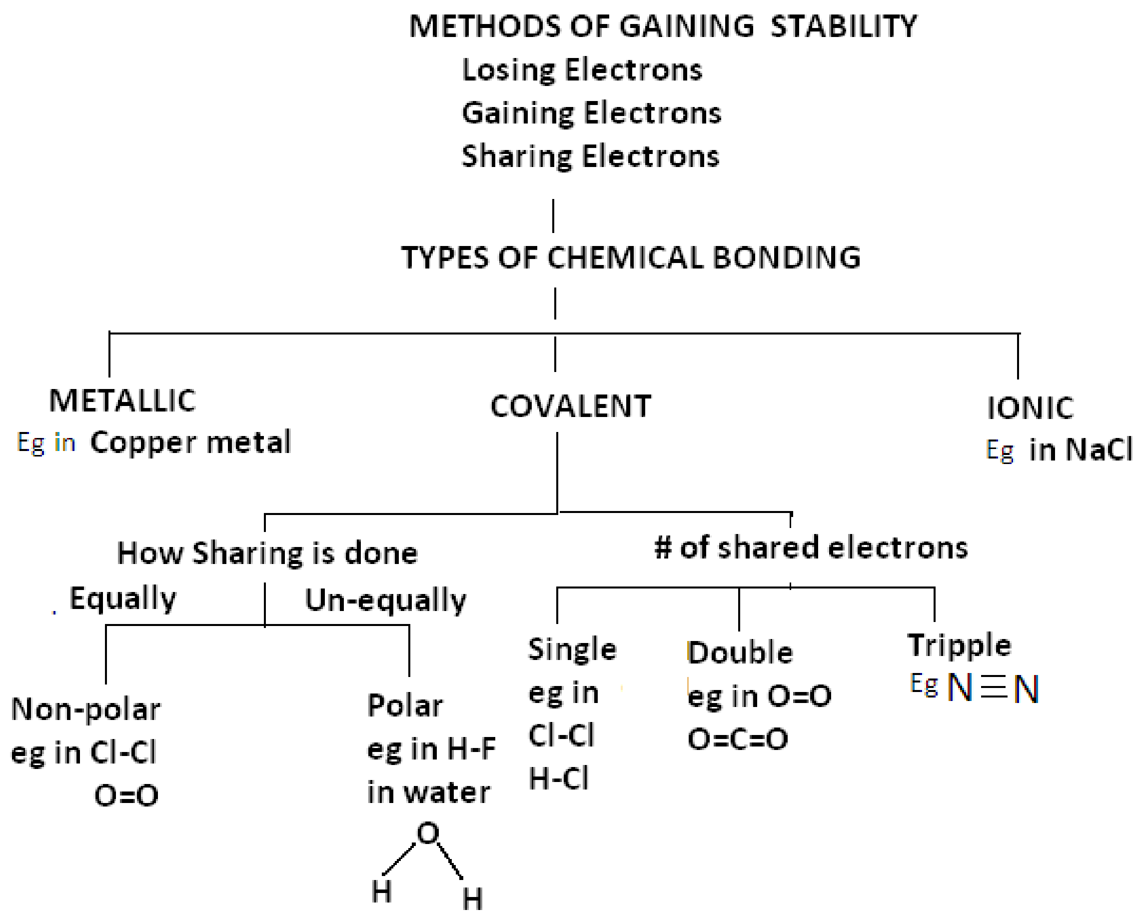
- Atoms in a metal are packed tightly together in a regular pattern.
- The tight parking causes outer electrons to be separated from the atoms and the result is a lattice of ions in a 'sea' of electrons.
- The great cohesive force resulting from delocalization is responsible for the strength of metals. The mobility of the delocalized electrons is responsible for the strength of metals. The mobility of the delocalized electrons account for metals being good conductors of heat and electricity.



Ions of metals in a sea of delocalized electrons

- Metallic bonding is therefore defined as the electrostatic attraction binding the positive ions of a solid metal together by means of a sea of delocalized electrons.
- Examples are the bonding in Lithium metal, copper metal etc.

In Summary refer to the following Flow diagram:



Periodicity of properties of elements in the periodic table:

- Periodicity is the recurrence of similar properties at regular intervals when elements are arranged in increasing atomic number order.
- Examples of these periodic properties are: Atomic radius, atomic volume, density, electro negativity, electro positivity, nuclear charge, effective nuclear charge.

- **Atomic radius.**
  - It is half the distance between the two nuclei in two adjacent atoms.
  - It increases down the group due to addition of shells.
  - It decreases across the periods due to an increase in nuclear charge which causes the atom to shrink due to the pulling effect of the nucleus.
  - Thus the atomic radius is affected by two factors namely: number of shells/ energy levels and the nuclear charge (atomic number).
- **Nuclear charge.**
  - It is the number of protons in the nucleus. For example the nuclear charge of He is +2, Na is +11 Cl is +17 etc.

- It increases across the period and down the groups.
- It affects the atomic radius.

- **The effective nuclear charge**.
  - It can be defined as the portion of the nuclear charge that is experienced by the highest energy level electrons.
  - Effective nuclear charge is always equal to the number of the outer most electrons. For instance the effective nuclear charge of potassium is +1, for magnesium is +2 and for Oxygen is +6.
- **Melting and boiling points.**
  - They increase to the middle of the periodic table and then decrease again. They are lowest on the right.

<u>Trends in the periodic table</u>:

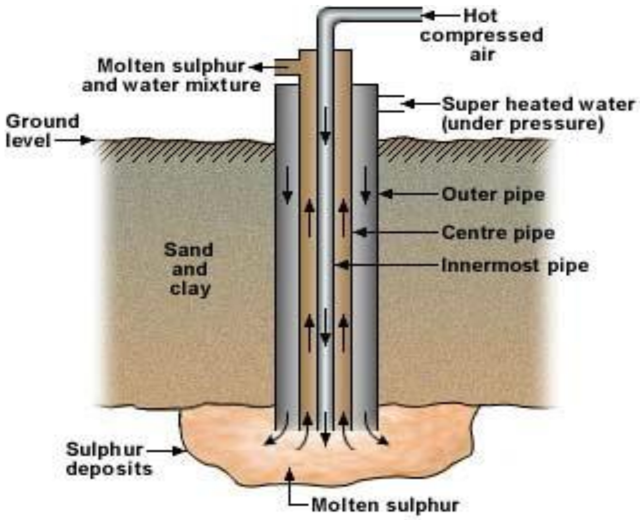
- Number of outermost shell electrons increase by 1 each time like the group number.
- Elements go from metals through metalloids to non-metals.
- Metal atoms have fewer outer shell electrons and lose them during chemical reaction to achieve full shell. Non –metals react by gaining or sharing electrons.
- The melting and boiling points increase to the middle of the period then decrease again. They are lowest on the right.
- All elements except the noble gasses react with oxygen to form oxides.
- Reactivity decreases across the period reaching the lowest at group 4 and then increases again reaching highest at group 7.
- All elements react with oxygen to form oxides except the group eight.

SULPHUR:

- It is a yellow non-metallic tasteless and order-less, naturally occurring element.
- It is the sixth most abundant element in the earth's crust
- It is in group 6 and period 3 of the periodic table.

Sources of sulfur:

- From underground sulfur beds. This is the main source.
  It is extracted from the underground by a process called *Frasch process*. In this process, superheated water under high pressure is pumped down to melt the sulfur. Compressed air is then forced down the inner pipe. Liquid sulfur is mixed with air forms an emulsion that is less dense than water and therefore rise to the surface as it is forced up through a middle pipe. Refer to the figure below:



Frasch process for the extraction of sulphur (or mining of sulphur).

- From crude oil , natural gas and some organic compounds in the form of hydrogen sulfide, H_2S and sulfur dioxide,SO_2.
- Found confined with metals in **metal ores** e.g. pyrite, FeS_2 and galena PbS. An ore is a rock or earth from which metals are extracted.

Physical properties of sulfur:

- It is brittle.
- It is yellow in color.
- It is made up of crown-shaped molecules, each with eight atoms.
- It exists in different allotropes.

Chemical properties:

- It burns easily with a blue flame in the presence of air to give sulfur dioxide.
  $S(s)+O_2(g)\longrightarrow SO_2(g)$
- It combines with metals to form metallic sulfides e.g.:
  $Fe(s)+S(s)\longrightarrow FeS.$
- When heated with sulfuric acid it gets oxidized to SO_2 according to the following:
  $S(s)+2H_2SO_4(aq)\longrightarrow 2H_2O+3SO_{2.}$
- It combines with non-metals such as H_2 to produce hydrogen sulfide characterized by the odor of rotten eggs. i.e. $H_2(g)+S(s)\longrightarrow H_2S(g)$.

Allotropy.

- It is the existence of an element in more than one crystalline form.

Allotropes.

- These are different physical forms of an element.
- E.g.; the allotropes of carbon are diamond which does not conduct electricity and graphite which is used to make pencils and it conducts partially.
- Allotropes of sulfur include rhombic sulfur, monoclinic sulfur, colloidal sulfur and plastic sulfur.

The major allotropes of sulfur:

- Rhombic sulfur and Monoclinic sulfur

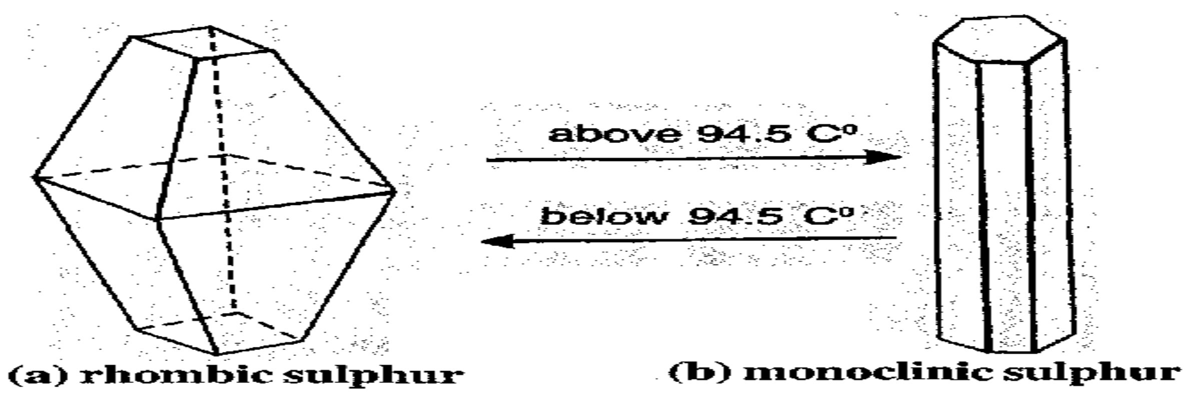
a) Rhombic sulfur

- It is also called alpha sulfur (α - sulfur)
- It is a relatively large, yellow translucent octahedral crystal.
- It forms at room temperature hence it is stable at any temperature below 96°C.
- It melts at 114°C and a density of $2 g/cm^3$.

b) Monoclinic sulfur.

- It is also called prismatic sulfur or beta sulfur (β -sulfur)
- It consists of needle-shaped transparent crystals.
- It melts at 119°C.
- It has a density of $1.98 g/cm^3$.
- It is stable at a temperature above 96°C. It converts to rhombic sulfur below 96°C.

The figure below shows the pictorial difference between Beta and alpha sulfur.



<u>**USES OF SULFUR**</u>

1. Used in making of sulfuric acid.
2. Used in **vulcanization** of rubber. Vulcanization is the process of making rubber tough and more elastic by addition of sulfur. Tyres are made in this way.
3. Used to make special concrete called sulfur concrete which is not affected by acids.
4. It is vital in the production of important chemicals such as carbon disulfide and calcium hydrogen sulfate which is used in paper industry.
5. Raw material in the manufacture of various drugs and ointments.
6. Used to produce pesticides and fungicides.
7. Used in sterilization (Killing of germs).
8. Used in the manufacture of matches and gun powder. The match head contains, among other materials, antimony sulfide, SbS. Gun powder is a combination of sodium (v)

nitrate, charcoal and sulfur. Fireworks locally known as 'makombola' result from this process.

SULPHURIC ACID, H_2SO_4

- It is a colorless, odorless oily liquid which has a density of 1.86 g/cm^3 and boils at 338°C.
- It is made by the contact process. This involves series of stages. Firstly, Sulfur is allowed to burn in air to produce sulfur dioxide. Later, sulfur dioxide produced is exposed to air under controlled conditions. This process leads to production of sulfur trioxide which is dissolved in water in order to produce the sulfuric acid. The following are word equations for the series of reactions in the contact process.

1. $S + O_2 \longrightarrow SO_2$
2. $SO_2 + O_2 \longrightarrow 2SO_3$
3. $H_2O + SO_3 \longrightarrow H_2SO_4$

- It is the cheapest acid.

USES OF SUPHURIC ACID:

1) It is used in the manufacture of fertilizers like calcium sulphate, $CaSO_4$
2) It is used in the extraction of metals and in the pickling process. (Pickling is cleaning metals with acid prior to painting.)
3) It is a raw material in the manufacture of fibers and plastics.
4) It used in the manufacture of synthetic paints, dyes, and explosives, soaps, detergents etc.
5) Used as an electrolyte in car batteries.
6) Used in the refining of petroleum.
7) Used in the manufacture of other chemicals.
8) Used in tanning of leather.
9) Used as a dehydrating agent. I.e. it can remove water from a substance. For instance, it turns blue copper (II) sulphate crystals into white powder by removing water of crystallization.
$CuSO_4.H_2O \xrightarrow{H_2SO_4} 5H_2O + CuSO_4$.
It also dehydrates sugar, paper and wood. When sugar is dehydrated, black staff, which is carbon, remains in the container. The water escapes away. Thus,
$C_{12}H_{22}O_{11} \xrightarrow{H_2SO_4} 12C + 11H_2O$
10) Dilute sulfuric acid reacts with metals to give hydrogen and salts called sulphates.
e.g. $Mg + H_2SO_4(aq) \longrightarrow MgSO_4 + H_2(g)$

SULPHATES:

- They are ionic compounds.

- Examples are Lead sulphate, $PbSO_4$, calciumsulphate, $CaSO_4$, barium sulphate, $BaSO_4$ etc.
- Most sulphates are soluble in water.

Tests for sulphates:

- Solubility in water. All sulphates are soluble except those made of Pb, Ca and Ba.
- Add a few drops of dilute HCl and a soluble barium salt like barium chloride, $BaCl_2$. A white precipitate of barium sulphate is produced according to the following equation:

$$Ba^{2+}(aq) + SO_4^{2-} \longrightarrow BaSO_4(s).$$

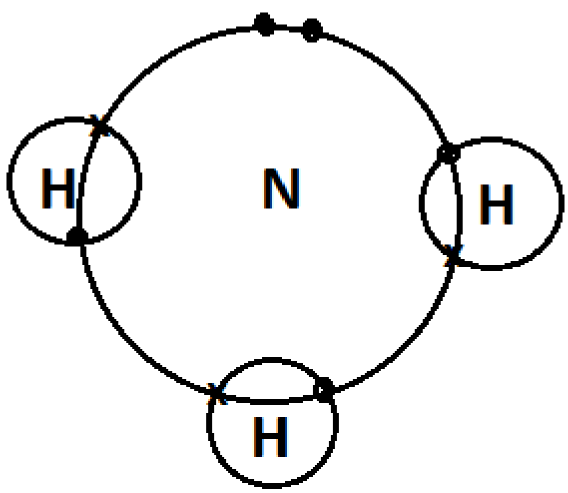
USES OF SULPHATES:

I. In fertilizer making. e.g. $CaSO_4$ for making ammonium sulphate, $(NH_4)_2SO_4$
II. In the manufacture of medicine e.g. $MgSO_4$ used as laxative Epson salts.
III. In the manufacture of plaster of Paris, POP. E.g. calcium sulphate.
IV. Used in glass and paper making. (Sodium sulphate).
V. Used in making of eye lotion and mouth washes e.g. Zinc sulphate. This is also used in dying of clothes and healing of wounds.
VI. Other uses include making pigments, purification of metals, electroplating and in diagnostic medical x-rays.

MANEB QUESTIONS IN THE RECENT THREE YEARS

2015 No 6

a. figure below shows an electron dot and cross diagram of ammonia



i. **Name the type of bonding that holds the atoms together.** ***Answer: Covalent bonding***
ii. **Give a reason for the answer in 6a(i)**
Both Nitrogen and hydrogen are non-metals and are sharing electrons
iii. **Write the chemical formula for ammonia** ***Answer:*** NH_3

B . (i) Mention any three properties of metals

- ***Conduct electricity, Are malleable, Are ductile, Are hard etc***

(ii) Explain how metallic bonding occurs

Answer: metals have free mobile electrons. There is force of attraction between the sea of free elections and the positively charged nuclei. This is metallic bonding

8b. **In terms of electrical conductivity, explain the difference between "polar" and "non-polar" covalent molecules.**

Answer:

Polar covalent molecules have one end slightly positively charged and the other negatively charged while the non-polar covalent molecules have neutral ends. This allows polar covalent molecules to slightly conduct electricity while the non-polar covalent molecules do not conduct electricity.

2014

a. State the three Subatomic particles of an atom

   Ans: ***electrons, protons, neutrons***

b. An atom with a mass number of 23 has 13 neutrons. Work out the electron configuration for the atom

   Answer:

   Number of electrons=mass number-number of neutrons = 23- 13 = 10

   Electron configuration = 2, 8

c. Table below shows the electrical conductivity of solids A, B, C, D and E when dissolved in water

Compound	Conductivity
A	Does not conduct
B	Conducts
C	Does not conduct
D	Conducts
E	Does not conduct

   (i) Classify the compounds as ionic and molecular

   Answer***: Ionic B and D*** ***Molecular: A, C , E***

   (ii) Give a reason for your answer above

   Answer: ***Ionic compounds form ions when dissolved in water hence they conduct electricity.***

2013

a. Mention any one difference between 'polar' and 'non-polar' molecules

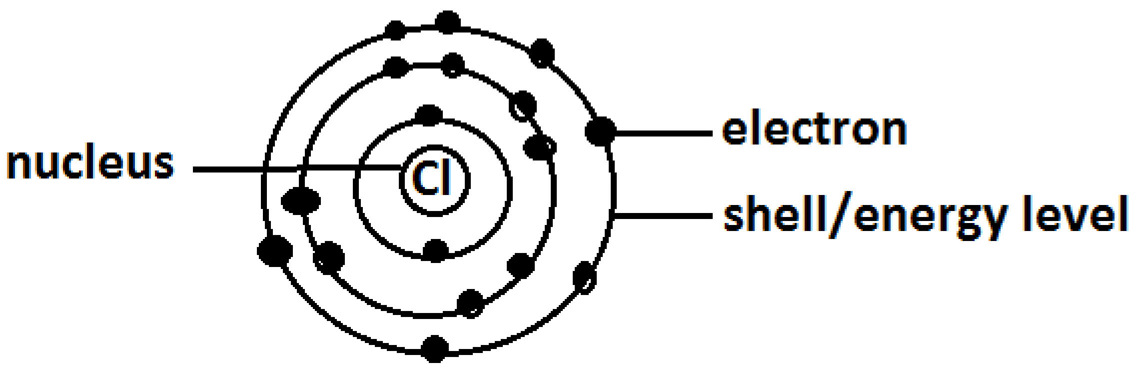
   Answer: Polar molecules have one end slightly positively charged and the other end slightly negatively charged while non-polar molecules have neutral ends

b. Table below shows atomic numbers, melting points and boiling points of group 7 elements

Elements	Atomic Number	Melting point (°C)	Boiling point (°C)
Fluorine	9	-220	-188
Chlorine	17	-101	-34
Bromine	35	-7	59
Iodine	53	114	184

(i) Which elements are gases at room temperature?
Answer: Fluorine and Chlorine

(ii) Draw the atomic structure of chlorine (Cl)
Answer



(iii) Why does iodine have a higher melting point than fluorine?
Answer: it is because iodine has a higher atomic number which leads to high IMF and also iodine is solid at room temperature which means its molecules are more compacted together than in fluorine hence more heat is needed to cause the boiling.

(iv) Calculate the number of neutrons in an iodine atom if its atomic mass is 127

Number of neutrons = A – Z = 127-53 = 74

2012 6

a. The table below shows electron configurations of element **R, S, T, U and V**

Element	Electron configuration
R	**2,7**
S	**2,8,6**
T	**2,8,2**
U	**2,4**
V	**2**

(i) Which elements in the table belong to period 2 of the periodic table? ***R and U***

(ii) Give a reason for your answer above. ***Have two shells, a number equal to period number***

(iii) Give a pair of elements that would form an ionic compound when they react***. T and U 0r T and S or T and R***

(iv) Draw an electron dot and cross diagram for the compound formed when S combines with U

b.State any three physical properties of halogens

- ✓ ***They are colored and they darken going down the group.***
- ✓ ***They exist as diatomic molecules because two atoms can gain full shells by sharing electrons with each other.***
- ✓ ***Their boiling points and melting points increase going down the group because of the increase in the force of attraction between the molecules. etc***

c. Explain what happens if chlorine is mixed with potassium bromide solution.
Displacement reaction would occur. There will be formation of potassium chloride since chlorine is more reactive that bromine.

2011. 4a

I. State three ways in which atoms attain stability.
By loosing electrons, By gaining electrons, By sharing electrons.

II. Explain how ionic bonding occurs.
Ans: It occurs between a metal and a non-metal. The metal loses electrons to become a cation while the non-metal accepts electrons to become an anion.

b. Table below shows atomic numbers and boiling points of some elements represented by letters **D, Q, T, X and Z.**

ELLEMENT	ATOMIC NUMBER	BOIING POINT (°C)
D	3	1342
Q	13	2467
T	16	445
X	18	-187
Z	19	760

I. Identify any two letters that represent elements which belong to period 3 in the periodic table.
Ans: Q, T or X.

II. Which element is in gaseous state at room temperature (25°C)?
Ans: X

III. What type of bonding would exist when element Q reacts with element T?
Ans: Ionic bond.

IV. Write down the chemical equation for the reaction that would occur between D and T.

$$D + T \longrightarrow DT_2$$

3.CHEMICAL REACTIONS1.

OBJECTIVES:

By the end of this topic you should be able to:

- Express a chemical reaction by a balanced equation.
- Use the mole in relation with other units.
- Relate the mass to unit of measurement.
- Calculate the empirical formula and molecular formula.
- Express concentration.
- Prepare standard solutions.
- Describe titration and its use.
- State molar volume.
- Calculate the reacting masses and gas volumes.
- Classify reactions as exothermic and endothermic.
- Draw energy level diagrams.

Chemical reaction:

- It is the rearrangement of atoms to form new species.
- Examples of chemical reactions are: rusting of iron, burning, precipitation of solids, decomposition of substances etc.
- Generally chemical reactions are affected by the following factors: concentration, temperature, particle size and catalysts.

Chemical equation:

- It is a quantitative statement used to summarize a chemical change.
- Substances found on the left of a chemical equation are called **reactants** (reagents) and those on the right are called **products**.

Types(Examples) of chemical reactions:

- Combination or synthesis. E.g. photosynthesis. Decomposition.Precipitation.Combustion or Burning. Redox (Reduction and Oxidation). Displacement. Neutralization. Nuclear. Electrolysis. Reversible. etc.

Balancing Chemical Equations:

Rules:

- Identify all reactants and products and write their correct chemical formula on both side of the equation.
- Indicate the physical states of the reactants and the products: (s) for solid, (l) for liquid, (g) for gas and (aq) for aqueous.
- Balance the equation by trying suitable coefficients. Don’t change subscripts as this may change chemical formula.

- Balance first, elements that appear least on either side of the equation. Those that appear in several places should be balanced at the end.
- Check your balanced equation to be sure that you have the same number of each type of atoms on both side of the equation.

Example:

Balance the following equation:

$H_2 + Br_2 \longrightarrow HBr$ Answer: $H_2(g) + Br_2(l) \longrightarrow 2HBr(l)$

Exercise:

Balance the following chemical equation.

1. $H_2 + O_2 \longrightarrow H_2O$
2. $H_2O_2 + O_2 \longrightarrow H_2O + O_2$
3. $S_8 + O_2 \longrightarrow SO_4$
4. $CH_4 + O_2 \longrightarrow CO_2 + H_2O$
5. $KClO_3 \longrightarrow KCl + O_2$
6. $Br_2 + SO_2 + H_2O \longrightarrow HBr + H_2SO_4$

Chemical Formula:

- It is a formula that expresses composition of a compound in terms of symbols of the atoms of the elements involved.

Relative Atomic Mass, A_r

- This is given by

  A_r = (Mass of one atom of an element)/($\frac{1}{12}$ x the mass of one atom of carbon).

- Atomic masses are found in the periodic table.

Relative Molecular Mass, M_r.

- It is given by

  M_r = (Mass of one molecule of a compound)/($\frac{1}{12}$ x the mass of one atom of carbon).

- It is also loosely referred to as molar mass.

Examples: work out the Relative Formula masses or molar masses of the following: (RAM: N = 14, O = 16, Cu = 64, H = 1, Al = 27, S = 32 Na = 23, C= 12).

1. H_2O 2. $Al_2(SO_4)_3$ 3. NaCl 4. SO_3 5. C_6H_5OH 6. $Na_2CO_3.10\ H_2O$
7. $CuSO_4$.

Solutions:

1. (1x2 + 1x16)= 18 2. (27x2 + 32x3+16x 7) = 262 3. 58 4. 60 5. 54
6. 266 7. 160

Calculating percent composition:

- Write down the formula of the compound.
- Using a list of RAMs work out its molecular mass.
- Write the mass of the element you want as a fraction of the total.

- Multiply the fraction by 100% to give percentage.

e.g:

Calculate the percent composition of Carbon in Urea, $(NH_2)_2CO$. (RAM: H =1, C =12, O = 16, N=14).

Ans. Formula is $(NH_2)_2CO$.

Molar mass = 2 x14 + 1x2x2+ 12+16 = 60g/mol

Percent Composition of Carbon = ($\frac{12}{60} x100\%$) = 20%

THE MOLE CONCEPT:

- A mole (mol) refers to number of particles equivalent to 6.02x 10^{23} particles.
- The mole of a substance is obtained by weighing out the RAM formula mass in grams.
- The number 6.022 x 10^{23} is called the Avogadro's number or Avogadro's constant.
- A mole is just like the unit dozen (12), unit (10) or gross (144)

Molar Mass:

- This is the mass of one mole of a compound or an element. E.g. magnesium has a molar mass of 24grams/mole.
- If m is a mass of a substance with molar mass M, then the amount of substance (moles), n is given by

  $$n = \frac{mass}{Molarmass} = \frac{m}{M}$$

  I.e. $\boldsymbol{n = \frac{m}{M}}$ where n is the number of moles, m is the mass and M is the molar mass.

  Examples:

  a. How many moles are there in
     1. 0.25g of CO_2
     2. 2g 0f CH_4
     3. 40g of NaOH.

  Solution:

  1. $n = \frac{m}{M} = \frac{0.25g}{(12+16x2)g/mole} = 0.00568moles$
  2. $n = \frac{m}{M} = \frac{2g}{(12+1x4)g/mole} = 0.125moles$
  3. $n = \frac{m}{M} = \frac{40g}{(23+16+1)g/mole} = 1mole$

  b. Find the mass of
     1. 0.50 moles of H_2O
     2. 5 moles of CO_2

  Solution:

1. Molar mass for water is 18 g/mole. $m = nM = 0.50x18 = 9g$
2. Molar mass is 44 g/mole hence $m = nM = 5x44 = 220g$

STOICHIOMETRY:

This is the analysis of the relationship between the amounts of reactants and products of a chemical reaction. The coefficients of a balanced chemical equation are called stoichiometric amounts.

Refer to the following balanced equation for the reaction of nitrogen gas and hydrogen gas to yield ammonia

$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

The equation above can be described in different ways like

1. 1 molecule of N_2 gas reacts with 3 molecules of H_2 gas to yield 2 molecules of NH_3 gas.
2. 1 mole of N_2 gas reacts with 3 moles of H_2 gas to yield 2 moles of NH_3 gas.

Since m = nM then in 1 mole of N_2 gas: m = nM = 1 mole x (14 x2) g/mole = 28g.

In 3 moles of H_2 m =nM= 3 moles x (1 x2) g/mole = 6 g

In 2 mole of NH_3 m = nM= 2 moles x (14 x 1+ 1x3) g/mole = 34 g.

3. 28g of N_2 gas reacts with 6g of H_2 gas to yield 34 of NH_3 gas.

In the equation above,

a. How many moles of hydrogen gas will react with 0.5 moles of nitrogen?
b. How many moles of ammonia will be formed from 0.5 moles of nitrogen?
c. How many grams of ammonia can be formed from 42 grams of nitrogen and how many grams of Hydrogen are required to completely convert that amounts?

Solution:

a. 1 mole of Nitrogen reacts with 3 moles of hydrogen
   0.5 moles will react with less mores of hydrogen

$$n = \frac{0.5}{1} x3moles = 1.5moles$$

b. 1 mole of Nitrogen forms 2 moles of ammonia
   0.5 moles of nitrogen will form less amount of ammonia

$$n = \frac{0.5}{1} x2moles = 1mole$$

c. 28 g of Nitrogen forms 34 g of ammonia
   42 g will form more

$$m = \frac{42}{28} x34g = 51g$$

28g of Nitrogen combines with 6g of hydrogen

42g wil combine with more hydrogen

$$m = \frac{42}{28} x6g = 9g$$

EMPIRICAL FORMULA

- It is defined as the formula which shows simplest ratio of atoms of elements.

- It tells us which elements are present and the simplest whole number ratio of the atoms but not necessary the actual number of their atoms present in the molecule.
- For example, the molecular formula of hexene is C_6H_{12}. Its empirical formula is CH_2.
- Molecular formula is a simple multiple of the empirical formula.

Finding empirical formula, from mass:

- Start with the numbers of grams that combine.
- Change the grams to the moles of atoms.
- From this, one can tell how many atoms combine.
- You then write down the formula.

Example 1:

An analysis of an organic compound showed that 5.4g of carbon combined with 0.9g hydrogen and 0.8g of oxygen. What is the empirical formula of this compound? (RAM: C=12, H=1 and O=16).

Solution:

Number of moles for C= (m/M) = (5.4/12) = 0.45moles.

Number of moles for H= (m/M) = (0.9/1) = 0.9moles.

Number of moles for O= (m/M) = (0.8/16) = 0.05moles.

Divide the number of moles by the smallest value which is 0.05

$$C = \frac{0.45}{0.05} = 9moles. \ H = \frac{0.9}{0.05} = 18moles. \ O = \frac{0.05}{0.05} = 1mole.$$

Thus the ratio of atoms is 9:18:1

The empirical formula is $C_9H_{18}O$

Example 2:

Given the following information obtained from an experiment: 79.2% Carbon, 20.8%Hydrogen. Find the

a. Empirical formula of the compound.
b. Molecular formula given that the molar mass is 80 g/mole.

Solution:

a. Assume that the percentages are masses in grams.

Number of moles for $C = \frac{79.2g}{12g/mole} = 6.6moles.$

Number of moles for $H = \frac{20.8g}{1g/mole} = 20.8moles.$

Divide by the smallest value which is 6.6

$$C = \frac{6.6moles}{6.6} = 1mole.$$

$$H = \frac{20.8moles}{6.6} = 3.15moles \approx 3moles$$

This means that the ration of Carbon to Hydrogen is 1:3 and the Empirical Formula becomes CH_3.

b. Find the molar mass for the empirical formula which is 12+1x3= 15 g/mole. Divide the molar mass of the compound by the molar mass of the empirical formula to obtain the multiplying factor, x. i.e. $x = \frac{80g/mole}{15g/mole} = 5.33 \approx 5$

The molecular formula = $(CH_3)_x$= $(CH_3)_5$= C_5H_{15}.

Example 3:

Given that Hydro Carbon A contains 85.7 % Carbon. The molar mass of A is 42 g/mole

Calculate the empirical formula of the substance. (RAM C =12, H = 1)

ATOM	MASS	Number of moles
Carbon	85.7g	$n = \frac{85.7}{12} = 7.1417 moles$
Hydrogen	14.3g	$n = \frac{14.3}{1} = 14.3 oles$

C : $n = \frac{7.1417 moles}{7.1417} = 1 mole$

H : $n = \frac{14.3 moles}{7.1417} \approx 2 moles$ Therefore, the empirical formula is CH_2

The molar mass from the empirical formula= (12 x 1 + 1 x1) g/mole = 14 g/mole.

The multiplying factor $x = \frac{42g/mole}{14g/mole} = 3$ the molecular formula is $(CH_2)_3$ = C_3H_6.

CONCENTRATION/ MOLARITY

- Concentration is the amount of solute present per unit solvent.
- A solute could be a liquid or a solid and the solvent is assumed to be a liquid.
- It is given in g/cm^3, g/liter etc.
- E.g. If 50g of Sodium Chloride, NaCl is dissolved in 100cm^3, what is the concentration of the solution prepared?

$$C = \frac{m}{V} = \frac{50g}{100cm^3} = 0.5g/cm^3$$

Molarity

- It is the number of moles of solute per cubic decimeters.
- Thus, it is the concentration expressed in moles per dm^3.

  Molarity = (number of moles of solute)/ (liters of solution).

Example:

- E.g. If 60g of Sodium Chloride, NaCl is dissolved in 100cm^3, what is the molarity of the solution prepared?

  Need to find the number of moles.

$$n = \frac{m}{M} = \frac{60g}{(23+35)g/mole} = 1.03 moles$$

Change the volume ($100cm^3$) to dm^3 (liters). Do this by dividing the given volume by 1000.

$$V = \frac{100}{1000} dm^3 = 0.1dm^3.$$

Molarilty= $\frac{\#moles}{volume, dm^3} = \frac{1.03moles}{0.1dm^3} = 10.3moles/dm^3 = 10.3M$

Molar Solution:

- This is the solution that contains 1 mole of a solute per cubic decimeter.

Standard solution:

- This is the solution whose concentration is accurately known.
- Standard solutions are used in titration and volumetric analysis and in solution preparation.

DILUTIONS OF SOLUTIONS:

- This is the process of preparing a less concentrated solution from a more concentrated one (usually called stock solution).
- Adding more solvent to a given amount of the stock solution changes (decreases) concentration without changing the number of moles of solute present in the solution. I.e. <u>number of moles of solute before dilution = number of moles of solute after dilution.</u>
- Since molarity is defined as moles of solute/liter of solution the number of moles is therefore given by

Moles of solute = Molarity x Volume of solution in liters.

- Considering the fact that all the solute comes from the original stock solution, one can easily conclude that $C_{initual} \times V_{initial} = C_{final} \times V_{final}$.

i.e. $C_iV_i = C_fV_f$ where C_i is initial concentration, V_i is initial volume, C_f is the final concentration and V_f is the final (new) volume. The other version of the dilution equation is

$M_iV_i = M_fV_f$ where the M stands for molarity and the subscripts simply describe the molarity as either initial or final.

The bottom line is that number of moles before dilution is equal to number of moles after dilution.

Examples:

1. $100cm^3$ of a solution with concentration of $50g/cm^3$ was diluted with water until its final volume was $250cm^3$. Calculate the new concentration of the solution.

Solution:

V_i= $100cm^3$, C_i=$50g/cm^3$, V_f= $250cm^3$, C_f is the unknown. Using the following equation,

$$C_iV_i = C_fV_f = 50g/cm^3 x 100cm^3 = C_f x 250cm^3$$

$$\Rightarrow C_f = \frac{50x100}{250} g/cm^3 = 20g/cm^3$$

2. Describe how you would prepare 500ml of 0.8 M HClsolution, starting with a 2.0M stock solution of HCl.

Solution:

Firstly, calculate the volume of the stock solution which has to be used.

V_i= ?, C_i=2M, V_f= 500ml, C_f = is the unknown. Using the following equation,

$$C_iV_i = C_fV_f = 2.0MxV_i = 0.8Mx500ml \Rightarrow V_i = \frac{0.8x500}{2}ml = 200ml$$

Next step is to dilute 200ml of the stock solution using distilled water (pure or de-ionized water) to give a final volume of 500ml. Use a 500ml volumetric flask to obtain accurate measurements.

PREPARING SOLUTION FROM CRYSTALS (SOLID PARTICLES):

Steps:

1. Determine the number of moles contained in the solution by using n = c v
2. Convert the number of moles to mass by using m = n M.
3. Highlight the procedure and materials to be used.

Example: **Describe how you can prepare 250 cm^3 of a 1.8 M solution of Sodium hydroxide, NaOH using sodium hydroxide pellets. (RAM Na = 23, O= 16 and H = 1).**

Solution:

Firstly, determine how many moles are contained in the solution. This is done by

$$n = CV = (1.8moles/dm^3)x(250/1000)dm^3 = 0.45moles$$

Next, convert the number of moles to mass. Molar mass of NaOH = (23 x1 +16 x 1+ 1x1) g/mole= 40 g/mole. It follows that

$$m = nM = (0.45x40)g = 18g$$

Weigh 18 grams of the sodium hydroxide pellets using a triple beam balance. Using measuring cylinder, measure 250 cm^3 of pure water and dissolve the sodium hydroxide pellets in the pure water. Stir or shake properly till all the pellets dissolve.

<u>Molar Volume:</u>

- This is the volume occupied by 1 mole of a gas at standard temperature and pressure.
- For reaction of gases, it is more usual to consider the volumes of reactants and products rather than their masses.
- One mole of a molecule of all gasses at standard temperature and pressure, **STP** (0°C & 1atm) occupies approximately **22.4dm^3**(22.4 l or 22400cm^3). This is called Molar Volume.
- At room temperature, 25°C and pressure 1atm, molar volume is 24dm^3.

<u>Example:</u>

- Calculate the volume occupied by 5g of oxygen gas at STP. (RAM O =16).

  Solution:

One has to find the number of moles of oxygen contained in the 5g.

$$n = \frac{m}{M} = \frac{5g}{(16x2)g/mole} = \frac{5g}{32g/mole} = 0.156 moles.$$

Now 1mole of any gas, at STP, occupies 22.4dm^3 .

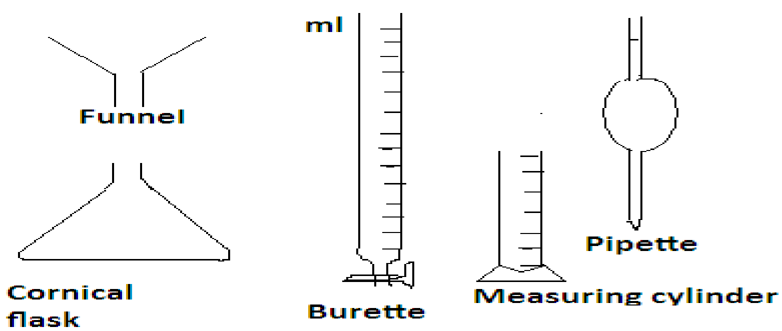
Hence volume of gas = 0.156 x 22.4dm^3= 3.5dm^3.

TITRATION:

- This is a gradual addition of a solution into another until the reaction is complete.
- There are different types of titration but the commonly carried out is **acid-base titration**.

Acid-Base Titration:

- In an acid-base titration the point at which the acid is completely reacted with or neutralized by the base is called **the end-point** or **equivalence point**.
- End point is signaled by a sharp color change of indicator added to an acid-base mixture. Indicators are substances that have distinct colors in acidic or basic media.
- An example of an indicator is phenolphthalein which is colorless in acids and pink in basic solutions.
- The apparatus used in the titration experiments include: conical flask, pipette, burette, funnels, measuring cylinder, pipette filler, indicators and sometimes a white towel.



- The following is the titration equation used in calculating either volumes or concentrations of solutions.

$$\frac{C_a x V_a}{n_a} = \frac{C_b x V_b}{n_b}$$

Where

notation	Meaning
C_a	Concentration of the acid.
V_a	Volume of the acid
n_a	Number of moles of the acid
C_b	Concentration of the base
V_b	Volume of the base
n_b	Number of moles of the base

Note: the number of moles is obtained from a balanced chemical equation summarizing the reaction. It is the coefficients of a balanced equation of usually acid and base. This is called Stoichiometry (the relationship between the amounts of reactants and the products in a chemical reaction).

Example 1:

- **Q:** 10cm^3 of hydrochloric acid, HCl neutralized 15 cm^3 of a 0.2M sodium hydroxide (NaOH) solution.
  1) Identify a standard solution and give a reason for your choice.
  2) Calculate the concentration of the hydrochloric acid.
- **A:** 1) it is the sodium hydroxide solution because its concentration is known.

  Equation:

  $HCl + NaOH \longrightarrow NaCl + H_2O$. It is balanced.

  V_a= 10cm^3, C_a=?, n_a= 1, V_b= 15cm^3, C_b= 0.2M, n_b= 1. Using the following:

$$\frac{C_a x 10cm^3}{1mole} = \frac{0.2Mx15cm^3}{1mole} \Rightarrow C_a = \frac{0.2x15}{10}M = 0.3M$$

Example 2:

- Q: In a certain process, 20cm^3 of a 1.2M solution of sodium hydroxide, NaOH was titrated against sulphuric acid. the process was done three times and the results are tabulated as below:

# of run	Volume of the H_2SO_4.		Volume used, cm^3
	Initial volume, cm^3	Final volume,cm^3	
1	50	35.1	
2	35.1	20.1	
3	20.1	5.3	

  1) Calculate the volume of the sulfuric acid used in each run hence find the average volume of the titer (the acid).
  2) Write a balanced chemical equation.
  3) Calculate the concentration of the sulfuric acid.
- A:
  1) This is done by filling-in the table as is below:

# of run	Volume of the H_2SO_4.		Volume used, cm^3
	Initial volume, cm^3	Final volume,cm^3	
1	50	35.1	**14.9**
2	35.1	20.1	**15**
3	20.1	5.3	**14.8**

Average volume = $\frac{14.9+15+14.8}{3}cm^3 = \frac{44.7}{3} = 14.9cm^3$

2) $H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(s) + 2H_2O(l)$

3) V_a= 14.9cm^3, Ca=? n_a= 1, V_b= 20cm^3, C_b= 1.2M, n_b=2. Using the following:

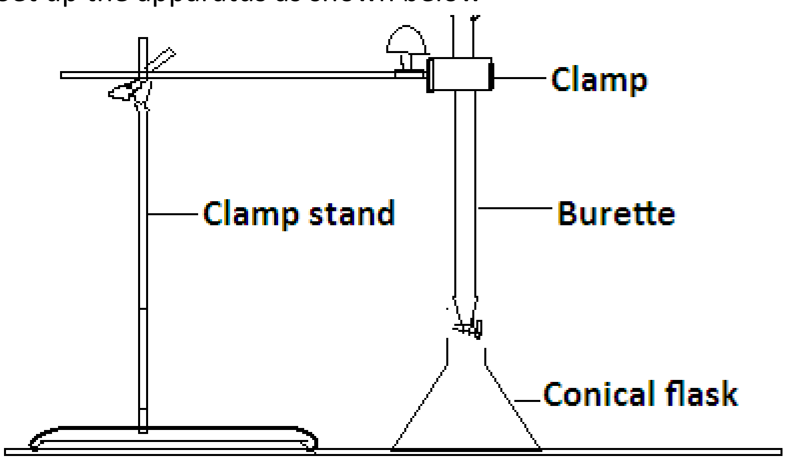
$$\frac{C_a x 14.9cm^3}{1mole} = \frac{1.2Mx20cm^3}{2moles}$$

$$\Rightarrow C_a = \frac{1.2x20}{2x14.9}M = 0.81M$$

The basic procedure is as follows:

You are provided with the following; burette, clamp and clamp stand, measuring cylinder conical flask, phenolphthalein (or any) indicator, basic solution (egNaOH) and acid, (egHCl)Theconcentration of either the acid or the base is known.

a. Set up the apparatus as shown below



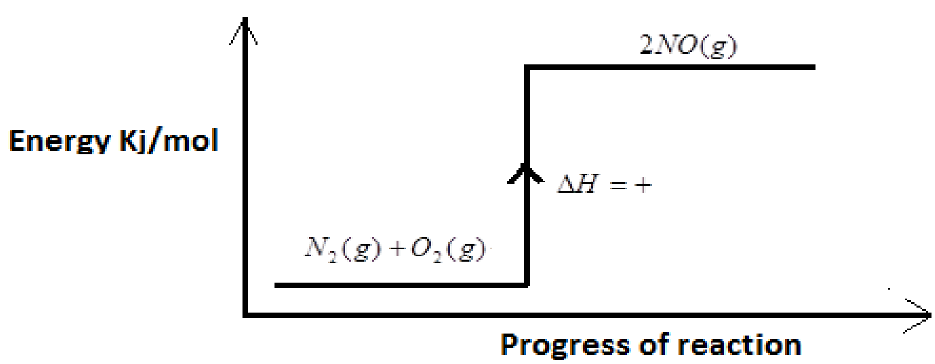
b. Fill the burette to the mark with the acid (e.g.HCl)
c. Record the volume of acid
d. Measure a given volume of the base e.g.NaOH and transfer it into conical flask
e. Add 2 drops of phenolphthalein(or any) indicator into the conical flask
f. Add the acid gradually, in small amounts from the burette into the conical flask. Swirl the conical flask to mix well
g. Stop adding acid when a color change is observed in the flask
h. Record the volume of acid remaining in the burette
i. Subtract the final volume of acid from the initial volume and record
   Initial volume of acid = ___________________________
   Final volume of acid =_____________________________
   Volume of acid used = _____________________________
j. Write a balanced chemical equation for the reaction
k. Calculate the concentration of either the acid or the base
l. Identify the standard solution in this experiment
m. State any two sources of error in the experiment.(These may include; failure to read the volume changes accurately, addition of acid whencolor change has taken place, malfunctioning apparatus like burette's tap not closing (opening) properly among others.

HEATS OF REACTION:

- There are two kinds of energy namely: potential energy and kinetic energy.
- Potential energy is energy due to position of an object.
- Kinetic energy is energy due to movement.
- Heat is a form of kinetic energy. It is associated with motion of molecules.
- The energy of chemical bonds is a form of potential energy emanating from the position of atoms and molecules with respect to each other.
- Energy is measured in joules.
- The study of heat changes in chemical reaction is called thermo chemistry.
- The energy stored in chemical bonds is called enthalpy and is represented by H.
- Change in enthalpy is denoted by ΔH (delta H).
- The **enthalpy of reaction** is the difference between the enthalpies of the products and the reactants. I.e. ΔH = H (products) - H (reactants).
- **ΔH** is called the **heat of reaction**.
- A reaction can either be **endothermic** or **exothermic.**

<u>Endothermic reaction</u>:

- This is a reaction in which energy is absorbed from the surrounding.
- In endothermic reactions
  - ΔH is positive because the products have higher energy than the reactants.
  - ΔT (change in temperature) is negative since the final temperature is lower than the initial temperature.
- Examples of endothermic reactions are: thermal decomposition, photosynthesis and dissolving, polymerization of ethene to poly-ethene, reactions that take place during food cooking, reduction of silver ions to silver during photography.
- Consider the reaction of Nitrogen with oxygen to produce nitrogen dioxide. $N_2(g) + O_2(g) \longrightarrow 2NO\ (g)$. Its energy level diagram or energy level profile will be as follows.

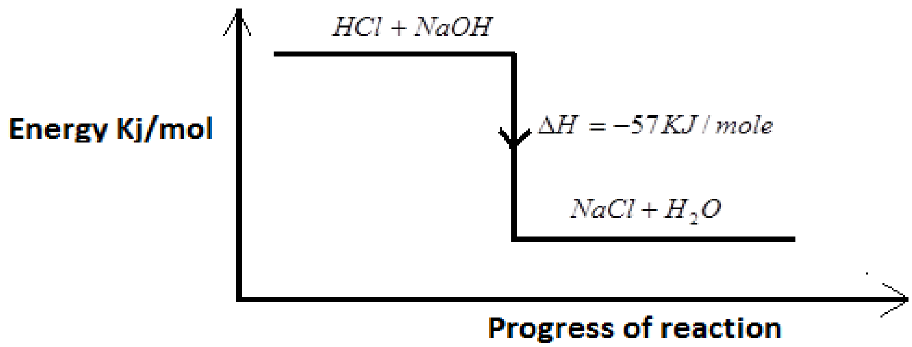


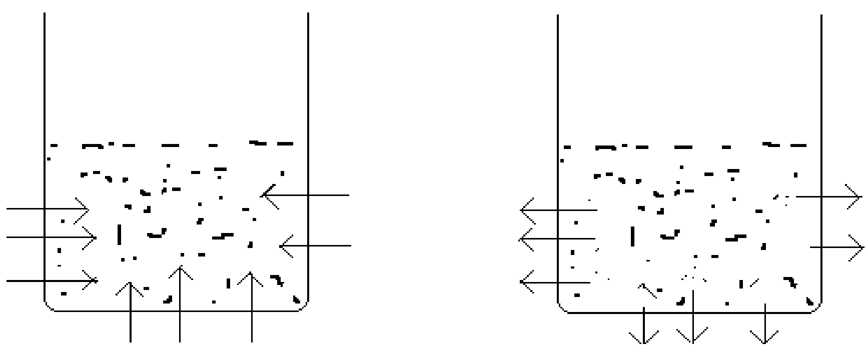
<u>Exothermic reaction</u>

- This is the reaction that releases heat to the surrounding.
- They are much less common than the endothermic ones.

- In exothermic reactions
  - ΔH is negative since the products have lower energy value than the products.
  - ΔT is positive.
- Examples include: fermentation, neutralization of acids by bases, ionization of acids in water, combustion of fuels and respiration in animal bodies.
- Consider the reaction of a hydrochloric acid, HCl and a sodium hydroxide solution, NaOH according to the following reaction.

  $HCl + NaOH \longrightarrow NaCl + H_2O$ And ΔH = -57KJ/mole. The energy level diagram will be as follows:





Heat absorbed from environment
Endothermic Reaction

Heat released into the environment
Exorthermic Reaction

HOW THE TOPIC HAS BEEN FEATURED BY MANEB IN THE RECENT 4 YEARS:

2015 No 5

a. **Give two ways of determining strength of an acid**

   Answers: By conductivity test, by use of universal indicator, by use of pH meter

b. **State any two ways of expressing the concentration of a solution**

   Answers: ***(i)as mass of solute per unit volume of solvent. (ii) As number of moles per volume in liters or cubic decimeters***

c. **In a titration, 25cm^3 of hydrochloric acid (HCl) of unknown concentration was titrated against 20cm^3 of 2M sodium hydroxide (2M NaOH) to which phenolphthalein was added.**

   (i) Name the standard solution in the titration. ***Answer: Sodium hydroxide (NaOH)***

(ii) Give a reason for your answer in 5c(i)

Answer: because its concentration is known

2014 **Number 3**

a. Define 'mole'

It a measure equivalent to 6.03×10^{23} ***particles or it is a measure of particles equal to Avogadro's number***

b. Magnesium (Mg) react with oxygen (O_2) according to the following equations:

$$Mg_{(s)} + O_{2(g)} \longrightarrow MgO_{(s)}$$

(i) What does "s" stand for in the equation? Answer: ***solid***

(ii) Balance the equation

$$2Mg_{(s)} + O_{2(g)} \longrightarrow 2MgO_{(s)}$$

(iii) If 120g of magnesium reacts completely in excess of oxygen. How many mores of oxygen are used? (RAM: Mg = 24, O =16)

120g of Mg $n = \frac{m}{M} = 120/24 = 5moles$

If 2 moles of Mg needs 1 mole of O_2 ,5 moles will need more

Number of moles of oxygen = $\frac{5}{2}\times 1mol = 2.5moles$

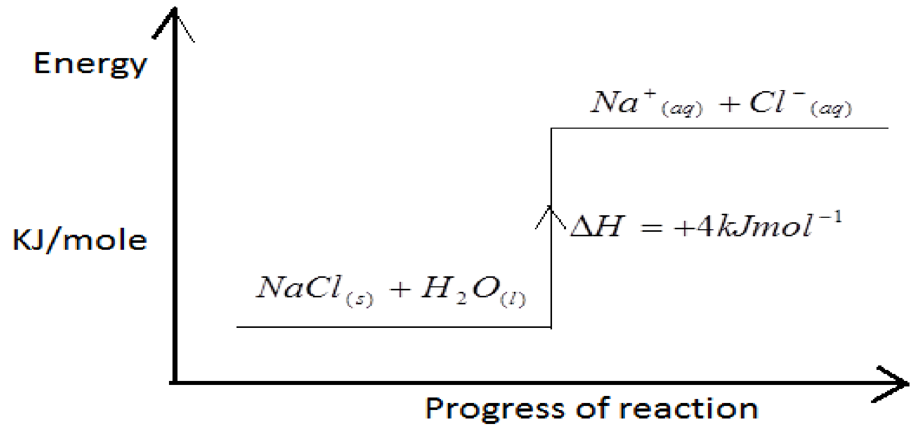
c. Sodium chloride (NaCl) dissociates in water as follows:

$$NaCl_{(s)} + H_2O_{(l)} \longrightarrow Na^{+}{}_{(aq)} + Cl^{-}{}_{(aq)} \Delta H = +4kJmol^{-1}$$

(i) Name the type of reaction basing on enthalpy change.

Answer Endothermic reaction

(ii) Draw an energy level diagram for the process



2013

3

a. What is an " empirical formula"?

Anwer: It is a formula that expresses atoms in their smallest ratio

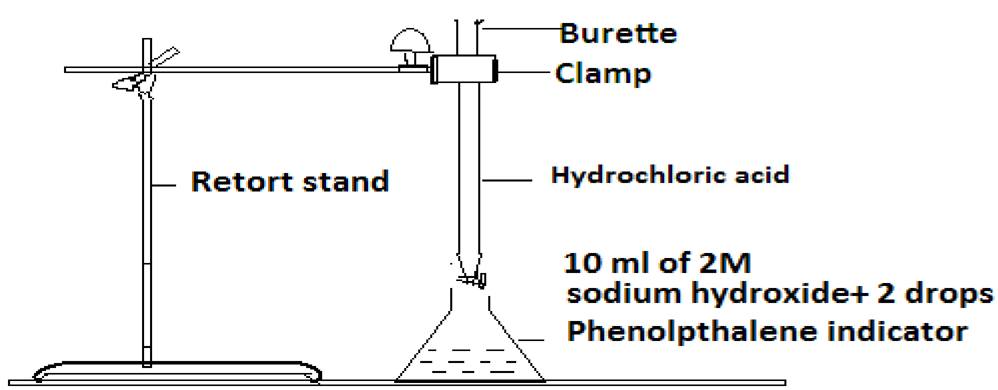
b. Calculate the empirical formula of copper oxide (CuO) with chemical composition of 32g of copper and 8g of oxygen (RAM: O =16 and Cu = 64)

element	mass	Number of atoms
Cu	32g	$n = \frac{m}{M} = \frac{32}{64} = 0.5moles$
O	8g	$n = \frac{m}{M} = \frac{8}{16} = 0.5moles$

Dividing by smallest value :Number of moles of Cu = 0.5/0.5 = 1mole and for oxygen = 0.5/0.5 = 1mole

Therefore empirical formula is CuO

c. Fiugre below is diagram showing the set up of an experiment on titration



(i) What is the function of phenolpthalene indictaor in the experiment?

Answer: to show or signal the end point of the reaction

(ii) Name the standard solution in the experiment

Answer: Sodium hydroxide

(iii) Give a reason for your answer above

Answer: because its concentartion is known

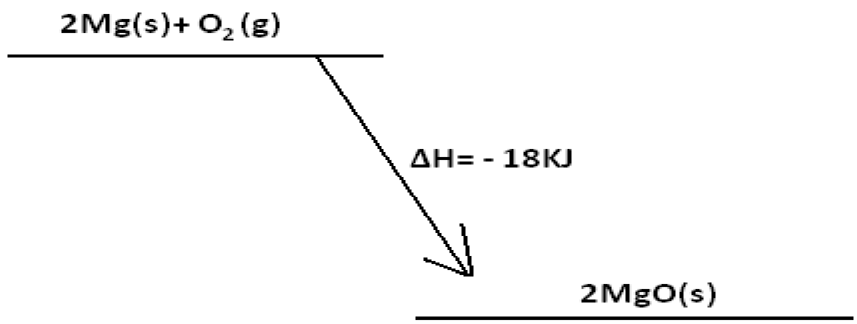
d. State any two ways of expressing the concentration of a solution

Answer:

- ***Mass of solute per unit volume of solvent***
- ***Number of moles of solute per unit volume of solvent in cubic decimeters***

2012

a. Figure below shows an energy level diagram for the reaction between magnesium Mg and oxygen O_2 .



i. Is the reaction exothermic or endothermic? ***exothermic***

ii. Give a reason for your answer above***. It is because the change in heat is negative which means that heat is given to surrounding making the products have low energy than reactants.***

iii. State the meaning of the arrow in the diagram***. It shows direction of reaction in terms of reactants and products***

---

4. CHEMICAL REACTIONS 2

OBJECTIVES:

By the end of the topic learners should be able to:

- Define oxidation and reduction.
- Define oxidation number.
- Identify reducing and oxidizing agents.
- Describe a displacement reaction.
- Explain the reactivity series.
- Explain rusting/corrosion.
- Discuss ways of preventing corrosion.
- Describe the process of electroplating.

- Define an acid and a base.
- Describe the formation of a hydroxyl and a hydronium ion.
- Identify a conjugate acid-base pair.
- Determine strength of acids and bases.

Definitions.

REDOX REACTION:

- It is a reaction in which both reduction and oxidation occur.

OXIDATION.

- It is the **loss** of electrons.

  E.g. $Mg - 2e \longrightarrow Mg^{2+}$

  It is shortened as OIL or LEO.

  OIL means **O**xidation **I**s **L**oss and LEO stands for **L**oss of **E**lectrons, **O**xidation.
- It is also defined as an increase in oxidation number. Oxidation number/state is the amount of charge that an atom would have in an element or compound if electrons were added or removed completely.

  E.g. $Fe^{+} \longrightarrow Fe^{2+}$.
- It is the **addition** of oxygen to a substance.

  eg. $Cu + O \longrightarrow CuO$

REDUCTION.

- It is the gain of electrons.

  E.g $Cl + e \longrightarrow Cl^{-}$.   It is shortened as RIG or GER.

  RIG means **R**eduction **I**s **G**ain and GER stands for **G**ain of **E**lectrons, **R**eduction.
- It is the **decrease** in oxidation number.

  $Cu^{2+} \longrightarrow Cu^{0}$
- It is the removal of oxygen from a substance.

Oxidation and reduction occur simultaneously. When one substance gets oxidized the other gets reduced.

REDUCING AGENT (REDUCTANT)

- It is a substance that is capable of donating electrons. It is an electron donor.

OXIDISING AGENT (OXIDANT)

- It is a substance that is capable of accepting electrons. It is an electron acceptor.

In short, the substance that gets oxidized is a reducing agent while that which gets reduced is an oxidizing agent. Redox reactions are also called **Electron transfer** reactions.

RULES FOR ASSIGNING OXIDATION NUMBERS/STATES

1. The oxidation number of an element in an uncombined state is **zero**. eg. Na^0, Cu^0, H_2^0, Al^0 etc.
2. In a compound or a polyatomic ion, the oxidation number of
   - Group 1 elements is +1

- Group 2 element is +2
- Aluminium is +3
- Oxygen is -2
- Silver is +1
- Fluorine is -1

3. For a neutral compound, the **sum** of oxidation numbers is **zero**.
4. The oxidation number of a monatomic ion is the charge on it
5. For a polyatomic ion, the sum of oxidation numbers is equal the charge on it.

Examples.

Work out the oxidation number of the given element in each compound given.

1. KCl, Cl.
   $(+1)+x=0 \Rightarrow x=-1$
2. $KClO_3$ (potassium chlorate), Cl.
   $(+1)+y+3(-2)=0 \Rightarrow y=+5$
3. NO_2 N
   $x+2(-2)=0 \Rightarrow x=+4$
4. NH_4^+ N
   $x+4(1)=+1 \Rightarrow x=-3$
5. $KMnO_4$Mn.
   $(+1)+x+4(-2)=0 \Rightarrow x=+7$

Pick out the oxidizing and reducing agent in the following reactions.

I. $Cu(s)+2Ag^+(aq) \longrightarrow Cu^{2+}(aq)+2Ag^0$
   Cu; from 0 to 2; oxidized hence a reducing agent.
   Ag; from1 to 0; reduced hence an oxidizing agent.
II. $2K(s)+Cl_2(g) \longrightarrow 2KCl$
   K; from 0 to +1; oxidized hence a reducing agent.
   Cl; from 0 to -1; reduced hence an oxidizing agent.
III. $Na(s)+AgNO_3 \longrightarrow NaNO_3+Ag$
   Na; from 0 to 1; oxidized hence a reducing agent.
   Ag; from +1 to 0; reduced hence an oxidizing agent.

HALF EQUATIONS

- It is an equation that shows electrons involved in either oxidation or reduction.
- They are written from an overall reaction.
  Examples.

1. $Cu(s)+2Ag^+(aq) \longrightarrow Cu^{2+}(aq)+2Ag^0$
   $Cu^0(s)-2e \longrightarrow Cu^{2+}(aq)$ Oxidation.
   $Ag^+(aq)+2e \longrightarrow 2Ag^0(s)$ Reduction.
2. $Cu^{2+}(aq)+Zn^0(s) \longrightarrow Cu^0(s)+Zn^{2+}(aq)$

$Cu^{+2}(aq) + 2e \longrightarrow Cu\ \ (s)$. Reduction.

$Zn^{0}(s) - 2e \longrightarrow Zn^{2+}(aq)$. Oxidation.

3. $2Al^{3+}(aq) + 3Mg^{0}(s) \longrightarrow 3Mg^{2+}(aq) + 2Al^{0}$

   $3Mg^{0}(s) - 6e \longrightarrow 3Mg^{2+}(aq)$

   $2Al^{3+}(aq) + 6e \longrightarrow 2Al^{0}(s)$

WRITING OVERALL/NET/FULL/SIMPLIFIED IONIC EQUATIONS

Steps.

- Balance the number of electrons as we do in linear simultaneous equation.
- Add the two equations together.

Examples:

Given the following half-reactions write down overall ionic equations:

I. $Na^{0}(s) - e \longrightarrow Na^{+}(aq)$

$$\underline{Mg^{2+}(aq) + 2e \longrightarrow Mg^{0}(s)}$$

$$2Na^{0}(s) - 2e \longrightarrow 2Na^{+}(aq)$$

$$\underline{Mg^{2+}(aq) + 2e \longrightarrow Mg^{0}(s)}$$

$$2Na(s) + Mg^{2+}(aq) \longrightarrow 2Na^{+}(aq) + Mg^{0}(s)$$

II. $Fe^{0}(s) - 2e \longrightarrow Fe^{2+}(aq)$ (Maneb 2009)

$$\underline{Sn^{2+}(aq) + 2e \longrightarrow Sn^{0}(s)}$$

$$Fe(s) + Sn^{2+}(aq) \longrightarrow Fe^{2+}(aq) + Sn^{0}(s)$$

DISPLACEMENT REACTION

- A displacement reaction is a reaction in which a more reactive element or ion displaces a less reactive element from a solution.
- Metals displace each other from a solution depending on the nature of reaction.
- In order to determine which element will displace which one in solution an **activity/reactivity/displacement/redox series** is given.

Potassium, K
Sodium, Na
Calcium, Ca
Magnesium, Mg
Aluminum, Al
Zinc, Zn
Iron, Fe
Lead, Pb
Hydrogen, H
Copper, Cu
Silver, Ag

increasing
Reactivity

Gold, Au

- Elements higher up in the activity series displace those below by forcing them to accept electrons.
- The more reactive elements act as reducing agents and the less reactive elements as oxidizing agent. E.g

I. $CuSO_4(aq) + Mg(s) \longrightarrow MgSO_4 + Cu(s)$

II. $ZnCl_2(aq) + Pb(s) \longrightarrow$ No reaction.

- The more reactive an element is, the more electropositive it is.

SIMPLE CELL

- It can be made by dipping two metals of different reactivity in an electrolyte such as dilute sulfuric acid, lemon juice etc.
- The more reactive metal becomes the cathode while the less reactive metal becomes the anode.
- The **greater the difference in reactivity** of the metals the **higher** is the voltage produced.

Examples.

Below are results of a set of experiments carried out by a pupil. Study them and answer the questions that follow. (Maneb 2001)

$Cu + MgSO_4 \longrightarrow$ No reaction.

$Mg + CuSO_4 \longrightarrow$ Fast reaction

$Zn + CuSO_4 \longrightarrow$ Slow reaction

$Mg + ZnCl_2 \longrightarrow$ Moderate reaction

$Zn + MgSO_4 \longrightarrow$ No Reaction.

I. Write the balanced equation for the reaction between Magnesium, Mg and Copper Sulfate, $CuSO_4$.

Ans: $Mg(s) + CuSO_4(aq) \longrightarrow MgSO_4(aq) + Cu(s)$.

II. Name the oxidizing and reducing agents in the reaction you have written.

Oxidizing agent: Copper

Reducing agent: Magnesium.

III. Arrange the elements in order of decreasing reactivity starting with the most reactive.

$\Rightarrow$ Mg, Zn, Cu.

IV. Which combination of metals would give a higher voltage, Magnesium/Zinc or Copper/Magnesium? Give a reason or your answer.

$\Rightarrow$ Magnesium/Copper, because the greater the difference in reactivity the higher the voltage.

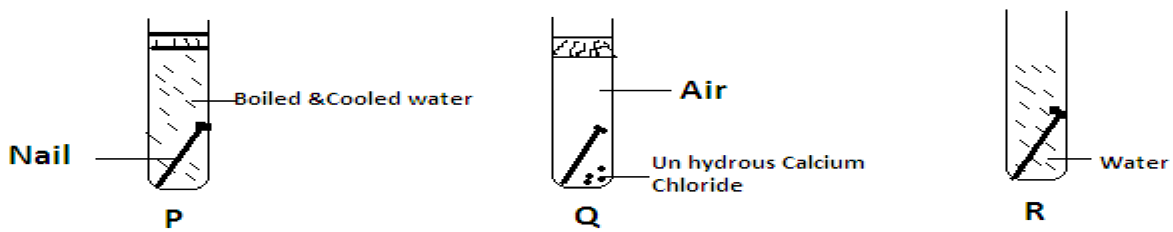
<u>CORROSION</u>

- It is a process where by an object is eaten up by a chemical process.
- Metals undergo corrosion depending on the condition. For example; iron rusts, Zinc Aluminum tarnish while green patina forms on copper.

RUST

- It is the powdery brown layer that forms on the surface of iron.
- The chemical name of rust is iron (II) oxide while its chemical formula is Fe_2O_3.
- The conditions necessary for rusting of iron are **water** and **air** (oxygen).
- During rusting oxygen gets reduced while iron gets oxidized.

EXPERIMENTS TO SHOW THAT BOTH WATER AND AIR ARE NECESSARY CONDITIONS FOR RUSTING OF IRON:



- The water in **P** is boiled then cooled to remove air.
- Wax or paraffin or Rubber bung prevents air from entering into the test-tube.
- Calcium chloride in **Q** absorbs the moisture or dries the air while the rubber bung prevents moisture from entering into the test tube.
- In the test-tube**R**, both water and air are present.

Results:

- In test tube P, no rusting takes place because there is no air.
- In test-tube Q, no rusting takes place because there is no water.
- In test tube R, rusting takes place since both air and water are present.

SOME WAYS OF PREVENTING CORROSION (RUSTING):

1. ***PAINTING***

   o It prevents water from entering and since both water and air must be present for corrosion to occur. No corrosion takes place.

2. ***OILING/GREASING***

   It prevents water from entering inside.

3. ***GALVANISING***.
   - It is the covering of iron by a thin layer of zinc metal using the process of electrolysis. Zinc only tarnishes and does not corrode all the way through. Galvanizing prevents water and air from entering the iron.
   - When part of zinc is damaged the iron gets exposed to moist air and rusting begins. But since zinc is more reactive than iron, it forces the iron to accept electrons there by reversing the process of rusting.

4. ***CHROMIUM COATING***.

   It is the coating of iron with a chromium metal.

5. ***TIN-PLATING***

- It is the covering of a metal such as iron by thin layer of tin using electrolysis.
- Tin only tarnishes and does not get attracted by acids.

6. ***CEMENT COATING***
7. ***PLASTIC COVERING***
8. ***SACRIFICIAL PROTECTION***

➢ This is a process of using a valuable metal to protect iron from rusting. It is largely done in ships where by magnesium pates are used to protect rusting. These plates are replaced over when they are completely corroded.

ELECTROLYSIS:

➢ **Electrolysis** is a process of decomposing an electrolyte by passing an electric current.

➢ **An electrolyte** is any substance that conducts electric current in aqueous or molten (fused) form.

➢ Examples of electrolyte include sulfuric acid, hydrochloric acids, sodium chloride solution etc.

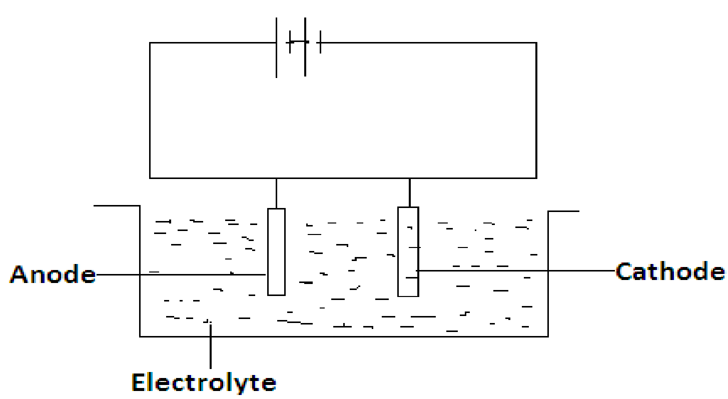
➢ For a substance to conduct electricity it must have free ions (mobile ions).

➢ **Cathode** is the negative electrode since it is connected to the negative terminal of a cell or battery.

➢ **Cations** (positive ions) are attracted to the cathode where reduction takes place.

➢ **Anode** is the positive electrode since it is connected to the positive side of the cell or battery.

➢ **Anions** (negative ions) are attracted to the anode where oxidation takes place.Below is the apparatus of electrolysis:



SOME USES OF ELECTROLYSIS:

➢ Production of gases e.g.: O_2, H_2, Cl_2 etc.

➢ Production of acids like H_2SO_4.

➢ Production of bases e.g. Sodium hydroxide NaOH.

➢ Extraction of metals e.g. Alkali metals (Li, Na, K,) Al, Cu etc.

➢ Purification of metals like copper

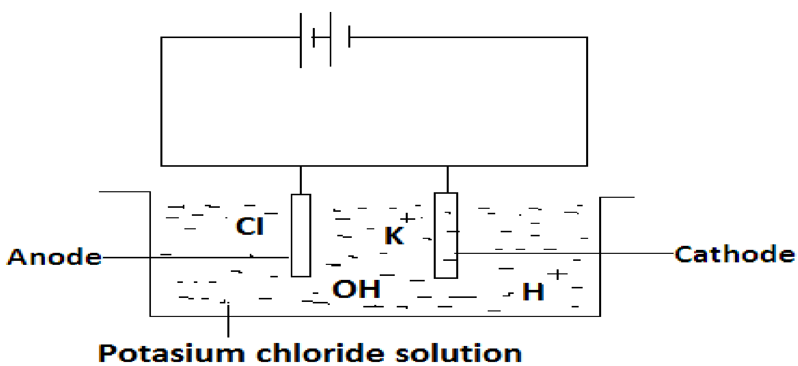
➢ Electroplating e.g. galvanization. (Rust prevention by use of zinc).

RULES OF DETERMINING OF WHAT GETS DISCHARGED AT THE ELECTRODES.

1. **AT THE CATHODE:**
    - The more reactive an element is, the more it likes to remain in the solution. Ions of a **less** reactive element are therefore **preferentially** discharged at the cathode.
2. **AT THE ANODE:**
    - If the ions of a halogen (like F^-, Cl^-) are present in the electrolyte they get discharged preferentially.
    - If no halogen ions are present **hydroxyl ions** (OH^-) are discharged instead resulting into formation of oxygen and water according to half equation below:
    $4OH^-(aq) - 4e \longrightarrow 2H_2O(l) + O_2(g)$.

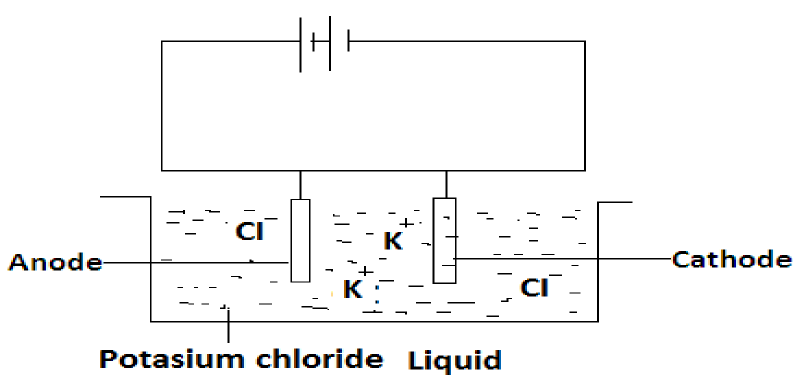
Examples.

1. **Electrolysis of potassium chloride solution (Maneb 1994).**



- At the cathode, hydrogen ions , H^+ get preferentially discharged resulting in the formation of hydrogen gas according to the half equation:
$2H^+(aq) + 2e \longrightarrow H_2(g)$.
- At the anode, chloride ions, Cl^- gets discharged preferentially resulting into the production of chlorine gas according to the half equation below:
$2Cl^-(aq) - 2e \longrightarrow Cl_2(g)$.
- **Overall effect** is that the solution becomes **basic** due to production of potassium hydroxide.

2. **Electrolysis of molten (fused) potassium chloride (Maneb 1998).**



- At the cathode, potassium ions, K^+ gets discharged preferentially resulting into production of potassium atoms which coat the cathode according to the half equation below:

  $K^+(l) + e \longrightarrow K(s)$.
- At the anode, chloride ions gets discharged there by forming chlorine gas according to the half equation below:

  $2Cl^-(l) - 2e \longrightarrow Cl_2(g)$.
- **Overall effect** is that the solution decreases until is all used up.

3. **Electrolysis of dilute sulfuric acid or acidified water (Maneb 2003 PII).**
   - At the cathode, hydrogen ions, H^+ gets discharged there by forming hydrogen gas according to the following equation:

     $2H^+(aq) + 2e \longrightarrow H_2(g)$ **……………………..1**
   - At the anode, hydroxyl ions, OH^- get preferentially discharged resulting into the production of oxygen and water according to the half equation:

   $4OH^-(aq) - 4e \longrightarrow 2H_2O(l) + O_2(g)$ **…………………2**
   - The overall effect is that the solution becomes more concentrated due to the decomposition of water molecules into hydrogen and oxygen gas.
   - The overall ionic equation would be as follows: first multiply the equation 1 by 2 to get

$4H^+(aq) + 4e \longrightarrow 2H_2(g)$. Then add the two equations 1 and 2.The result is:
$4H^+(aq) + 4e + 4OH^-(aq) - 4e \longrightarrow 2H_2(g) + 2H_2O(l) + O_2(g)$. The net is:
$2H_2O(l) \longrightarrow 2H_2(g) + O_2(g)$.

4. **Electrolysis of copper sulphate solution using carbon electrodes.**
   - At the cathode, copper ions (Cu^{2+}) will be discharged preferentially there by forming copper atoms which coat on the cathode according to the half-equation:

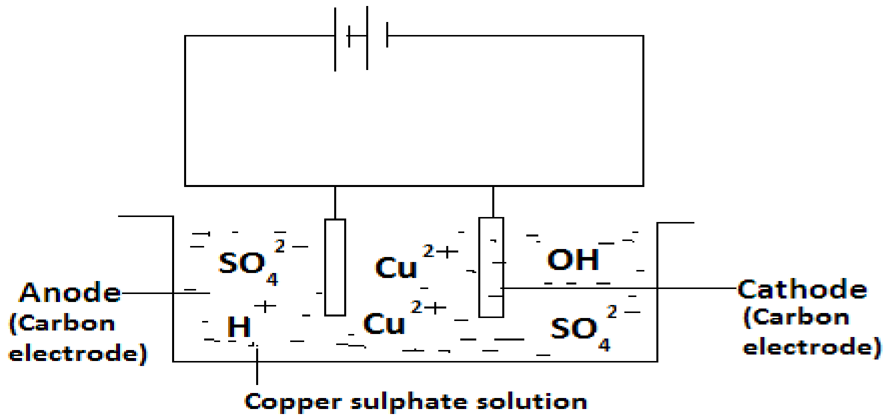
     $Cu^{2+}(aq) + 2e \longrightarrow Cu(s)$.
   - At the anode hydroxyl ions get discharged preferentially there by producing oxygen and water according to the half-equation;

     $4OH^-(aq) - 4e \longrightarrow 2H_2O(l) + O_2(g)$
   - The overall effect is that the blue color of copper sulfate solution becomes pale due to decrease in copper ions in the solution.
   - The solution becomes acidic due to the formation of sulfuric acid.
   - The cathode becomes thicker due to copper atom deposits on it.
5. **Electrolysis of copper sulphate solution using copper electrodes.**
   - At the cathode, copper ions (Cu^{2+}) will be discharged preferentially there by forming copper atoms which coat on the cathode according to the half-equation:

     $Cu^{2+}(aq) + 2e \longrightarrow Cu(s)$..

- The anode dissolves there by releasing copper ions which go to the cathode via the solution. The half equation is :

  $Cu(s) - 2e \longrightarrow Cu^{2+}(aq)$



- The resultant effect is that the blue color of copper sulfate solution remains the same for some time due to continuous supply of copper ions from the dissolving anode.
- The cathode becomes thicker due to copper atoms on it.
- The anode decrease in size due to the formation of copper ions from copper atoms.

ELECTROPLATING

- It is the covering of objects with a thin layer of a metal using electrolysis.

CONDITIONS FOR ELECTROPLATING

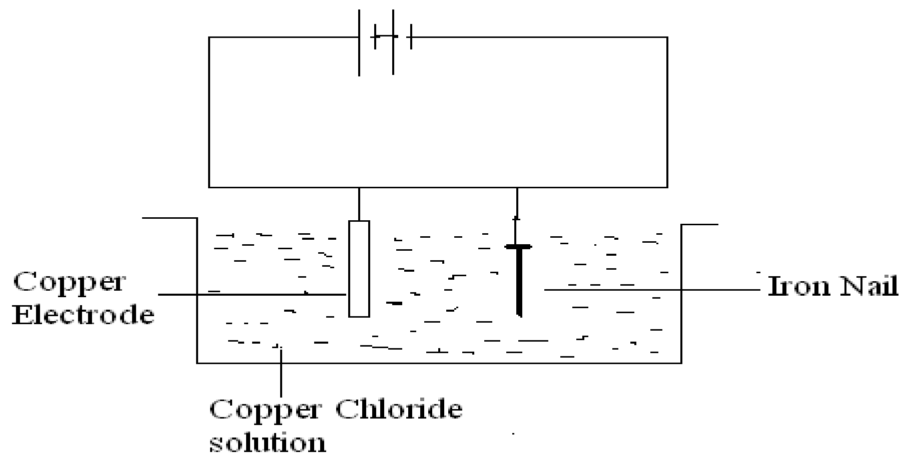
1. The metal to be electroplated becomes the cathode.
2. The covering metal becomes the anode.
3. The electrolyte should be a soluble salt of the metal that makes up the anode.

Example:

a) Draw a well labeled apparatus that would be used to electroplate an iron nail with copper chloride as an electrolyte.
b) Explain what happens during the process of electroplating by the nail. Support the explanation with relevant chemical equations.

Solution:

a)



b) At the cathode, (iron nail) copper ions get discharged preferentially there by forming copper atoms which coat on the nail. The half equation at the cathode is as follows:
$Cu^{2+}(aq) + 2e \longrightarrow Cu(s)$.

c) The anode dissolves there by releasing copper ions into the solution which go to the cathode when they get reduced to form copper atoms. The half equation is as follows:

$Cu(s) - 2e \longrightarrow Cu^{2+}(aq)$. (2005 Maneb P1 #7)

SOME USES OF ELECTROPLATING:

- Corrosion is prevented e.g. tin-plating, galvanization,
- Appearance is improved.
- Worn out machinery is replenished.
- A hard layer is introduced that reduces wear and tear.

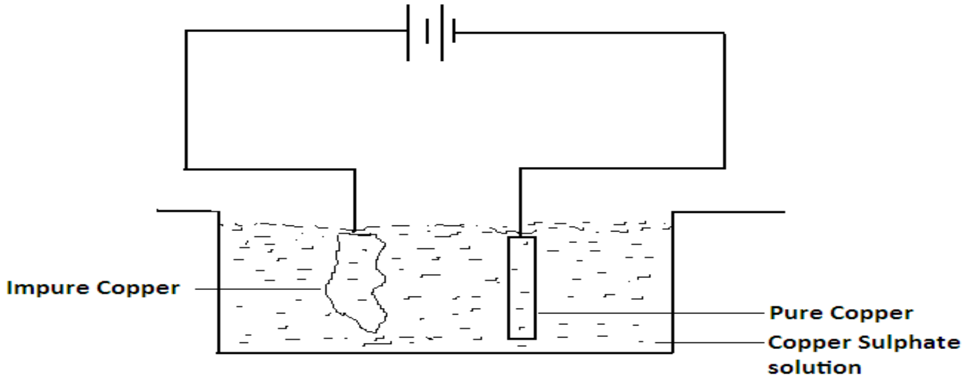
PURIFICATION OF METALS:

Conditions of purification of metals are:

1. The pure metal becomes the cathode.
2. The impure metal becomes the anode.
3. The electrolyte should be soluble salt of the metal being purified.

Example: (Maneb 2009 PII #4)

With the aid of a clearly labeled diagram, describe how impure copper could be purified by electrolysis. The description should include relevant chemical equations.



- At the cathode copper ions get discharged preferentially thereby forming copper atoms which coat on the pure copper. The half equation is as follows:
  $Cu^{2+}(aq) + 2e \longrightarrow Cu(s)$.
- The anode dissolves there by releasing copper ions into the solutions which go to the cathode where they get reduced to form copper atoms. The half equation is:
  $Cu(s) - 2e \longrightarrow Cu^{2+}(aq)$.
- As the process progresses, the cathode becomes thicker due to the copper deposits on it.
- Deposits of impurities are observed just below the anode.

ACIDS AND BASES. (PROTON-TRANSFER REACTIONS.):

- A proton is a hydrogen ion, H^+. This is the ion that is responsible for the acidic properties of a substance.
- An acid is a substance that is capable of donating protons. It is a proton donor. This is according to Lowry-Bronsted theory. Examples of acids include HCl, H_2SO_4, HNO_3 etc.
- A base is a substance that is capable of accepting protons. I.e. proton acceptor. E.g. NH_3, NaOH, CuO etc.
- The acid (according to Arrhenius) is also defined as a substance that ionizes in water to release protons while a base is a substance that ionizes in water to accept protons.

PROPERTIES OF ACIDS

I. They have a sour taste.
II. They conduct electricity.
III. They have a pH less than 7. pH is the power of hydrogen ion concentration.
IV. They facilitate rusting.
V. They react with metals to produce salt and hydrogen gas. A salt is an ionic compound whose cation is a metal and the anion is a non-metal except (OH^-)and oxide, O^{2-}.
e.g. $2HC(aq) + Zn \longrightarrow ZnCl_2(s) + H_2(g)$
VI. They react with bases to produce salt and water in what is called neutralization process.

$$H_2SO_4 + NaOH \longrightarrow Na_2SO_4 + H_2O$$

VII. They react with carbonates and hydrogen to produce salts, carbon dioxide and water.
E.g. $CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO_2 + H_2O$

PROPERTIES OF BASES

I. They have a pH more than 7.
II. They have a bitter taste.
III. They have a soppy feel.
IV. They facilitate rusting.
V. They conduct electricity.
VI. They neutralize acids.

Examples include, NaOH, KOH, CuO etc.

CONJUGATE BASES

- It is the species that is formed after a proton; H^+ has been removed from an acid.

Examples:

ACID	CONJUGATE BASE
HCl	Cl^-
H_2SO_4	HSO_4^-
HSO_4^-	SO_4^{2-}
NH_4^+	NH_3
H_2O	OH^-

CONJUGATE ACID

- It is the species that is formed after a proton has been added to a base.

BASE	CONJUGATE ACID
OH^-	H_2O
H_2O	H_3O^+
NH_2^-	NH_3
NH_3	NH_4^+
HCO_3^-	H_2CO_3
$H_2PO_4^-$	H_3PO_4
HCl	H_2Cl^+

REVERSIBLE REACTIONS

- A reversible reaction is a reaction that goes in either direction.
- Once enough products are formed they start to react there by reversing the forward reaction. The symbol for a reversible reaction is $\longleftrightarrow$.

- When the rate of forward reaction equals the rate of backward reaction, an equilibrium point is reached and it is symbolized by $\longleftrightarrow$.

AMPHOTERIC SUBSTANCE

- This is a substance that can act as an acid in one reaction and as a base in another reaction. Water is a classic example.
- Water as a base:

  $CH_3COOH(aq) + H_2O \longleftrightarrow CH_3COO^- + H_3O^+$.

- Water as an acid:

$H_2O(l) + NH_3 \longleftrightarrow HO^-(aq) + NH_4{}^+$

HYDROXYL(OH^- **) AND HYDRONIUM ,** H_3O^+

- ✓ A hydroxyl ion is usually formed when water undergoes auto-ionization (self-ionization) or when it acts as an acid by donating a proton.
- ✓ It is also an anion.
- ✓ eg: $H_2O(l) \longleftrightarrow HO^-(aq) + H^+$

  $H_2O(l) + NH_3 \longleftrightarrow HO^-(aq) + NH_4{}^+$.

- ✓ A hydronium ion is a cation which is usually formed when water acts as a base by accepting protons.

  $HCl + H_2O(l) \longrightarrow H_3O^+(aq) + Cl^-$

STRONG AND WEAK ACIDS

- ✓ A strong acid is the acid that ionizes fully in water there by releasing more protons.
- ✓ A strong acid is also a strong electrolyte. I.e. it allows large amount of electric current to pass through. E.g. HCl, H_2SO_4, HNO_3 etc.
- ✓ A weak acid is an acid that ionizes partially in water there by releasing a few protons.
- ✓ A weak acid is also a weak electrolyte. e.g. H_2CO_3, CH_3COOH, citric acid etc.

STRONG AND WEAK BASES

- ✓ A strong base is the base that ionizes fully in water there by accepting more protons.
- ✓ A strong base is also a strong electrolyte e.g. NH_3, NaOH, KOH e.t.c.
- ✓ A weak base is a base that ionizes slightly in water.
- ✓ A weak base is also a weak electrolyte e.g. Amino methane (CH_3NH_2), CuO, $Zn(OH)_2$

STRENGTH OF ACIDS AND BASES

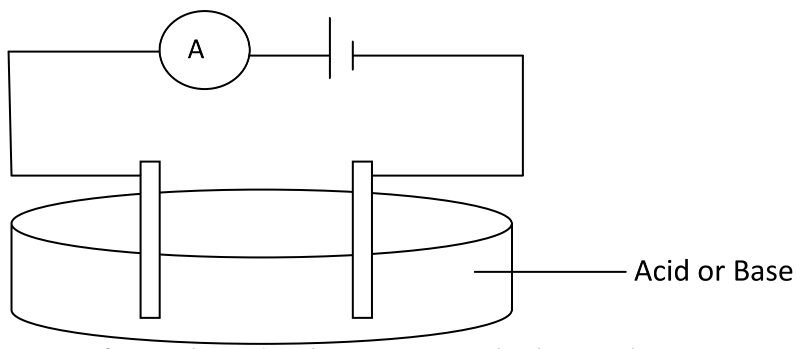
- This can be determined by using any of the following:
  1. Conductivity test
  2. Universal indicator
  3. PH meter.

1. **CONDUCTIVITY TEST**.

- The two acids / bases being tested must have same:

- Concentration
- Temperature
- Volume
- Electrode spacing
- Electrode depth
- Voltage supply

The apparatus below is used:



-Record the current for each acid or base in turn. The larger the current reading, the stronger the acid or base

2. UNIVERSAL INDICATOR.

- Pour equal amount of each acid / base into two separate test tubes.
- Add equal drops of universal indicator of the two acids / base and shake gently.
- Observe the color change and match with those that are found on the pH scale in order to determine which acid or base is stronger than the other.

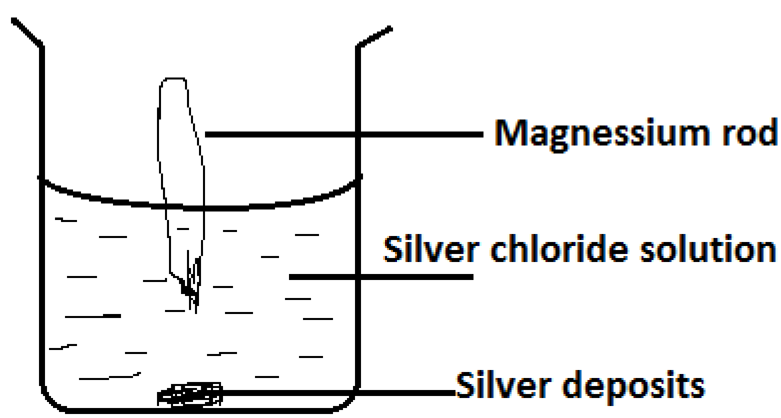
3. PH METER.

- This is more accurate and quickest way of determining strength of an acid or base.

HOW THE TOPIC HAS BEEN FEATURED IN THE LAST 4 YEARS OF MANEB EXAMINATIONS (Find some suggested answers in italics).

2015 8a

Figure below shows the reaction between magnesium (Mg) and silver chloride solution (AgCl)



i. **Explain the reaction in figure above**

<u>Answer: Magnesium, being more reactive than silver, will donate electrons to silver hence silver will be displaced instead magnesium chloride will be formed</u>

ii. Write a chemical equation for the reaction

$$Mg(s)+2AgCl(aq)\longrightarrow MgCl_2(aq)+2Ag(s)$$

5d.(i) Which metal is used to galvanize iron? ***<u>Answer Zinc</u>***

(ii) Explain how a scratched galvanized iron sheet is protected from rusting.

<u>Answer: When Iron gets oxidized (iron atoms turn into iron ions, the Zinc gets oxidized too. Since Zinc is more reactive than iron it donates electrons to iron making it reduced (reversing rusting)</u>

2014 No 3

d.

(i) What is a "weak acid"?

This is an acid that ionizes in water partially there by donating a few protons

(ii) State any one way of determining the strength of an acid

- ***By conductivity test, By use of universal indicator, By use of a pH meter***

(iii) The conjugate acid-base pair for the reaction between water molecules are H_2O/H_3O^+ ***and*** H_2O/OH^- write an equation for the reaction

$$H_2O_{(l)}+H_2O_{(l)}\leftrightarrow H_3O^+{}_{(aq)}+OH^-(aq)$$

2013 **No 3**

(i) State any two ways of preventing rusting

- ***By painting, Plasticcovering, Sacrificialprotection, Oiling/greasing, electroplating***

(ii) Explain how rusting occurs

Rusting occurs when iron gets oxidized while oxygen gets reduced in the presence of water. The iron reacts with water and oxygen to form hydrated iron oxide.

2012 5

b. Define "electroplating" ***This is covering a metal with a thin layer of another metal***

c. Iron (Fe) displaces copper (Cu) from copper sulphate solution ($CuSO_4$).

i. Write down a balanced chemical equation for the reaction

$$Fe(s)+CuSO_4(aq)\longrightarrow FeSO_4(aq)+Cu(s)$$

ii. What is the reducing agent in the reaction above? ***Iron, Fe***

iii. Give a reason for your answer. ***Its oxidation has increased from 0 to +2. It means it has donated 2electrons to copper.***

d. What is the deference between "oxidation" and "reduction"? ***Oxidation is the increase in oxidation number or gain in oxygen atoms or loss of electrons while reduction is decrease in oxidation number, loss of oxygen atoms or gain of electrons***

e. (i) Define "concentration" of a solution**. *It is the amount of solute per unit volume of solvent***

(ii) The volume of sodium hydroxide solution, NaOH of concentration 20g/l is increased from 60cm^3 to 600cm^3 by adding distilled water. Calculate the concentration of the new solution in g/l

$$C_1V_1 = C_2V_2 \Rightarrow C_2 = \frac{C_1V_1}{V_2} = \frac{20x60}{600} g/l = 2g/l$$

5. FORCES AND MOTION

OBJECTIVES:

By the end of this chapter learners should be able to:

- Differentiate between a scalar and a vector.
- Add vectors.
- Resolve vectors components.
- Distinguish between distance and displacement.
- Differentiate between speed and velocity.
- Define acceleration.
- Analyze Velocity-Time graph.
- State the Newton's Laws of Motion.
- Discuss the application of the Laws of motion.
- Describe the relation between the mass and stretching force.

FORCE:

- Force is pull or a push.
- SI unit of force is Newton, (N).
- Force cannot be seen but its effects can be observed. Thus force is capable of:
  - Increasing speed of an object (acceleration).
  - Decreasing speed of an object (deceleration).
  - Cause a change in direction.
  - Cause a change in shape (deformation).

- Making an object at rest to start moving.
- Making a moving object to come to a halt.
- Causing heat production.
- Causing sound production.

❖ Force is an example of a **vector quantity**. A vector quantity is the one that has both magnitude (size) and direction. Other examples of vectors include; displacement, velocity, acceleration, momentum, etc.

❖ Other quantities are called **scalar.** A scalar is any quantity with magnitude only but no direction. Examples are: mass, speed, distance, height, volume etc.

Vector Representation:

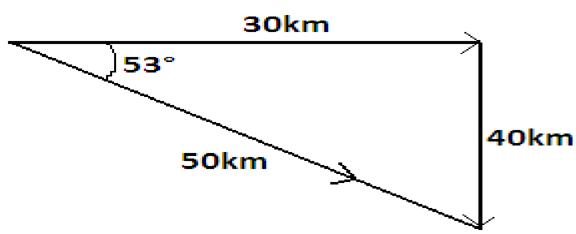
- A vector mathematically is a line segment.
- It is represented by a straight line with direction.
- The length of the line represents magnitude while the arrow gives direction.
- To specify a vector, the three terms, value (size), unit and direction must be given.Eg

A 50N B

This is a vector AB whose magnitude is 50N. It is different from BA.

Vector Addition:

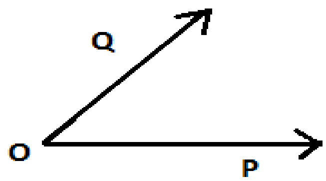
- **V**ectors are added geometrically by either parallelogram rule or triangular rule which ensures that the direction as well as their magnitude is considered.
- A **resultant vector** is the single vector that represents two or more vectors acting at particular point.
- For example a displacement of 30km eastward followed by a displacement of 40km south wards produces a resultant displacement of 50km in the direction 53° south of East.

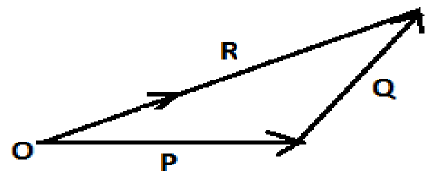


- The above result has been obtained by using Pythagoras theorem and trigonometry (for the angle).
- Note that the tail of one vector is joined to the top of the other vectors to ensure that original vectors point in the same direction round triangle.

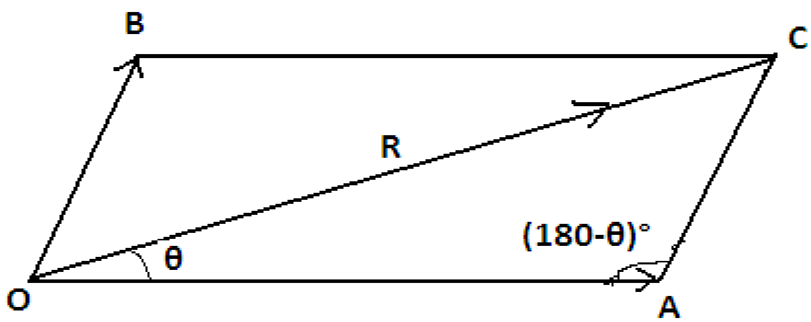
PARALLELOGRAM RULE:

- **C**onsider two forces **P** and **Q** acting at a point O. The resultant will be vector R.

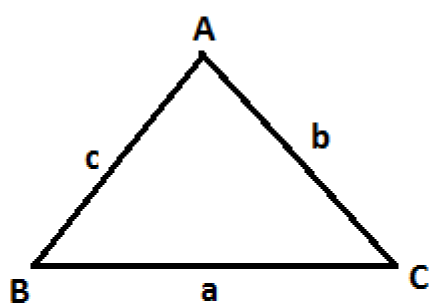




- R is a diagonal of the parallelogram of which P and Q are two sides. This is the parallelogram rule.
- The parallelogram rule states that if two vectors, **OA** and**OB** are represented in magnitude and direction by sides $\overrightarrow{OA}$ and $\overrightarrow{OB}$ of a parallelogram OACB then**OC** represents the resultant



- **S**ometimes the calculation of the resultant vector usually requires the use of the cosine rule as well as the sine rule for a triangle like:



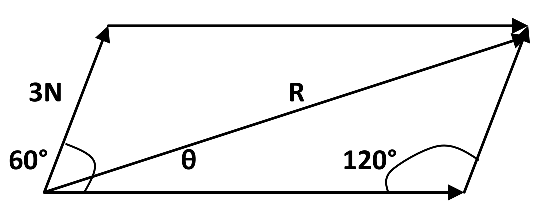
Cosine rule: $a^2 = b^2 + c^2 - 2bc.CosA$

Sine rule: $\frac{a}{SinA} = \frac{b}{SinB} = \frac{c}{SinC}$

Example:

A force of 3N acts at 60° to a force of 5N. Find the magnitude and the direction of their resultant.

B **C**



O 5N A

$$R^2 = 3^2 + 5^2 - 2x3x5.Cos120^0 = 49N^2 \Rightarrow R = 7N$$

Applying Sine rule $\frac{R}{Sin120^0} = \frac{3}{Sin\theta} \Rightarrow Sin\theta = \frac{3Sin120^0}{R} = \frac{3Sine120}{7} = 0.3712$

$$\therefore \theta = Sin^{-1}(0.3712) \Rightarrow \theta = 21.8^0$$

The resultant therefore is a force of 7N acting at 21.8° to the 5N force.

QUESTIONS:

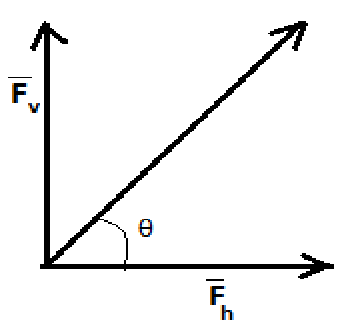
1. Find the magnitude and the direction of the resultant of each of the following pairs of vectors.

   a. 7N at 90° to 24N
   b. 60m East and 40 m West.
   c. 20N at 60° to 30N
   d. 40m/s West plus 40m/s East.
   e. 40N at 110^0 to 50N.
   f. 40m/s west and 40m/s east.
   g. 60N at 150^0 to 30N.

2. Find the resultant of a displacement of 30m due east followed by a displacement of 70m due south?

COMPONENTS OF VECTORS:

-In some circumstances it is useful to split vector up into two parts labeled components of a vector.
-Just as two vectors may be added to form a single resultant, a single vector may be resolved (split) into two components at right angles to each other.
-Very often two components are taken horizontally and vertically in which the two parts are called horizontal component of the vector and the vertical component of the vector respectively.
-In figure below force, F is resolved into two components, F_h is the horizontal component and F_v I s the vertical component.



- The magnitude of the two components are given by the following:

$$\overrightarrow{F_h} = FCos\theta$$

$$\overrightarrow{F_v} = FSin\theta$$

- Example: Calculate the horizontal and vertical components of a force of 30N acting at 30^0 to the horizontal component.

  $$\overrightarrow{F_h} = 30NCos30^0 = 25.98N$$

  $$\overrightarrow{F_h} = 30NxSin30^0 = 15N$$

DISTANCE AND DISPLACEMENT:

DISPLACEMENT:

- It is the distance moved in a certain direction. It is a vector.
- The magnitude of displacement is equal to the distance. This is true for linear motion.
- The SI unit of displacement is meters, m.

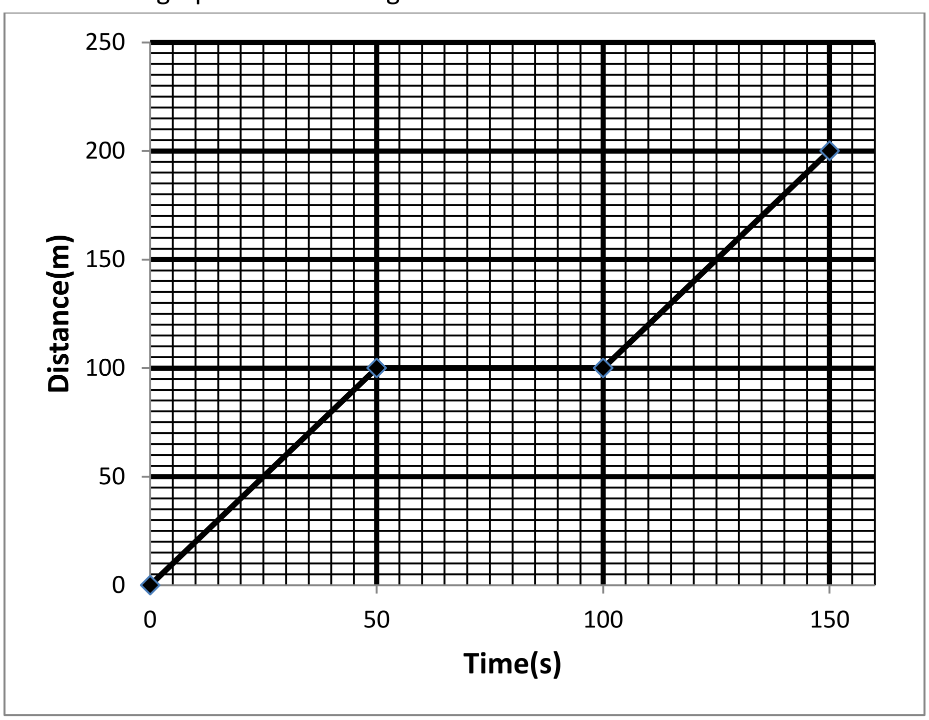
DISPLACEMENT-TIME GRAPH:

- The slope (gradient) yields velocity.
- The average velocity is found by dividing the total displacement by the total time.

DISTANCE-TIME GRAPH:

- The slope gives speed.
- Average speed is obtained by dividing the total distance by the total time.
- Horizontal line means no motion. I.e. the body is stationary.

  Below is the graph of Distance against time.



Calculate

a. Speed in the first 50 seconds

Answer: speed= slope $s = \frac{y_2 - y_1}{x_2 - x_1} = \frac{100m - 0}{50 - 0} = 2m/s$

b. How long did the body stop? Answer (100-50)s = 50 seconds

c. The average speed

Average speed = total distance/ total time hence $s = \frac{200m}{150s} = 1.33m/s$

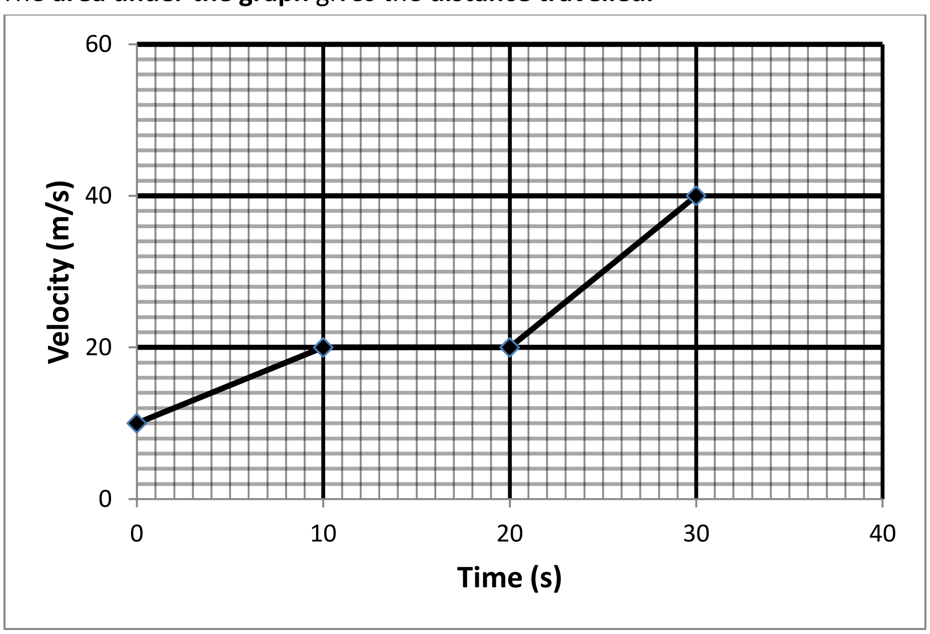
SPEED, VELOCITY &ACCELERATION:

- **Speed** is defined as the rate of change of distance. (Distance per unit time.)
- **Velocity** is the rate of change of displacement. I.e. displacement per unit time.
- Velocity is a vector quantity while the speed is a scalar.
- **Acceleration** is the rate of change of velocity. It is a vector. It is given in m/s^2.
- **The acceleration** can be positive or negative. The negative acceleration also known as deceleration or retardation.
- Mathematically acceleration= (final velocity- initial velocity)/time taken.
- Let a, be the acceleration, v, final velocity, u, initial velocity and t, time taken. We have:

$$a = \frac{v - u}{t}$$

VELOCITY-TIME GRAPH:

- In this part, we use velocity and speed interchangeably. The same case with distance displacement.
- The slope of this graph gives acceleration.
- Negative slope implies deceleration.
- Horizontal line means constant velocity (constant speed). The particle is not changing in its speed. Its acceleration is zero.
- The **area under the graph** gives the **distance travelled.**



Work out

a. acceleration in the first 10 seconds

Answer: acceleration = slope therefore $a = \frac{y_2 - y_1}{x_2 - x_1} = \frac{20m/s - 10m/s}{10s - 0} = 1m/s^2$

b. Total distance traveled.

Answer: Consider area under the graph.

$$A = \frac{1}{2}(10m/s + 20m/s)10s + 20m/sx10s + \frac{1}{2}(20m/s + 40m/s)10s = 650m$$

c. Acceleration in the last 20 seconds

$$a = \frac{y_2 - y_1}{x_2 - x_1} = \frac{40m/s - 20m/s}{30s - 20s} = 2m/s^2$$

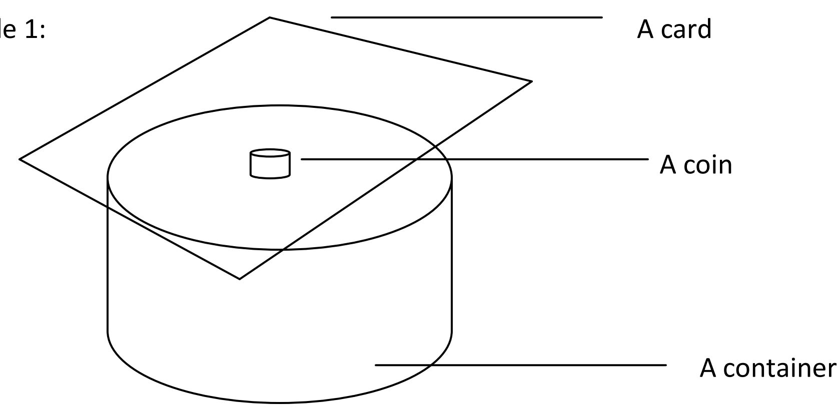
NEWTON'S LAWS OF MOTION:

- These are laws on which science of mechanics is based.
- Inertia is defined as the resistance of a body to start moving or to stop moving once it has started. Or resistance to change in velocity.
- A body of large mass requires a large force to change its speed and direction by a noticeable amount.
- Mass is the quantity of matter in an object. Its SI unit is kilogram, Kg.
- Weight is the force acting on an object because of its attraction towards the earth. I.e. force of gravity.

NEWTON'S FIRST LAW OF MOTION:

- It states that" Everybody continues in its states of rest or of uniform motion in a straight line unless it is acted upon by some external unbalanced forces.
- The law is another way of saying that all matter has a built in opposition to being moved if it is at rest or being stopped if it were in motion.

Example 1:



- If the card is flicked sharply the coin stays where it is and falls onto the container while the card flies off.

Example 2:

- Occupants of a car which stops suddenly. They jerk forward in an attempt to continue moving. This is why seat belts are vital.
- If a moving body speeds up or slows down or simply changes direction then we know that some unbalanced forces must be acting on the body.
- Force always produces acceleration of a body.

MOMENTUM:

- It is the product of mass and its velocity.
- Thus momentum = mass x velocity.
- The SI unit of momentum is the Kg m/s.
- When the resultant external force acting on a system is zero the total momentum of the system remains constant.
- External force = rate of change of momentum= $\frac{mv-mu}{t}=\frac{m(v-u)}{t}=ma$
- It means F = ma where m is the mass in Kg
  u is the initial velocity
  v is the final velocity
  t is the time

THE NEWTON'S SECOND LAW:

- It states that the rate of change of momentum of a body is directly proportional to the external force acting on the body.
- Consider a body of constant mass m being pushed by a constant force, F and its velocity increases from u to v in time t. By Newton's second law we have
  Change in momentum/time α Force.
  F α ma where a is the acceleration due to the applied force.
- As an equation it becomes F = kxmxa where k is a constant which has no unit. The SI unit of force (Newton) is defined in such a way that k = 1 provided the rate of change of momentum is also expressed in the relevant SI unit (kg m/s). Force is therefore given by

$$F = ma$$

Examples:

1. A body originally at rest attains a velocity of 30m/s in 6 seconds of its motion. Calculate its acceleration. If the body weighs 60kg what will be the value of the force that brings the acceleration?
   Solution:
   u= 0 m/s, v = 30 m/s , m = 60kg, t =6seconds.

$$a=\frac{v-u}{t}=\frac{30m/s-0m/s}{6s}=5m/s^2$$

$$F = ma = 60kgx5m/s^2 = 300N$$

2. A 200kg car changes its speed from 15m/s to 45 m/s in 10 seconds. Work out the force that cause the car's acceleration. m = 200kg, u =15m/s, v =45m/s an t = 10 seconds.

$$a = \frac{v-u}{t} = \frac{45m/s - 15m/s}{10s} = 3m/s^2$$

$$F = ma = 200kgx3m/s^2 = 600N$$

NEWTON'S THIRD LAW OF MOTION:

- It states that if a body A exerts a force on body B then B exerts equal but opposite force on A. In other words it states that for every action there is a reaction.
  Examples of cases where the third law is demonstrated:

1. Jumping from a canoe; one exerts a force on it and in return the canoe pushes the individual away.
2. Walking; your feet pushes the ground backward and in return the ground pushes you forward. The same applies to acceleration of cars due its tyres pushing the ground backward.
3. A balloon rocket; it moves forward as a result of the push exerted on it by the exhaust gases which the rocket has pushed out.

Conservation of Momentum:

- It state that momentum before collision is equal to momentum after collision.
- It is a direct consequence of the Newton's third law of motion.

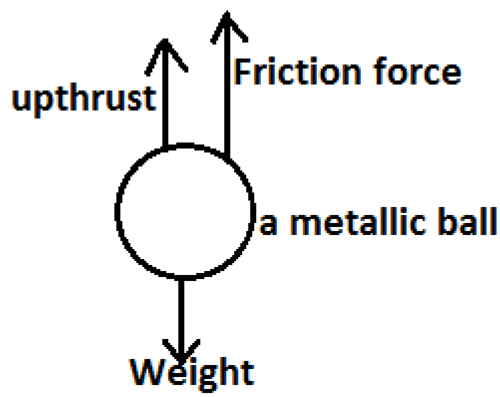
Examples:

1. A 60 kg body travels at speed of 5m/s and it hits a stationary body of mass 40kg, they coalesce and move together. Find the common speed.
   Solution: mass= 60kg, we shall P to denote momentum.
   $P = mv$. Total momentum before collision is
   $P = mv = 60kgx5m/s + 40kgx0m/s = 300kgm/s$. Momentum after collision is
   $P = mv = (60kg + 40kg)v = 100kgv$. Since momentum before collision = momentum after collision hence $100kgv = 300kgm/s \Rightarrow v = \frac{300kgm/s}{100kg} = 3m/s$
2. A 40 kg body moving at speed of 15m/s hits an 80kg body moving at 5m/s. If they coalesce and move together. Find the common speed.
   Solution:
   $P = mv$. Total momentum before collision is
   $P = mv = 40kgx15m/s + 80kgx5m/s = 1000kgm/s$. Momentum after collision is
   $P = mv = (40kg + 80kg)v = 120kgv$. Since momentum before collision = momentum after collision hence $120kgv = 1000kgm/s \Rightarrow v = \frac{1000kgm/s}{120kg} = 8.3m/s$

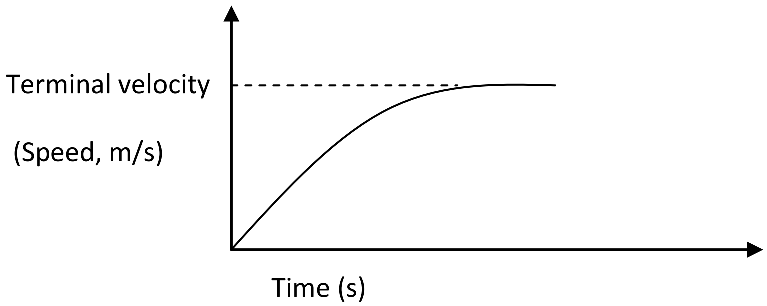
FREE FALL

- A body is said to be in free fall if the only force acting on it is the gravitational force. (Weight). Thus "free fall" is the kind of falling in which weight is the only force acting on the falling body.
- It then has an acceleration downwards relative to the surface of the earth of about 9.8 m/s^2 usually rounded to $10m/s^2$ and is denoted a letter g.
- The gravitational force (weight) is given by $F_w = mg$ where m is the mass and g is the acceleration due to gravity and is 10 m/s^2 in the case of free fall.
- It is $-10m/s^2$ if it is upward and $+10\ m/s^2$ if the motion is downwards.
- Consider a sphere falling from rest through a resistive medium e.g. a viscous fluid like oil, glycerin etc.

Sphere falling through a resistive medium



- The forces that are acting on the sphere are three namely
  1. Its **Weight (W)**
  2. The **up thrust** (U) due to the displaced fluid
  3. The **viscous drug (Frictional force).**
- Initially, the downward force W is much greater than the sum of the upward forces, U+F i.e. **W > U+F** and the sphere accelerates downwards. As the velocity v increases so too does the friction force and eventually U+F equals W. i.e. **W- (U+F) = 0.** The resultant force is zero.
- The sphere continues to move downwards but because there is now no net force acting on it, its velocity has a constant maximum value known as its **terminal velocity**.
- Terminal velocity is the maximum velocity of a freely falling body in a fluid when the opposing forces are equal in magnitude but opposite in direction.
- Acceleration of a falling object is not uniform, because the resultant force decreases as the velocity decreases.



- Heavy objects, whatever their size are only slightly affected by air resistance.
- Weight, W and Up thrust, U do not change during the falling. They remain constant. Friction force is the one that changes.
- Friction force depends on the following:
    a. **Size** of the object.
    b. **Speed** of the object in the medium
    c. **Viscosity** of the fluid.

Viscosity:

- It is the resistance of fluid to flow or how easily a fluid flows.
- Water is less viscous than cooking oil. It means a small metallic sphere will face less resistance when falling in water than in oil.

FACTORS WHICH AFFECT TERMINAL VELOCITY:

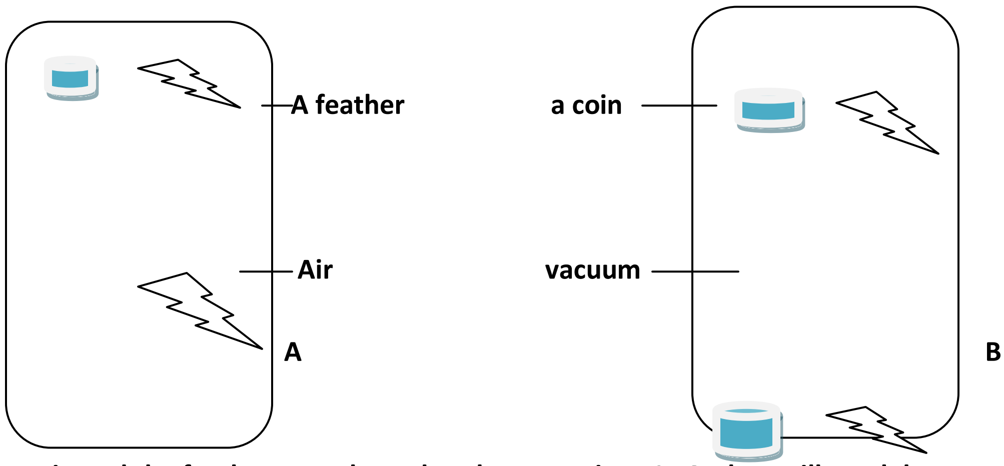
a) **Size of the object**:
    - A small and dense object such as steel ball-bearing has a high terminal velocity.

b) **Shape of the object:**
    - A light object e.g. a rain drop or materials with a large surface area like open parachute has a low terminal velocity and it only accelerates over a comparatively short distance before air resistance equals its weight.

c) **Viscosity of the fluid:**
    - The more viscous the fluid is the smaller the terminal velocity. A steel ball bearing will have a larger terminal velocity in water than in oil

Falling in Vacuum:

- In a vacuum, a falling body experiences only gravitational force hence it is under free fall. Its acceleration is due to gravity whose value is $10m/s^2$. If two or more objects of similar mass are released at the same time and from the same height then they will reach at the bottom at the same time. They will all be under the influence of gravitational force (weight).
- However, in air, the same objects will reach bottom at different times if their mass is the same but have different shapes. Shape has an effect on the terminal velocity. Consider the two diagrams below

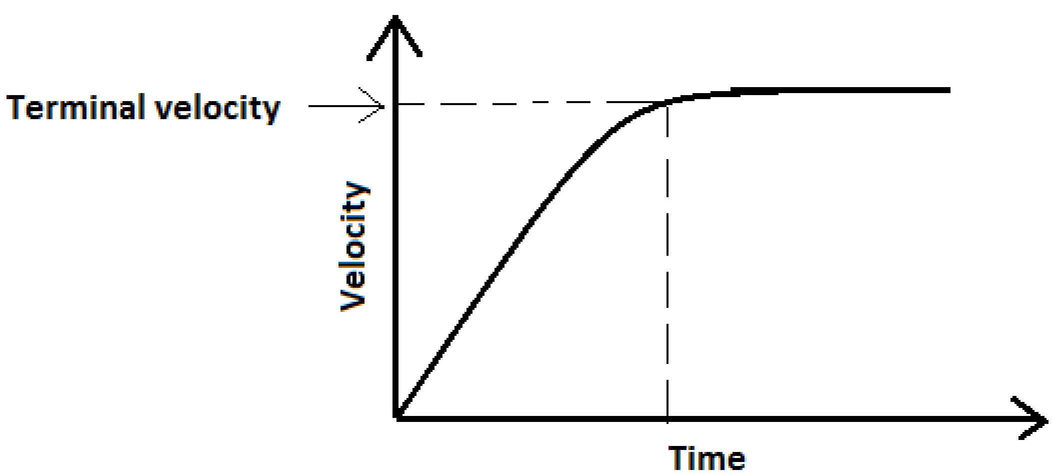


The coin and the feather are released at the same time. In A, they will reach bottom differently due to different levels of air resistance they experience. In B, the two will reach at the bottom at the same time since they will be under free-fall.

Falling of Parachute

A parachute achieves two terminal velocities as it falls down the air.

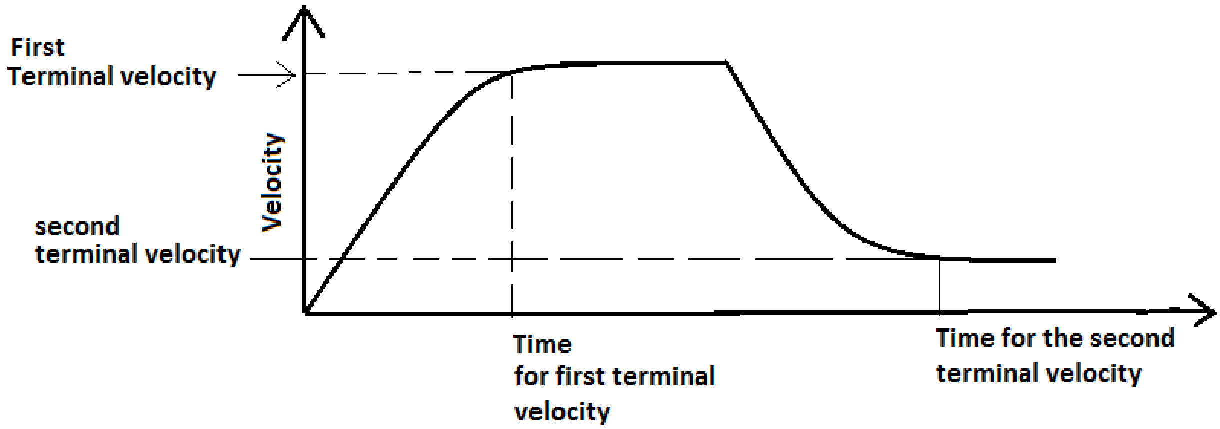
- When a skydiver is falling with parachute un-open, he accelerates because of the downward pull of gravity on him/her
- As the speed increases so too does the air resistance
- He/she reaches terminal velocity when the opposing forces become equal



With parachute open

- The opening of the parachute increases the surface area hence an increase in the air resistance. This results into slowing down of the parachute

- **As he slows down the air resistance becomes equal to weight, thus second terminal velocity is reached. This terminal velocity is lower than the previous one and is safe for landing**



FORCE AND MASS

Stretching Force:

- ✓ When a spring is stretched the difference between its stretched and un-stretched length is called the **extension.**
- ✓ In a spring stretching experiment, the spring is fixed on one end and stretched in stages by hanging more and more standard masses from the other end.
- ✓ The extension in each case in measured.
- ✓ When a graph of extension against stretching force is plotted it is found to be a straight line passing through the origin and is straight up to a certain point say, E.
- ✓ It can be concluded that over a certain section of the graph, the extension is directly proportional to the stretching force. This means that doubling the stretching force the extension also gets doubled. Mathematically:

$$F \alpha e \Rightarrow F = ke \Rightarrow K = F / e$$

Where F is the stretching force an e is the extension. K is the proportionality constant or the force constant.

Elasticity:

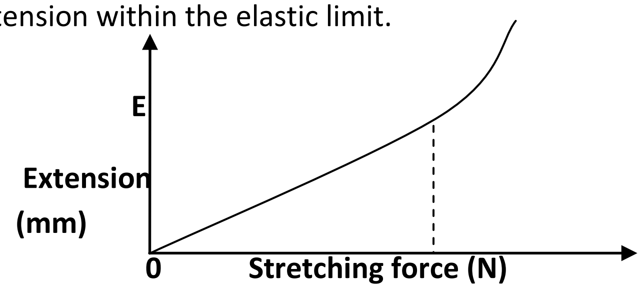
- This is the ability of a body to regain its original shape after being stretched.
- A material is elastic if it is able to regain its original shape after being deformed. e.g. a spring, rubber band

Elastic limit, E:

- This is a point which marks an important point in the behavior of a spring. Beyond E, the spring becomes permanently stretched.

Hooke's Law

- A material is said to obey Hook's law if its extension is directly proportional to the stretching force.
- Hooke's law states that the stretching force of a spring is directly proportional to the extension within the elastic limit.



Example:

- A spring is stretched 10mm by a weight of 2N. Calculate
  - **a.** The force constant, k of the spring
  - **b.** The weight W of an object which causes an extension of 80mm.

Solution:

a. $\Rightarrow K = F/e = 2N/10mm = 0.2N/mm$

b. $\Rightarrow F = ke = (0.2N/mm)x80mm = 16N$

HOW THE TOPIC HAS BEEN FEATURED IN THE LAST 4 YEARS OF MANEB EXAMINATIONS (Find some suggested answers in italics).

2015No 7

a. State the difference between 'distance' and 'displacement'

- ***Distance is a scalar while displacement is a vector quantity***
- ***Rate of change of distance gives speed while rate of change of displacement gives velocity***

b. State any two examples of vector quantities

Answer*: force, displacement, velocity, acceleration, momentum etc*

c. A 15Kg box is pulled horizontally with force of 90N. Calculate the acceleration of the box

Answer: $F = ma \Rightarrow 90N = 15Kg \times a \therefore a = \frac{90N}{15Kg} = 6m/s^2$

2014 4

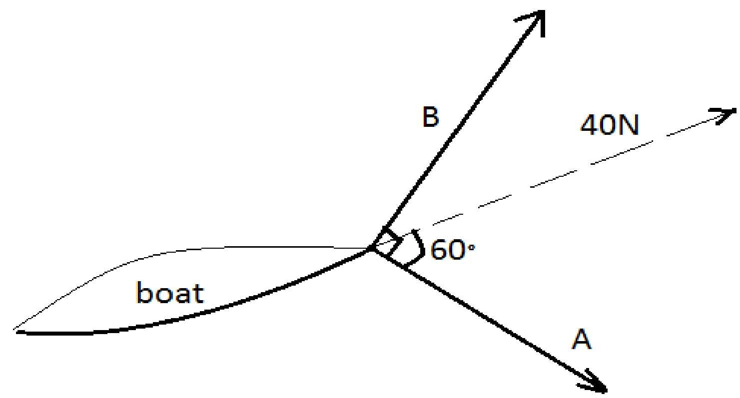
a. Name two forces that act against the motion of a stone thrown vertically into the air

Answer: ***Weight and frictional force***

b. State two ways of adding vectors

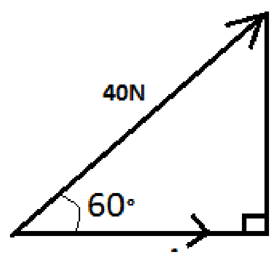
Answer: By triangular rule and by parallelogram rule

c. Figure below is a diagram showing a boat being pulled by two forces A and B at right angles to each other. A resultant force of 40N is produced at an angle of 60° to force A



Calculate the force A

Find the horizontal component $\cos 60° = \dfrac{A}{40N} \Rightarrow A = 40 \times \cos 60° = 20N$



2013

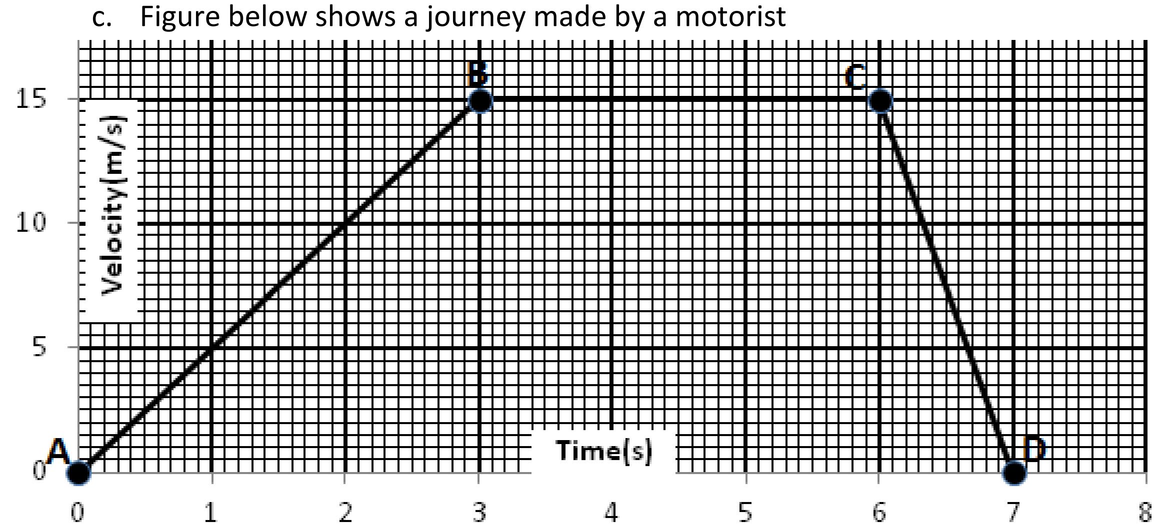
a. Define 'terminal velocity'

This is the maximum speed reached by a falling body when opposing forces are equal in magnitude but opposite in direction

b. Mention three factors that affect the terminal velocity of an object falling in a liquid

Viscosity of the liquid, Shape of the object/ surface area, Mass of the object

c. Figure below shows a journey made by a motorist



Calculate the distance covered by the motorist from A to C

Distance = Area under graph

$$D = A = \frac{1}{2}(3s + 6s)15m/s = 0.5 \times 9 \times 15 = 67.5m$$

2012 No 7

a. State the Newton's third law of motion

It states that if body A exerts force on body B, B will exert equal but opposite force on body A (i. e for every action force there is a reaction force)

b. Give two properties of vector quantities. ***Have magnitude and direction***

c. Mention one method of adding vectors acting at an angle to each other. ***By parallelogram vector law or by triangular vector rule.***

d. A car decelerates at a rate of $3m/s^2$ for 5 seconds. If the initial speed is 20m/s, calculate the final speed.

Deceleration = - acceleration.

$$a = \frac{v-u}{t} \Rightarrow d = -a = -\frac{v-u}{t} = -\frac{v-20}{5} = 3 \Rightarrow -v + 20 = 15 \therefore v = 5m/s$$

6.<u>ORGANIC CHEMISTRY 1</u>

OBJECTIVES:

By the end of this chapter learners should be able to:

- State the names of the first ten un-branched primary alkanols.
- Draw the structure of the first ten primary alkanols.
- Write the general and molecular formula of the first ten alkanols.
- Describe the production of ethanol by fermentation of sugars
- Describe the oxidation of akanols to carboxylic acids.
- State the names and draw the structures of the first un-branched carboxylic acids.
- Write the general and molecular formula of the first ten carboxylic acids.
- Explain why carboxylic acids are classified as acids.
- Give examples of natural sources of carboxylic acids.
- Describe the reaction of ethanoic acids and ethanol to form an ester.
- Use flow diagram in identifying organic compounds.
- Apply the general formula in problem solving.
- Describe the melting and boiling points in relation to strength of IMF.

- Relate the differences in conductivity of alkanols and carboxylic acids to their functional group

---

ORGANIC CHEMISTRY:

- This is the branch of chemistry that deals with carbon compounds.
- Carbon forms more compounds than any other element. It forms four covalent bonds.

ORGANIC COMPOUNDS:

- These are compounds with carbon atoms. The carbon in the compound is often bonded to elements such as hydrogen, oxygen, nitrogen and other elements.
- Hydrocarbons are the organic compounds with carbon and hydrogen atoms only. E.g. methane CH_4, ethane C_2H_4, nonane C_9H_{20} etc.

HOMOLOGOUS SERIES:

- This is a family of organic compounds which have similar structure, name endings and properties.
- They show a trend in physical properties and their formula can be represented by a general formula.
- Most of these they contain a **functional group**. A functional group is the atom or group of atoms which are responsible for the characteristic reaction of a compound. This definition does not apply to alkenes for they have a **double bond** as a functional group.
- Examples of homologous series (organic families) include:
  - **i.** Alkanes C_nH_{2n+2}
  - **ii.** Alkenes C_nH_{2n}
  - **iii.** Alkanols $C_nH_{2n+1}OH$
  - **iv.** Carboxylic acids $C_nH_{2n+1}COOH$
  - **v.** Esters R'COOR

NOMENCLATURE (NAMING SYSTEM)

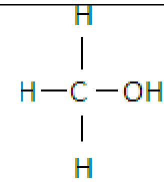
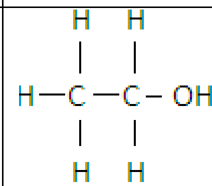
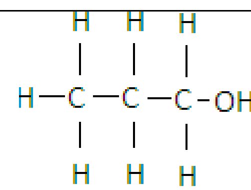
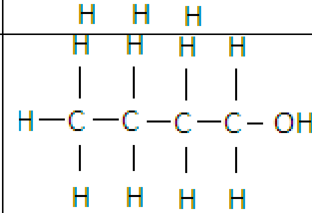
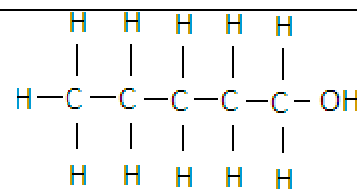
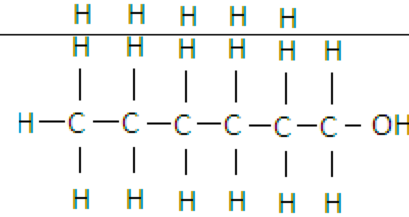
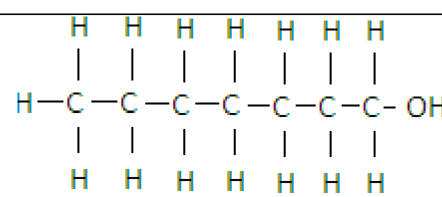
The following prefixes are used

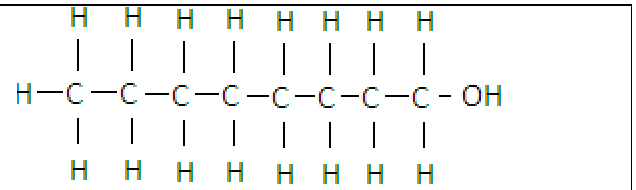
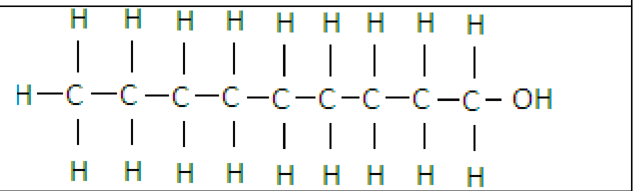
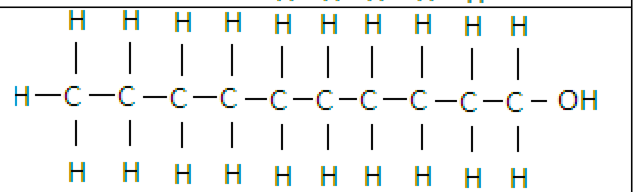
Number of carbon atoms	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Prefix	**Meth-**	**Eth-**	**Prop-**	**But-**	**Pent-**	**Hex-**	**Hept-**	**Oct-**	**Non-**	**Dec-**

ALKANOLS (ALCOHOLS):

- It is a homologous series of organic compounds whose general formula is $C_nH_{2n+1}OH$.
- They contain the functional group –OH which is called the hydroxyl group.

- According to the International Union of Pure and Applied Chemistry (IUPAC) system, alcohols are named by taking the name of alkane with the same number of carbon atoms and changing the ending from –ane to –anol.
- They increase by **$-CH_2-$**
- The table below shows names, formula of the first ten un-branched alkanols:

n	NAME	FORMULA	STRUCTURE
1	**Methanol**	**CH_3OH**	
2	**Ethanol**	**C_2H_5OH**	
3	**Propanol**	**C_3H_7OH**	
4	**Butanol**	**C_4H_9OH**	
5	**Pentanol**	**$C_5H_{11}OH$**	
6	**Hexanol**	**$C_6H_{13}OH$**	
7	**Heptanol**	**$C_7H_{15}OH$**	

8	**Octanol**	**$C_8H_{17}OH$**	
9	**Nonanol**	**$C_9H_{19}OH$**	
10	**Decanol**	**$C_{10}H_{21}OH$**	

ETHANOL:

- It is the best known of the alkanols. In fact it is often called alcohol.
- IT is a good solvent; it dissolves many substances that are not soluble in water. It also evaporates quickly so it is used in glues, paints, varnishes, synthetic drags. Printing inks, deodorants (perfumes), explosives, dyes, aftershaves etc.
- It is also a raw material for making other substances such as synthetic rubbers and flavorings.
- It is also well known for making people drunk. Beer, wine and all alcoholic drinks contain some ethanol.
- Methylated spirit (Meths) is mainly ethanol, mixed with a little methanol which is poisonous. The coloring is added and a horrible taste is to stop people drinking it. Ethanol in which other substances have been added is called denatured alcohol.

PROPERTIES OF ETHANOL:

1. Clear colorless liquid that boils at 78°C.
2. It is miscible in water (dissolves in water).
3. Burns in air (react with oxygen in combustion process).
4. React with sodium to form sodium ethoxide and hydrogen gas.
   $$2C_2H_5OH + 2Na \longrightarrow 2C_2H_5ONa + H_2$$
5. Can be dehydrated to form ethene.
6. If left standing in air, gets oxidized to form ethanoic acid

$$C_2H_5OH \xrightarrow{[O]} CH_3COOH$$

7. It does not conduct electricity.

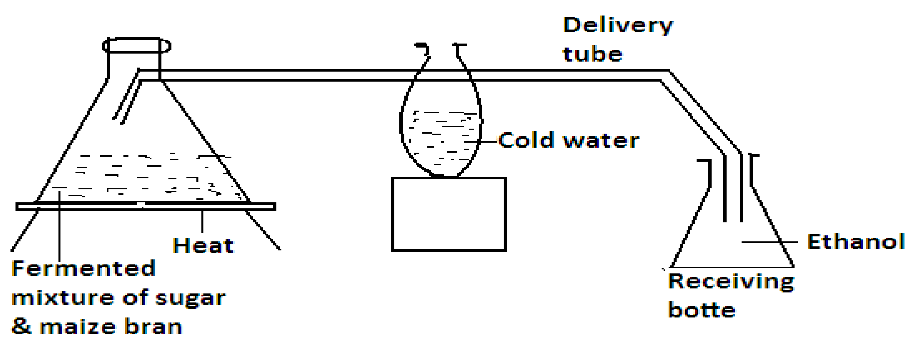
PREPARATION OF ETHANOL:

1. **By fermentation**:

- Fermentation is a reaction in which glucose is changed into alcohol and carbon dioxide by the action of enzymes in yeast.
- The ethanol in alcoholic drinks is made by fermenting carbohydrates in form of glucose obtained from fruits e.g. (grapes, vegetables, cereals, maize and burley).
- During fermentation, the enzymes called zymase, catalyzes the fermentation of glucose into ethanol and carbon dioxide. The equation below summarizes the fermentation process:

$$C_6H_{12}O_6\,(aq) \xrightarrow{zymase} 2C_2H_5OH + 2CO_2$$

- When beer is made from barley by fermentation, the barley grains are crashed and soaked in water to extract the glucose. The liquid is strained and yeast of fungus plant is added. The yeast converts the glucose by ethanol.
- Fermentation is allowed to go on until enough ethanol has formed. The beer is then carefully heated to kill the yeast.
- Ethanol can also be prepared using local technology. Figure below shows an indigenous way of preparing ethanol in form of kachasu by **distillation process.**
- The pure ethanol is obtained by distillation.



2. **Hydration of ethene:**

- This involves mixing ethene with water (steam) and passed over a catalyst. The following addition reaction takes place.

$$C_2H_4(g) + H_2O \xleftrightarrow{catayst} C_2H_5OH$$

- The product becomes a solution of ethanol in water. Most of the water is then removed by fractional distillation. The mixture of water and ethanol is then heated at about 78°C. Figure above illustrates how the process is done.

GENERAL USES OF ETHANOL:

1. Used as a source of fuel.
2. Used as essential ingredient of alcoholic beverages.
3. Used as a raw material in pharmaceuticals, perfumes and flavorings.

4. Used as a solvent for many organic substances.
5. It is an intermediate in the manufacture of other chemicals such as acetaldehydes.

PHYSICAL PROPERTIES OF ALKANOLS:

a. **Solubility:**
   - All the alkanols are solubility in water. The higher the proportion of –OH group to the alkyl group, the more soluble the alkanols become and vice-versa.
   - The lower members; methanol, ethanol, propanol and butanol are completely soluble in water while higher ones have a less solubility rate.

b. **State at room temperature:**
   - Aliphatic (straight chain) alcohols with less than 12 carbon atoms are liquids at room temperature.

c. **Melting and boiling points:**
   - They have higher melting and boiling points than those of alkanes of comparable molecular mass. This is due to the strong polar bond –OH which needs strong heat energy to be broken. Boiling points and melting points increase with an increase in molecular mass.

     E.g.

C_3H_8 **-42°C**	**C_2H_5OH** **78°C**
C_8H_{18} **126°C**	**$C_7H_{15}OH$** **180°C**

   - In the table above, masses of the propane and ethanol are almost within each other. 44 for propane and 46 for ethanol and yet they have a very big difference in boiling points. The same applies to octane and heptanol.

d. **Good solvents**:
   - The polar –OH group enables them to dissolves NaOH and KOH as well as non-polar solutes such as hexane.

e. **Non-electrolyte:**
   - They do not conduct electricity and as such they are non-electrolytes though they ionize slightly.

CHEMICAL PROPERTIES:

1. They are amphoteric:
   They behave as acids and bases due the presence of the –OH group.
2. They react with highly electropositive metals like sodium and potassium to give off hydrogen gas and alkoxides.

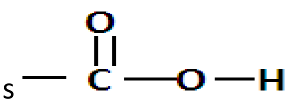
$$2C_2H_5OH + 2Na \longrightarrow 2C_2H_5ONa + H_2$$

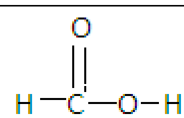
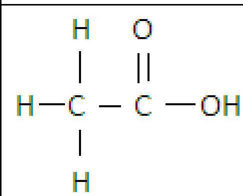
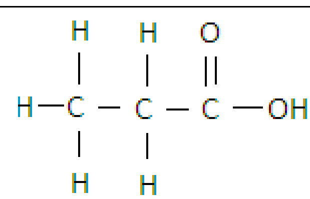
3. They react with alkanoic acids to produce esters.
4. They undergo oxidation by oxygen and other reducing agents to form alkanoic acids.

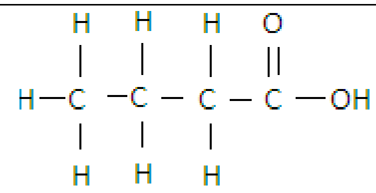
USES OF ALKANOLS

1. Used as a source of fuel.
2. Used as essential ingredient of alcoholic beverages.
3. Used as a raw material in pharmaceuticals, perfumes and flavorings.
4. Used as a solvent for many organic substances.
5. It is an intermediate in the manufacture of other chemicals such as acetaldehydes.
6. Used in ester production

ALKANOIC ACIDS (CARBOXYLIC ACIDS):

- They consists of a carbon atom bonded by an oxygen atom and by a single bond to a hydroxyl group which may be represented as 
- Thus the functional group of carboxylic acids is the carboxyl **–COOH.**
- Their general formula is $\mathbf{C_nH_{2n+1}COOH}$.
- According to IUPAC nomenclature of the alkanoic acids, the **–e** of the corresponding alkane is replaced with**-oic** and acid is added as a second word i.e. the **–ane** is changed to **–anoic acid**.
- They increase in size by $–CH_2$-
- They are weak acids.

NAME	FORMULA	STRUCTURE	M.P(°C)	B.P(°C)
Methanoic acid (Formic acid)	HCOOH		8	100
Ethanoic acid (Acetic)	CH_3COOH		17	118
Propanoic acid	C_2H_5COOH		-21	140

Butanoic acid	C_3H_7COOH		-5.5	163

Example 1

Write down the name and formula of an alkanoic acid with 4 carbon atoms

Name: Butanoic acid

Molecular formula C_3H_7COOH

Example 2

Write down the name and formula of an alkanoic acid in which n = 4

Name: Pentanoic acid

Molecular formula C_4H_9COOH

SOURCES OF CARBOXYLIC ACIDS:

- Carboxylic acids are found in both plants and animal kingdom.
- Examples of natural sources of carboxylic acids are listed in the table below:

SOURCE	**NAME OF THE ACID**
Citrus fruits	**Citric acids**
Sour milk, breast milk, cow's milk	**Lactic acid**
vinegar	**Ethanoic acid**
Sour wine	**Ethanoic acid**
Rancid butter	**Butanoic acid**
Gum benzoic	**Benzoic acid**
Sweet potatoes	**Oxalic acid**
Ground nuts, bees and beetles	**Methanoic acid**

Physical properties of Carboxylic acids:

- Long chain acids are liquids at room temperature.
- Melting and boiling points increase with an increase in molecular mass.
- Are soluble in water. However, solubility decreases as number of carbon atoms in the molecule increases.

Chemical properties of the Carboxylic acids:

- They react with carbonates and hydrogen carbonates to form salts and rebate carbon dioxide.

$$2CH_3COOH + Na_2CO_3 \longrightarrow CH_3COONa + CO_2 + H_2O$$

- They neutralize alkali to form corresponding salts and water.

$$CH_3COOH + KOH \longrightarrow CH_3COOK + H_2O$$

- Their solutions affect color of indicators.
- They react with alkanols to form esters

  $$C_2H_5OH + CH_3COOH \longleftrightarrow CH_3COOC_2H_5 + H_2O$$

- They undergo chlorination with exception of formic acid. E.g. they react with phosphorous pent chloride, PCl_5 to yield chloride.

  $$CH_3COOH + PCl_5 \longrightarrow CH_3COCl + POC_3 + HCl$$

- They undergo decarboxylation reaction (removal of CO_2) to alkanes. e.g.

$$CH_3COOH + NaOH \xrightarrow{heat} CH_3COONa \xrightarrow{heat} CH_4 + Na_2CO_3 + H_2O.$$

USES OF CARBOXYLIC ACIDS

- **Manufacture of soaps, Used to make dyes and perfumes eg. Acetic acid, Used as solvent, Used to preserve food stuffs, Used as food flavors in salads and soft drinks, Used to make esters**

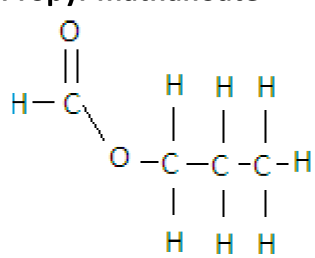
ESTERS (ALKANOATES):

- Alkanoic acids react with alcohols to form pleasant smelling compounds called esters.
- The reaction in which akanols react with carboxylic acids in the presence of sulfuric acid to produce esters and water is called "Esterification".
- When naming esters, the alcohol part is named first followed by the name of carboxylic acid modified to change in –noate.
- Examples are given in the table below:

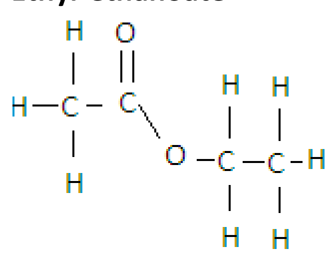
NAME OF ESTER	FORMULA	AKANOL USED	CARBOXYLIC ACID USED
Ethyl-ethanoate	$CH_3COOCH_2CH_3$	Ethanol	Ethanoic acid
Propyl-methanoate	$HCOOCH_2CH_2CH_3$	Propanol	Methanoic acid
Octylethanoate	$CH_3COOC_8H_{17}$	Octanol	Ethanoic acid

STRUCTURE OF SOME ESTERS:

Propyl-mathanoate



Ethyl-ethanoate



- Many esters come from plants like pineapples, olive oil, coconut oil, ground nuts etc. All these have mixtures of natural esters that contain fat acids and glycerol.
- Esters are used as solvents for many organic compounds, used in the production of perfumes, soaps, cosmetics and food flavorings. They are a source of energy.

FLOW DIAGRAMS USED IN IDENTIFYING ORGANIC COMPOUNDS:

Recall from JCE work on properties of alkenes and alkanes

ALKANES

- General formula is C_nH_{2n+2}
- Are called saturated hydrocarbons because all bonds are completely used up
- Are called paraffin meaning, less reactive
- Are insoluble in water
- Do not conduct electricity
- The first few members exists as gases at room temperature
- Undergo combustion

  $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$
- **Get involved in substitution reaction**

  Eg methane + Oxygen →mono-chloromethane and hydrogen chloride gas

  $CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl(g)$

  Eg methane + Oxygen →dichloromethane and hydrogen chloride gas

  $CH_4 + Cl_2 \longrightarrow CH_2Cl_2 + HCl(g)$

  Eg methane + Oxygen →tri-chloromethane and hydrogen chloride gas

  $CH_4 + Cl_2 \longrightarrow CHCl_3 + HCl(g)$

  Eg methane + Oxygen →Tetra-chloromethane (Carbon tetra chloride) and hydrogen chloride gas

  $CH_4 + Cl_2 \longrightarrow CCl_4 + HCl(g)$

ALKENES

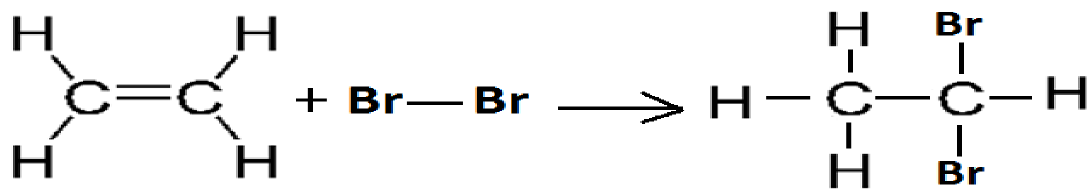
- General formula is C_nH_{2n}
- Are called unsaturated hydrocarbons because of carbon- carbon double bond. more atoms could be added to them when the double bond breaks
- Are recognized due to carbon- carbon double bond

  $C=C$
- Are insoluble in water
- Do not conduct electricity
- The first few members exists as gases at room temperature
- Undergo combustion

  $2C_3H_6 + 9O_2 \longrightarrow 6CO_2 + 6H_2O$
- **Get involved in addition reaction**

  Egethene + bromine→1,2-dibromothethane

  $C_2H_4 + Br_2 \longrightarrow C_2H_4Br_2$



- Get involved in polymerization
- Using their chemical properties, one can carry out simple experiments to identify organic compounds like alkanes, alkenes, alkanols and alkanoic acids since all these are color-less, they cannot be identified by a mere sight.

  a) Solubility test:
  - Alkanes and alkenes are insoluble in water. Two layers are observed when they have been mixed with water.
  - Alkanols and alkanoic acids with few carbon atoms are soluble in water. The solubility decreases as the carbon chain increases,.
  - This test involves putting/ addition of 2 to 10 drops of water to two test tubes having the alkanes and alkenes.

  b) Bromine test:
  - Add 2 to 10 drops of bromine solution (brown in color) to alkanes and alkenes.
  - The mixture of alkenes and bromine is color-less, an indication that addition reaction takes place. The result is a brown color in the mixture of alkanes and bromine.

  c) Acid test:
  - Add about 10 drops of dilute sodium hydroxide, NaOH in two separate test tubes and add 1 or 2 drops of phenolphthalein indicator. It turns pink.
  - Add one of the chemical into one of the test tube. A color-less mixture will indicate it's an acid. Pink will signal presence of an alkanol.

  d) Combustion test:

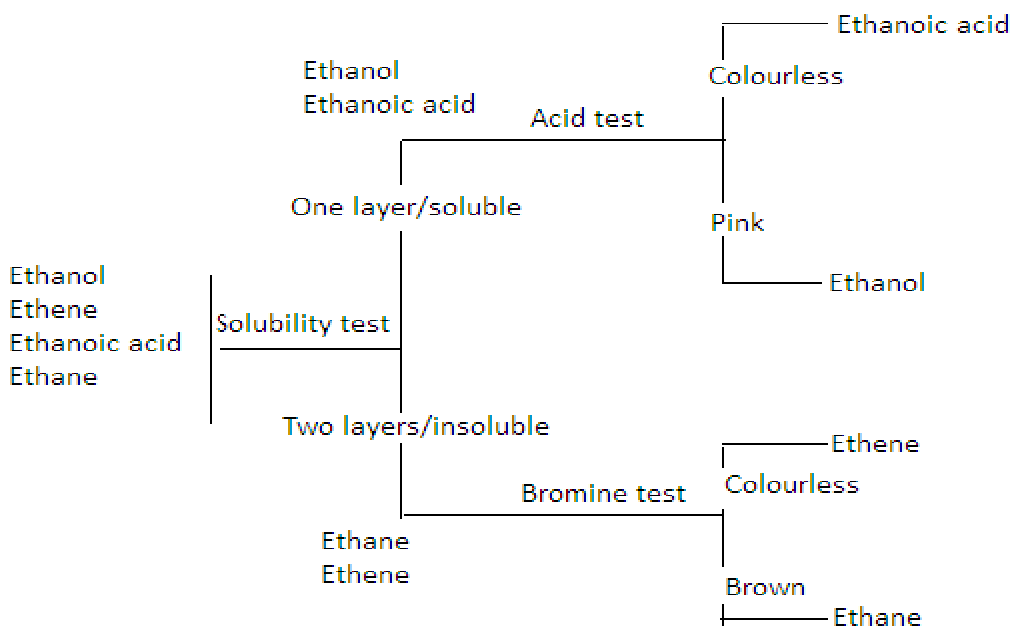
  i. complete combustion:
  - It occurs in plenty of oxygen, Produces a lot of energy, Produces blue flame, Less smoke is produced, Almost soot-less, Produces water and carbon dioxide

  ii. Incomplete combustion
  - It occurs in insufficient supply of oxygen, Produces less amount of energy Produces yellow flame, more smoke is produced, produces more soot Produces Carbon and carbon monoxide in addition to water and carbon dioxide

Note: organic compounds with fewer carbon atoms burn very well than those with larger number of carbon atoms.

- Figure below shows a flow diagram that can be used to identify which substance is an alkene, alkane, alkanol or carboxylic acid.

For example: Use a flow diagram on how the following can be distinguished from each other: Ethanol, Ethanoic acid, Ethane and Ethene.



---

7. ORGANIC CHEMISTRY 2

OBJECTIVES:

By the end of this chapter learners should be able to:

- Define isomers.
- Draw structure of isomers.
- Name the isomers.
- Write down the condensed structural formula.
- Differentiate monomers from polymers.
- Describe the types of polymerization.
- Describe the properties of polymers,
- State the uses of polymers
- Explain different types of plastics.
- Discuss waste management.

ISOMERISM:

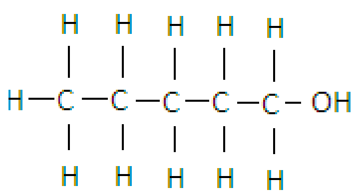
- It is the existence of different compounds with the same molecular formula but different structural formula

- **Isomers** are compounds with the same molecular formula but different structural formula.
- The isomers do have different melting and boiling points.
- A structural formula gives a clear arrangement and bonding of the atoms. The number of atoms is also specified.
- The names of isomers are given according to the IUPAC system of nomenclature.
- The following are guidelines for naming isomers:
  - Name the longest un-branched carbon chain.
  - Name the substituent group.
  - Give the position of the substituent groups.
- During numbering of the long chain carbons, start with the carbon that is closer to a functional group.

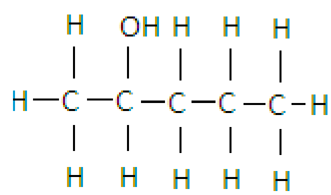
Examples:

The following are isomers of pentanol:

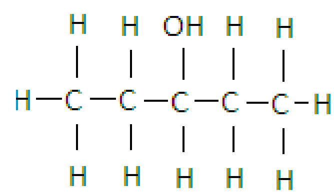
Pentan-1-ol



Pentan-2-ol

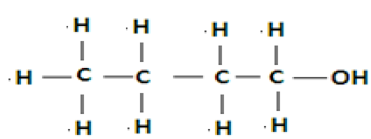


Pentan-3-ol

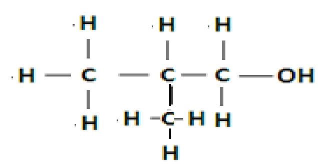


Isomers of butanol , C_4H_9OH

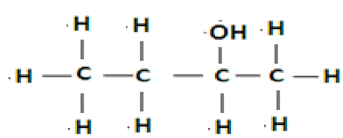
1



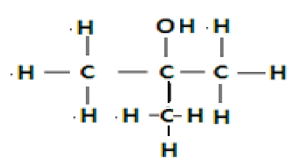
3



2

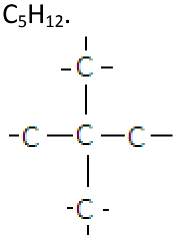


4

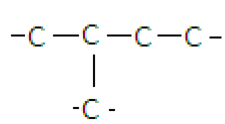


Isomers of Pentane, C_5H_{12}.

Normal pentane

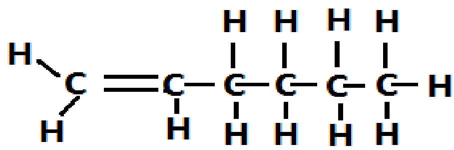


2, 2- dimethyl propane

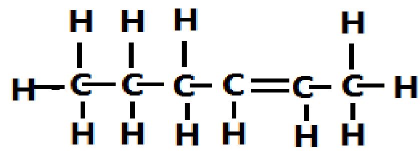


2-methyl butane

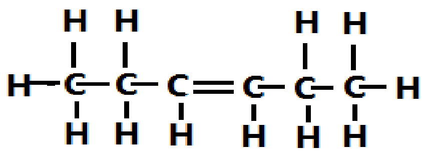
Isomers of Hexene C_6H_{12}: just three of them but they are more



Hex-1-ene



Hex-2-ene

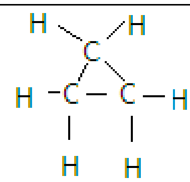
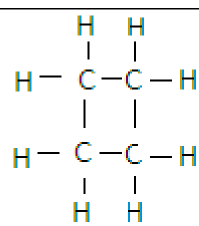


Hex-3-ene

Carbon rings:

- **Cyclo-alkanes:**

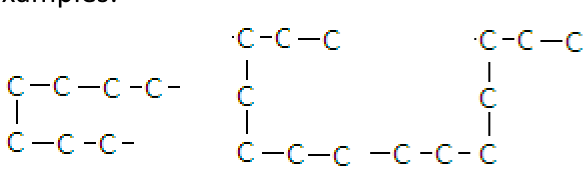
  These are alkanes in which carbon atoms are arranged in a ring. Egcyclopropane, C_3H_6, cyclobutane, C_4H_8, cyclopentane, C_5H_{10}, cyclohexane, C_6H_{12}.
- Cycloalkenes: Examples include benzene C_6H_6 and cyclohexene,C_6H_{10}.

Cyclo-alkane	**Formula**	**Structure**
Cyclo-propane	C_3H_6,	
cyclobutane	C_4H_8	

CONFORMATIONS:

- These are structures which are identical except their shape.
- Normally, they arise due to bending and twisting of the carbon-carbon bonds.

Examples:



CONDENSED OR REDUCED STRUCTURAL FORMULA:

- It is a formula which indicates the structure of the molecules and how the different atoms are joined together.

  Examples:

Write down the condensed formula of the following:

1) C_3H_8. Ans: $CH_3CH_2CH_3$
2) C_5H_{10} Ans: $CH_3CH_2CH_2CHCH_2$. Or $CH_3CHCHCH_2CH_3$.
3) C_4H_9OH. Ans: $CH_3CH_2CH_2CH_2OH$

POLYMERISATION:

- This is a process in which small units of molecules combine to form large and complex molecules.
- The long chain molecule formed is called a **polymer**.
- A **monomer** is a unit molecule which forms a polymer.
- In a polymer, hundreds or thousands of unit molecules (monomers) of a given substance are bonded together to form polymers (macro-molecules).

CLASSFICATION OF POLYMERS:

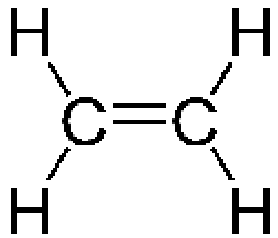
a. Natural polymers (Bio-polymers):
   Examples are: carbohydrates, proteins, natural rubber, deoxyribonucleic acid (DNA) etc.
b. Synthetic (artificial) polymers:
   These are man-made polymers which include polythene, nylon, terylene, human hair poly vinyl chloride (PVC) etc.

TYPES OF POLYMERIZATION:

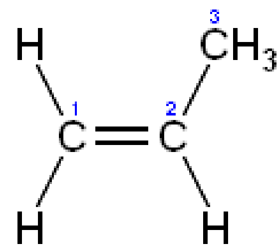
a. Addition polymerization
b. Condensation polymerization.

a) **Addition polymerization**:

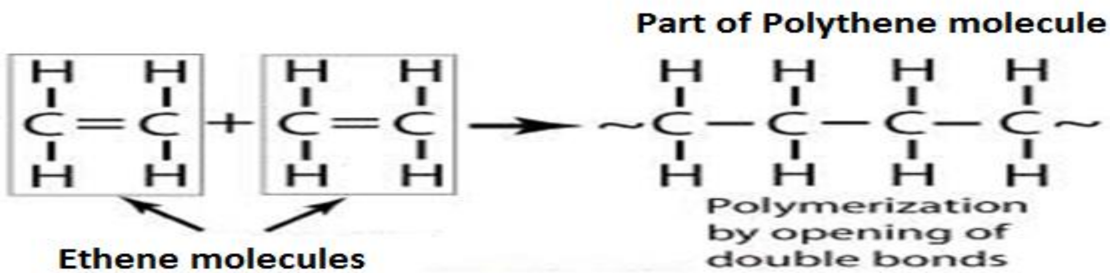
- It is also known as poly-addition.
- It involves monomers with carbon-carbon double bond
- There is no loss of part of monomer molecules
- It involves a successive addition of repeating monomer molecule.
- Unsaturated ethene molecule (CH_2=CH_2) and its derivatives (Chloroethene/ vinyl Chloride) undergo self-addition reactions to give high polymers of linear structures.

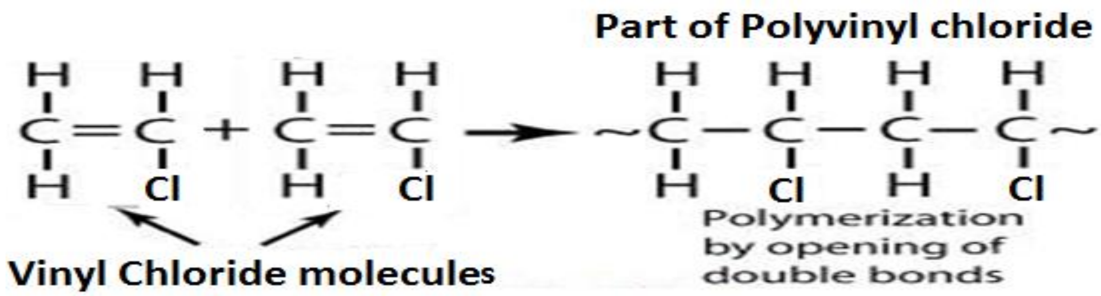


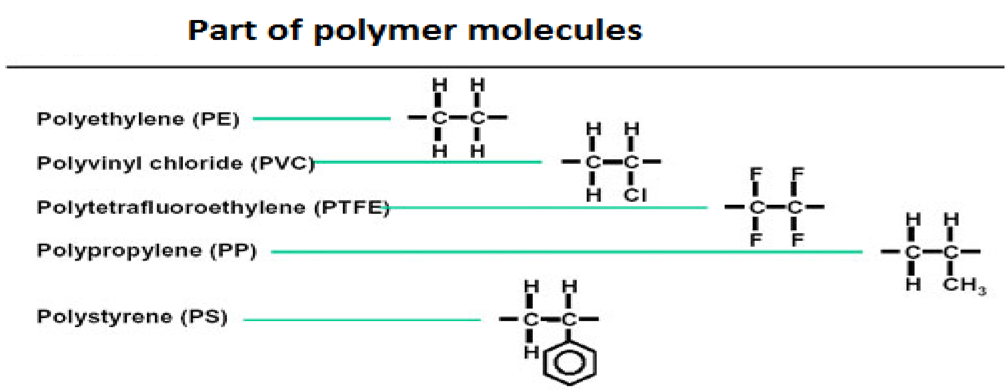
Ethene which forms polythene



Propene which forms Poly-propene







- Examples of polymers formed in this way are polythene, PVC, polystyrene, Perspex, polypropene, Teflon etc.
- It takes place when the carbon-carbon double bond breaks under the presence of a suitable catalyst.

b) **<u>Condensation polymerization</u>**:
- This is a polymerization which involves elimination of part of monomer molecules.
- It involves different monomer molecules.
- It involves monomers with many functional groups
- Examples of small molecules that are eliminated from the functional group of adjacent monomers include water, H_2O and ammonia, NH_3.
- Examples of polymers formed in this way are Terylene and nylon.

CATEGORIES OF PLASTICS:

a. **Thermoplastics**.
- Are also known as **thermo softening**plastics.

- Examples include polythene and PVC
- They are flexible and do not easily break. This is due to the absence of cross-linking bonds.
- Stretch under tension because molecules slide over each other.
- Melt at low temperature.
- They can be molded into shape after they are already made. (Easy to recycle).

b. Thermo setting plastics.

- They are also known as **thermo sets**.
- Examples include melamine and Bakelite.
- When heated, they char/break down rather than melt.
- They are rigid and break rather than bends. If dropped, the giant structure breaks at weak points. They have cross-linking bonds which make them strong.
- They are molded into shape while they are being made because the shape cannot be altered anymore.

USES OF POLYMERS:

a. **Category of plastics:**

I. polythene(polyethene)

- This is made from ethylene (ethane)
- It is tough and flexible
- It is resistant to most chemicals such as acids and bases.
- It is used for making polythene bags, wrappings and covering as well as water pipes.
- It is also used in the manufacture of flexible bottles, films and insulation wires.

II. poly vinyl chloride (PVC):

- It is used for electrical equipment, floor tiles, rain coats, shower curtains and hose pipes.

III. poly propene

- It is durable and used for light weight bottle crates and carpets.

IV. poly tetra fluoroethene (PTFE/Teflon):

- It is resistant to heat and some chemicals.
- It used for electrical insulation, greaseless bearings in liners for pots and pans.

V. Perspex:

- It is a tough, clear and transparent plastic.
- It is used in aircrafts industry, used instead of glass in the manufacturing of prisms, lenses, lab equipment, surgical tools and dentures (false teeth).

b. **Category of fibers**:

I. Terylene:

- This is a polyester fiber formed as a product of condensation polymerization.
- It has a considerable strength, resistant to chemicals and insects such as months.
- It used for designing of clothes, sheets, tires, nets.

II. Nylon:

- It is a white solid with much greater strength than any natural fiber.
- It is used for clothing, tents, ropes, tires, nets etc.
- Other fibers include viscose (artificial silk), cellophane and Orion.

c. **Proteins:**
- Are built up by polymerization of amino-acid units
- Examples include keratin, insulin, pepsin, hemoglobin and antibodies.

d. **DNA (Deoxyribonucleic acid):**
- This is responsible for heredity.
- IT transmits characteristics of a parent cell to a daughter nucleus.

e. **Carbohydrates:**
- Main source of energy.
- Classified as; monosaccharide, disaccharides and polysaccharides.

WASTE MANAGEMENT (WASTE DISPOSAL):

Wastes, if not handled well, could provide fertile grounds for micro-organism. There are a number of ways of disposing off of the wastes.

a) **Recycling**:
It is the use of wastes as raw materials for new production.
Metallic scraps, paper wastes and some plastics can be recycled.

b) **Incineration**.
It involves burning the wastes. The heat can be used for heating. It kills germ. However, the fumes and other products of incomplete combustion can pollute the environment.

c) Land-fill:
Wastes are covered with a thin layer of soil. The wastes get compacted together. The layer has to be of reasonable size otherwise it may get corroded during the rains and expose the wastes to the environment.

d) Composting:
Turning wastes into organic manure.

e) Production of bio-degradable materials:
This involves manufacturing and using material that can easily be broken by the action of micro-organisms.

HOW THE TOPICS (ORGANIC CHEMISRTY 1 & 2) HAVE BEEN FEATURED IN THE LAST 4 YEARS OF MANEB EXAMINATIONS

(Find some suggested answers in italics).

2015 3a

i. Name the products formed during the fermentation of sugar by yeast

Answer: Ethanol and carbon dioxide

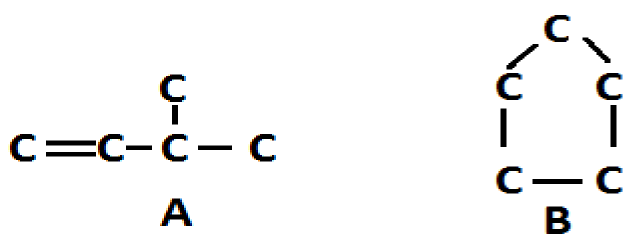
ii. Describe how fermentation of sugar by yeast occurs

Answer: the yeast contains natural enzymes which catalyze the breakdown of glucose to ethanol and carbon dioxide. Heat increases the rate at which fermentation is done.

b. Explain why thermosetting plastics do not melt when heated

Answer: their polymer chains are joined together by cross-links, so they cannot slide or glide past each other when heated

c. The following are isomers of organic compounds A and B



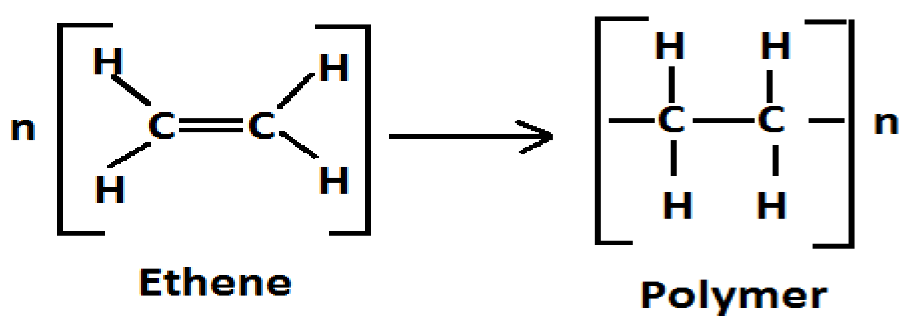
(i) Name the isomers A and B

A: is 3-methybut-1-ene *B: cyclopentane*

(ii) To which homologous series do the isomers belong?

A: belongs to alkenes *B: alkanes*

d. Polymerization of ethane takes place according to the following equations



(i) Name the polymer *Answer: Polythene*

(ii) Give any two advantages of the polymer

- *It cannot be attacked by microorganism*
- *Can be recycled*
- *It is light*

(iii) Explain how the polymerization takes place

The monomers are exposed to conditions that allow the carbon-carbon double bond to break giving room for formation of a long chain

2014 No 5

a. What are hydrocarbons?

These are organic compounds with carbon and hydrogen atoms only

b. Figure below shows formula of some organic compounds A, B, C and D

C_3H_7OH	C_5H_{10}	C_2H_5COOH	C_9H_{20}
A	B	C	D

(i) Which compound are hydrocarbons?

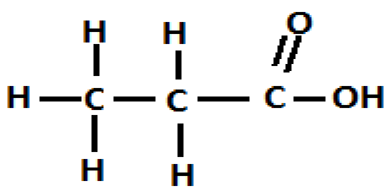
Answer: B and D

(ii) Name compound A

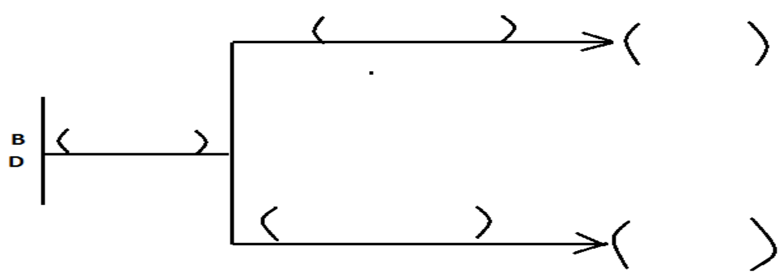
Answer: ***Propanol***

(iii) Draw molecular structure of compound C

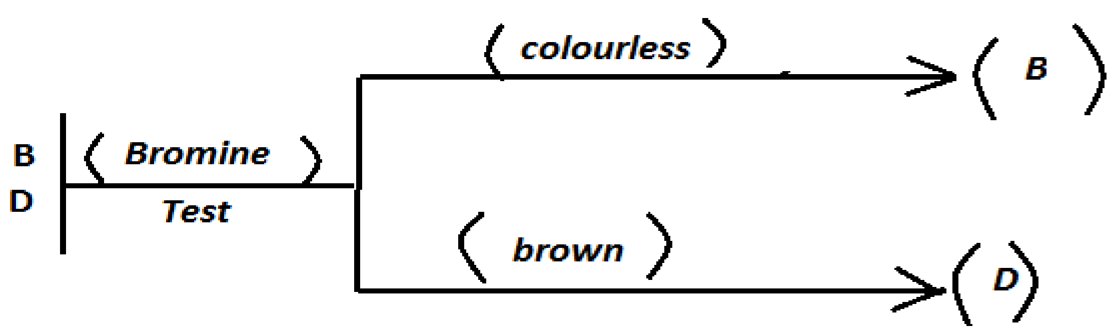
Answer



(iv) Complete the flow diagram for differentiating compounds B and D by filling in the missing information in the brackets



Answer

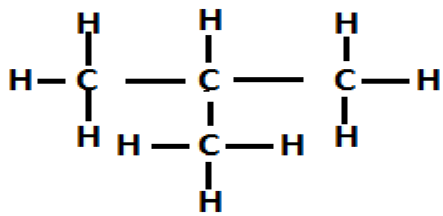


c. State any three properties of synthetic polymers

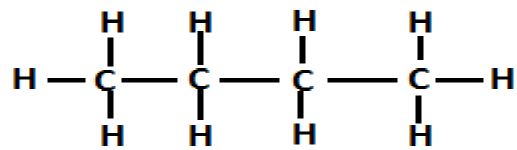
- ***Are very strong***
- ***Do not conduct electricity***
- ***Cannot be decomposed by micro organism***

- ***Are versatile (have many uses)***

d. Draw the structures of the two isomers of butane(C_4H_{10})



and

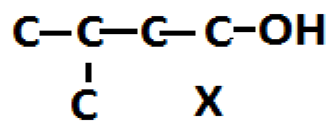


2013 N0 5

a. Figure below shows structures of some organic compounds W, X, Y and Z

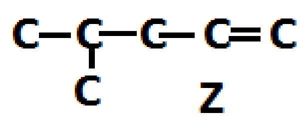
Note: Compound X was not correctly drawn in Maneb exam. The double bond was not supposed to be there.

W



X

Y



Z

(i) To which homologous series do compounds X and Z belong?

X: alkanols

Z: alkenes

(ii) Mention any three chemical properties of compound X

- ***React with carboxylic acids to form esters***
- ***Undergo combustion to produce energy***
- ***React with sodium to form sodium alkoxide***
- ***Gets oxidized to carboxylic acid***

(iii) Write the general formula for compound Y

$$C_nH_{2n+1}COOH$$

(iv) Name two products that are formed when compounds X and Y react

Esters and Water

(v) Which compounds belong to the same homologous series?

W and Z

(vi) Give a reason for your answer above

They have the same functional part; the carbon carbon double bond for alkenes

b. Figure below shows structures of plastics A and B

A
B

(i) Which structure represents thermosetting plastics?

Answe:r B

(ii) Give a reason for your answer above

Answer: It has cross-links which make it rigid, among other properties

c. Explain how ethanol (C_2H_5OH)could be distinguished from hexane (C_6H_{14})

By solubility test. If a few samples of each are mixed with water, ethanol is soluble; forms one layer while hexane is insoluble; it forms two layer

2012

3 . The following are general formulae of organic compounds A and B

A = $C_nH_{2n+1}COOH$ B = $C_nH_{2n+1}OH$

a. To which family does compound B belong? ***Alkanols***

b. Mention any three properties of compound A

I. Long chain acids are liquids at room temperature.

II. Melting and boiling points increase with an increase in molecular mass.

III. Are soluble in water. However, solubility decreases as number of carbon atoms in the molecule increases.

IV. They react with carbonates and hydrogen carbonates to form salts and rebate carbon dioxide.

$$2CH_3COOH + Na_2CO_3 \longrightarrow CH_3COONa + CO_2 + H_2O$$

V. They neutralize alkali to form corresponding salts and water.

$$CH_3COOH + KOH \longrightarrow CH_3COOK + H_2O$$

VI. Their solutions affect color of indicators.

VII. They react with alkanols to form esters

c. State any three uses of compound B

i. Used as a source of fuel.

ii. Used as essential ingredient of alcoholic beverages.

iii. Used as a raw material in pharmaceuticals, perfumes and flavorings.

iv. Used as a solvent for many organic substances.

v. It is an intermediate in the manufacture of other chemicals such as acetaldehydes.

vi. Used in ester production

d. Mention the products formed when compound A and B react

Ester and water

e. Work out the molecular formula of compound A if n is 5

$C_5H_{11}COOH$

f. Describe how compound A could be distinguished from compound B

By carrying out an acid test. Add a few drops of dilute sodium hydroxide, NaOH in two separate test tubes and add 1 or 2 drops of phenolphthalein indicator. It turns pink.

Add chemical A into one of the test tube. A color-less mixture will indicate it's an acid. Pink will signal presence of B

8. ELECTRICITY AND MAGNETISM 1

OBJECTIVES:

By the end of the chapter learners should be able to:

- Explain the different types of electricity.
- Analyze types of charges
- Describe the uses of electrostatics in our everyday life.
- Discuss current electricity.
- Calculate total resistance in series and parallel circuit.
- Deduce resistance of resistors from color codes and standard notation.
- Explain the meaning of electrical power.
- Calculate the electrical power using different equations.
- Interpret power rating of electrical appliances
- Calculate total electrical energy used.
- Determine the cost for electrical energy.
- Describe method of magnetization and de-magnetization of steel or iron.
- Discuss the phenomenon of electro-magnetism.
- Describe the interaction of current and magnetic field
- Determine the field pattern for a conductor currying current.
- Investigate the induction of emf.
- Explain how a transformer works.
- Use transformer equations in problem solving.
- Describe power loss and control in transformers

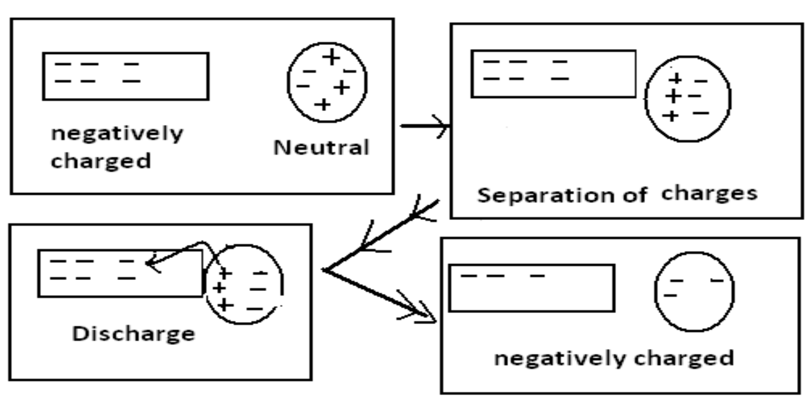
STATIC ELECTRICITY:

- There are two types of electricity namely static electricity and current electricity.

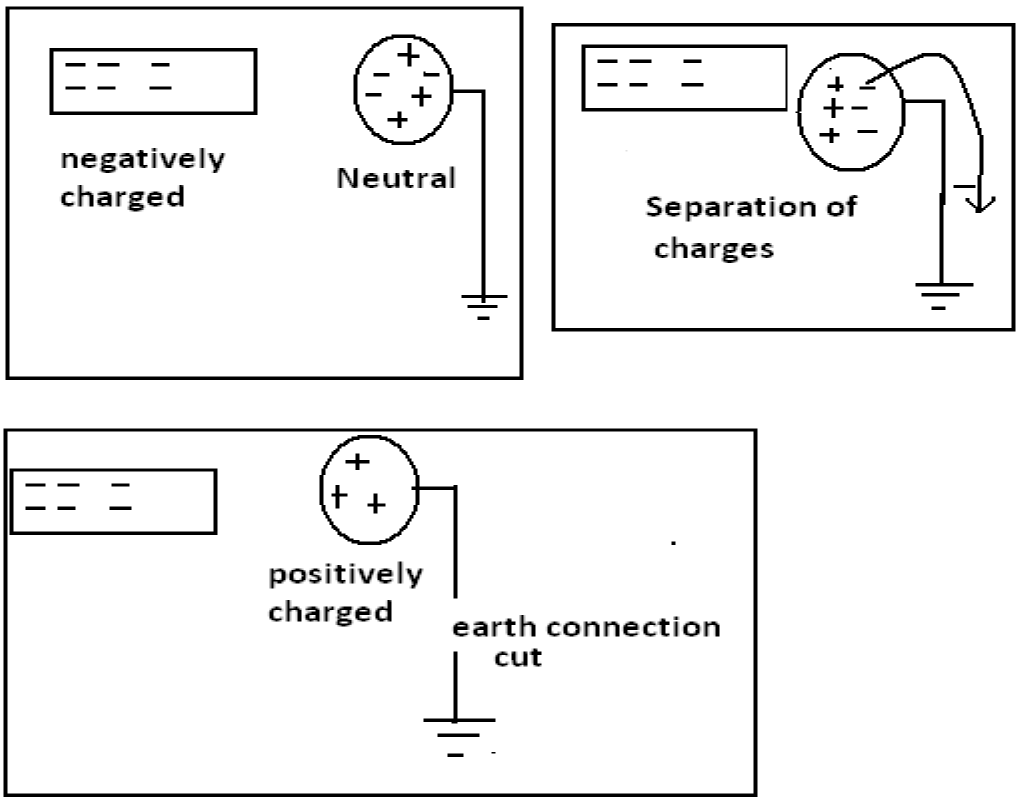
- Static electricity is the type of electricity which does not involve charge movement.
- The term charge refers to electrons and ions.
- There are two types of charges and these are **positive** charges and **negative** charges.
- Electrostatics is usually experienced in insulators in which the outer most electrons are strongly held by their nuclei.
- Between or among charges there exist forces of attraction and repulsion.
- The law of charges state that **like charges repel and unlike charges attract**.
- A material with the same number of charges is said to be neutral.
- When a cellulose acetate strip is rubbed with a piece of white cloth or against hair, it becomes positively charged. The polythene strip becomes negatively charged when rubbed by the same.
- The charging result into in-balance of the number of electrons. There are more positive charges in a rubbed acetate strip than the negative charges while polythene strip has many electrons than protons.
- The number of electrons exchanged determines the degree of strength of the charges.
- The electrical charge is measured in Coulombs.

METHODS OF CHARGING:

- An object can be charged by the following methods:
  - Friction (Rubbing).
  - By contact.
  - Induction.
- **Charging by rubbing** causes electrons to jump from the material into cloth/hair (in case of cellulose acetate strip) leaving the material positively charged. Electrons, sometimes, move into the material being rubbed such that it is left with excess of electron leaving it negatively charged like polythene strip.
- **Charging by contact**: when a charged material is brought closer to a neutral one, separation of charges takes place. The objects are then brought in contact, the unlike charges cancel each other out (discharge). Refer to the steps below



- Charging by induction does not involve touching of objects. There is separation of charges. An earth wire provides path for electrons into the ground. A person may just touch the object and the electrons would move through the person into the ground. Follow the figure below



- Materials which normally get positively charged include cellulose acetate strip, glass, and Perspex.
- The list of materials that become negatively charged when rubbed include polythene strip, balloon rubber, Bakelite and silk.
- Note that metals cannot be charged by rubbing because the charges are conducted away as soon as they are gained so that the balance of negative and positive charge is restored.

CHARGE DETECTION:

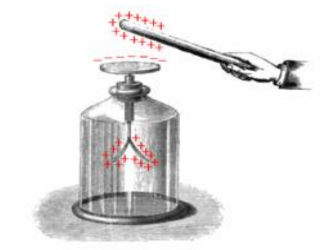
- The **presence, type and strength** of an electric charge can be determined by electroscope. This is a device which detects charge.
- Most commonly used electroscopes are **<u>Pith ball</u>** electroscope and **<u>Gold leaf</u>** electroscope.

a. **Pith ball electroscope**:

- This is a very light ball that has a conducting surface of aluminum and is suspended freely by a thin insulating thread of nylon.
- A rod of known charge is brought in contact with the pith ball and repulsion reveals that the pith-ball and the rod are of the same charge.

- Alternatively, a rod of unknown charge is brought near to the pith-ball electroscope of known charge. Attraction suggests the two possess opposite charges.

b. **Gold-leaf electroscope**:



- Suppose the cap and the leaf are negatively charged and a negatively charged body is brought near the cap, then the electrons will be repelled down the leaf and the leaf will diverge further.
- In general if the leaf of a charged electroscope diverges further when an object is placed near the cap, the object is charged and the charge has the same sign as that on the electroscope. The underlying rule is that like charges repel while unlike charges attract.

LIGHTNING:

- This is a giant spark of electricity.
- IT happens due to friction between raindrops and ice crystals caused by wind. As they rub together violently, friction causes the transfer of electric charges (electrons) from one drop to another. As the amount of opposite charges build up the force between them and the bottom clouds becomes greater and greater. This results into occurrence of the giant spark of electricity (lightning) coupled by a heavy sound (thunder) due to a sudden expansion of air. This takes place when the electricity passes through air.
- When a conductor is charged up, the charges repel each other so they collect on the outside; the charges are concentrated near the sloppiest points. This is where the electric filed is strongest and the field lines closest together.

PREVENTION OF EFFECTS OF LIGHTENING BY A CONDUCTOR:

- A lightning conductor which is usually made from a strip of copper has a sharp point.
- The conductor does two functions:
    a. **Providing path for the lightning to the ground.**
    b. **Discharging the cloud there by preventing lightening from striking.**
- Normally, if a positively charged cloud passes over a building conductor a negative charge is induced on the point at the top of the cloud. Because of high density charge at the point, electrons are sprayed into the air and attracted by positive charge on the cloud and make a lightening spark less likely to occur. If a discharge does take place, the charges flow harmlessly down the lightening conductor.

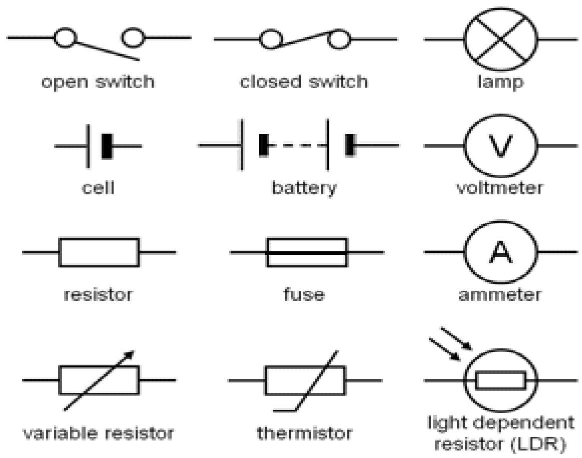
APPLICATIONS OF ELECTROSTATICS:

- There are several applications of the knowledge and concepts of electrostatics some of which will be discussed.
  a. **Designing of Capacitors:**
     - A capacitor is a device which is used to store electric charges.
     - A simple capacitor consists of two flat pieces of metal separated by an insulator of very high resistance called dielectric.
     - The ability of a capacitor to store charge is measured by its capacitance.
     - Thus, capacitance is the amount of charge stored on each plate of capacitors per unit voltage.
     - Capacitance are used for:
       - Smoothening out current changes.
       - Passing on signals from one circuit to another.
       - Tuning circuits so that they respond to signals of one frequency e.g.: radio-tuning.
       - Used in flash cameras to store charge.
  b. **Functioning of Photocopiers:**
     - Photocopiers contain a negatively charged drum and when the paper to be copied is laid on the glass plate, the light reflected from white parts of paper causes the charge to disappear from the corresponding parts of the drum. The charge pattern remaining on the drum corresponds to the dark colored printing on the original. Powdered ink (toner) is then dusted over the drum, and sticks to the parts which are still charged. When a sheet of paper passes over the drum, the particles of toner are attracted to it and fused into place by a short burst of heat. The heat melts the powdered ink to enable it stick to the paper.
  c. **The working of electro-statics Precipitators:**
     - This is a way of cleaning up pollution of air in the form of smoke (dust particles) from the atmosphere.
     - The smoke is passed through electric field which produces ions which are adhered to the dust particles giving the charge.
     - The charged particles are attracted towards an earthed plate and collect on it.
     - They are periodically removed by striking the plate with a mechanical hammer. The dust particles fall into collector for disposal.
  d. **Paint Spraying:**
     - In paint spray guns, the static charge ensures an even distribution of the droplets of paint. The same happens in crop sprayers.

CURRENT ELECTRICITY:

- Current electricity is the uniform flow of electric charge. It is usually the free uniform movement of electrons.

- A circuit is the path traced by the electrons. Circuit symbols are used when drawing a circuit.
- There are two types of circuits namely: **series circuit and parallel circuit**.
- In series circuit, components are joined in a single conducting loop (path).
- In parallel circuits, components are joined in several conducting paths.
- The following are some of the circuit symbols:



- **Conventional current** flows from positive to negative terminals.
- **A terminal current is** considered to flow from negative to positive.
- Movement of charges requires energy. This is the **Voltage or the potential difference**. Thus, Voltage is the amount of energy or work required to move a unit charge between two or more points.
- **Electro-motive force, EMF** is the potential difference across the terminals of a cell or battery when not connected to a circuit. It is usually labeled on the cell, say 1.5V.
- In any circuit, there are three things which have to be determined. These are summarized in the table below:

QUANTITY	ITS SYMBOL	SI UNIT	MEASURED BY
CURRENT	I	AMPS, A	AMMETRE
VOLTAGE	V	VOLTS, V	VOLTMITRE
RESISTANCE	R	OHMS,Ω	OHMMETRE

ELECTRICAL RESISTANCE:

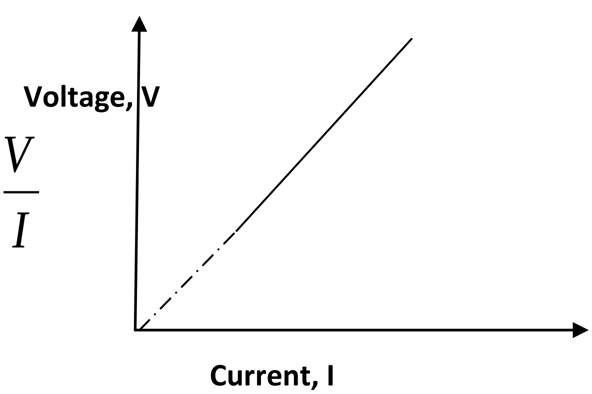
- It is the opposition to the flow of electric current.
- It is due to the ability of the substance to slow down the uniform speed of charges in an electric circuit there by reducing current size.
- When electrons are flowing they collide with stationary ions causing the ions to vibrate. As the electrons are colliding with the ions, they get slowed down.

- The degree of resistance varies from material to another such that there are some with low resistance and others with high resistance.
- Good conductors of electricity have low resistance because they have free electrons less strongly held by the ions. Examples of good conductors of electricity are copper, silver, gold etc. These are used as connecting wires for electricity.
- Materials like **nichrome (nickel + chromium)**, **tungsten and constantan** (**60% copper&40% nickel**) have high resistance. The higher the resistance the higher the value of heat energy produced.
- Nichrome is used as heating element of electric kettles, ovens and geezers.
- Tungsten is used in bulb filament and constantan is used in designing of resistors.

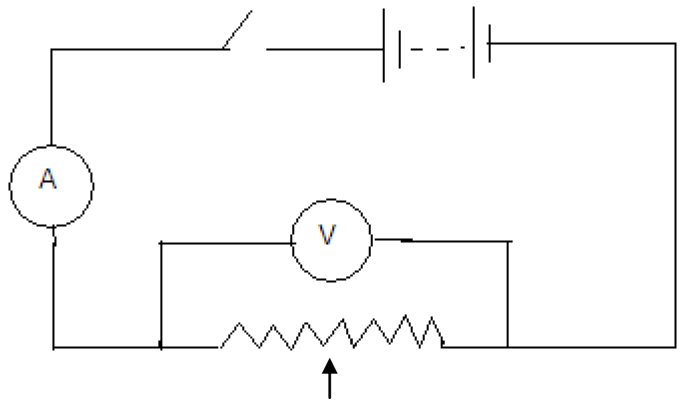
RESISTORS:

- These are conductors which provide the opposition to flow of current.
- They are used to:
    - **Limit flow of current there by protecting appliances from excessive currents.**
    - **Control volume in radios (in case of variable resistors).**
    - **Produce heat.**
- Ammeters do have a low value of resistance so that they measure the exact current value passing through an appliance. ON the hand, voltmeters do have high resistance hence are connected in parallel with the component so as not to reduce current value.
- The voltage, V, current, I and resistance, R are related by the equation $V = IR$. This equation is derived from the Ohm's Law which states that "**For a metal conductor at constant temperature, the potential difference (P.d) applied across the ends of the conductor is directly proportional to the current I in the conductor**.
- Thus, $V \alpha I$ Graphically,

$$R = \frac{V}{I}$$



- The slope of the above graph gives the resistance as show.
- The data for the graph can be verified by setting up an apparatus as illustrated in the figure below



.

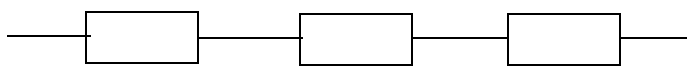
Coil of resistance wire. (Can be a variable resistor, which is also called Rheostat).

- Voltage is varied by adding cells while resistance is varied by using different lengths of the same wire of uniform cross section.

FINDING TOTAL (EFFECTIVE) RESISTANCE:

RESISTORS IN SERIES:

- The total resistance for resistors in series is obtained by finding **the sum of the total resistances.**

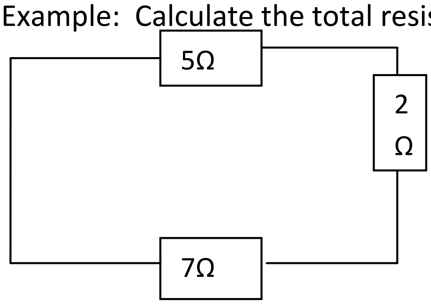


R_1 **R_2** **R_3**

Total Resistance= Sum of the resistances.

I.e. $R_T = R_1 + R_2 + R_3$

Example: Calculate the total resistance in the following circuit:



R_T = 5Ω + 2Ω + 7Ω = 14Ω

RESISTORS IN PARALLEL:

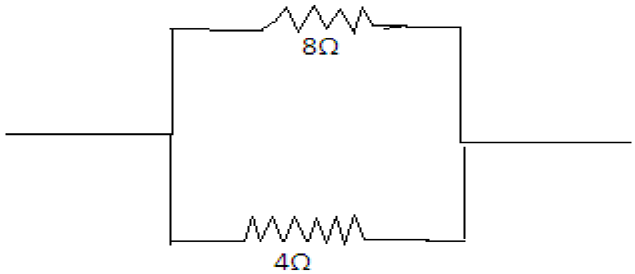
- The resistance of the resistors in parallel is found by the following equation:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_4} + ...+ \frac{1}{R_n}$$

- If only two resistors are used in parallel then the total would be given by the following:

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R_T = \frac{R_1 x R_2}{R_1 + R_2} = \frac{\Pr oduct}{sum}$$

Example: Work out the total resistance in the following:



$$\Rightarrow R_T = \frac{R_1 x R_2}{R_1 + R_2} = \frac{8\Omega x 4\Omega}{8\Omega + 4\Omega} = \frac{32\Omega^2}{12\Omega} = 2.67\Omega$$

- If two resistors of **equal resistance are joined in series** then the total resistance would just be **twice the value of resistance of one of the resistors**.
  E.g. Given that an 8Ω resistor is joined in series with another 8Ω resistor, find the total resistance. **$R_T = 2 R_1 = 2 R_2 = 2 \times 8\Omega = 16\ \Omega$**
- On the other hand, **if two resistors of equal resistance are joined in parallel** then the total resistance is **just half the resistance of one of the resistors**.
  Given that the same resistors above are joined in parallel to each other what would be the total resistance? **$R_T = (8 \times 8)/ (8 + 8) = (64 /16) = 4\Omega$ which is just half of 8Ω.**

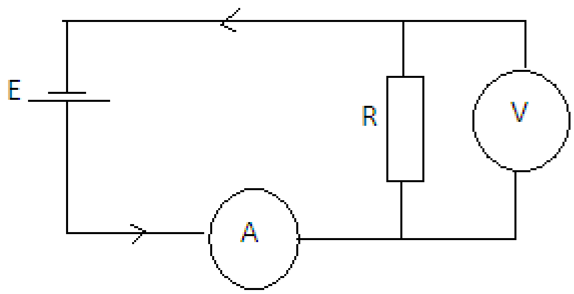
INTERNAL RESISTANCE OF A CELL:

- Practically, it is found out that chemicals inside a cell have a small resistance of their own. This is called internal resistance of a cell. This implies that some voltage (potential difference) gets used up inside the cell.
- Denoting the internal resistance by r one would have the following equation:

  $E = Ir + IR = v + V \Rightarrow r = \frac{E - V}{I}$.

  E is electro-motive force (emf).

  Refer to the figure below



The cell, in the figure above has an emf of 1.5V.The voltmeter reading is 1.35V. Ammeter records the value of the current as 0.3A. Calculate (a) the internal resistance of the cell and (b) the value of the resistance R.

a) $\Rightarrow r = \frac{E - V}{I} = \frac{1.5V - 1.35V}{0.3A} = 0.5\Omega$

b) Since E = Ir + IR then $R = \frac{E - Ir}{I} = \frac{1.5V - 0.3Ax0.5\Omega}{0.3A} = 4.5\Omega$.

FAST FACTS:

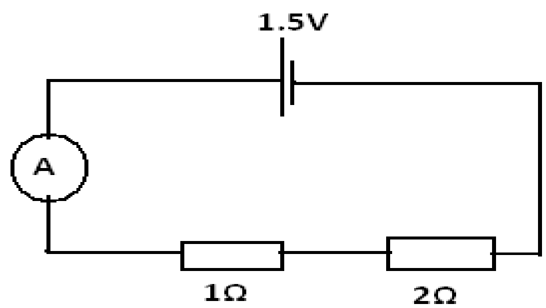
1) **Current in series circuit is the same**
2) **Voltage in series circuit is shared across components**
3) **Current in parallel circuit is shared at junctions**
4) **Voltage across components in parallel circuit is the same**

ADVANTAGES OF PARALLEL CIRCUIT OVER SERIES CIRCUIT

a) Components work independently
b) If a component is faulty, the other components still work
c) In case of bulbs, addition of more bulbs has no effect on brightness of the others

CIRCUIT PROBLEMS

1. The fig below shows a circuit



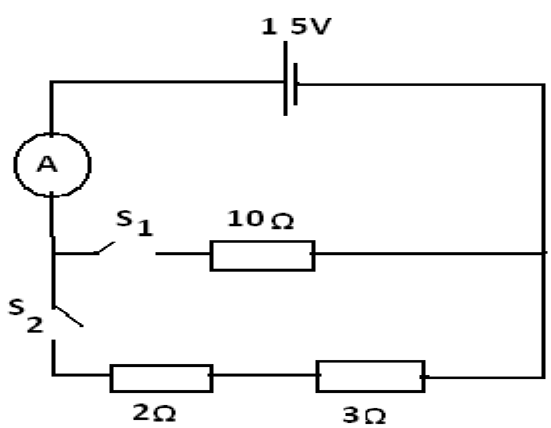
Work out the following

a) Ammeter reading
b) Voltage across each of the resistors

a) R_T = 1Ω+2Ω=3Ω so $I = \frac{V}{R} = \frac{1.5V}{3\Omega} = 0.5A$

b) Across 1Ω resistor V = IR= 0.5A x 1Ω =0.5V and Voltage across 2Ω resistor =IR = 0.5A x 2Ω= 1V

2. Use the circuit below



Work out **the ammeter reading** when

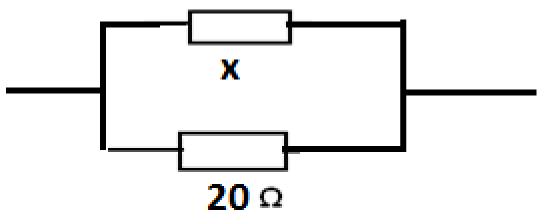
a) **S1 is open and S2 is closed**
b) **S1 closed and S2 open**
c) **Both S1 and S2 are closed**

a) $$I = \frac{V}{R} = \frac{15V}{(2+3)\Omega} = 3A$$

b) $$I = \frac{V}{R} = \frac{15V}{10\Omega} = 1.5A$$

c) $$R = \frac{10x(2+3)}{10+(2+3)} = \frac{10x5}{10+5} = \frac{50}{15}\Omega \quad I = \frac{V}{R} = \frac{15V}{\frac{50}{15}\Omega} = 4.5A$$

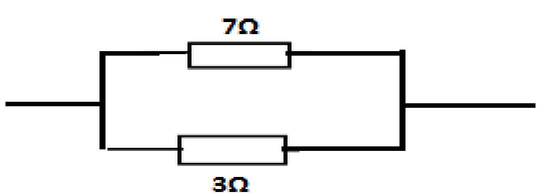
3. If the total resistance is 4Ω, find the value of resistance x in the set up below



Ans: 5Ω

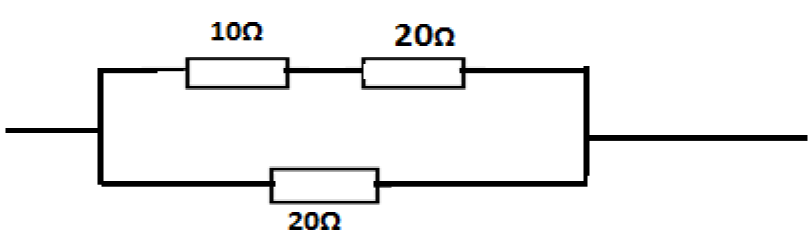
4. **Find the total resistance in the following circuits**

e.



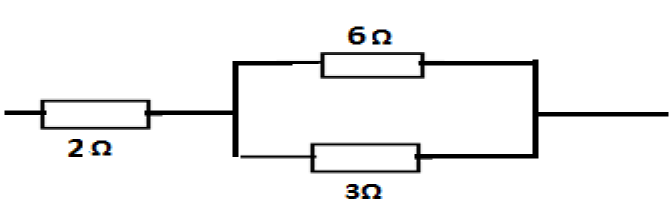
Answer : 2.1Ω

f.



Answer: 12Ω

g.



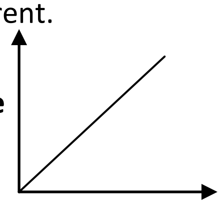
Answer: 4Ω

<u>FACTORS THAT AFFECT THE RESISTANCE OF A CONDUCTOR (WIRE):</u>

- There are four factors that affect the magnitude of resistance in a conductor and these are: **<u>length</u>, <u>temperature</u>, <u>thickness of the wire</u>** and **<u>type of material</u>** from the conductor is made.

a) <u>Length:</u>

- The longer the wire the higher the resistance and vice-versa. IF the wire is longer, the electrons bump or collide into each other for a long distance hence having a huge effect on the resistance. This consequently, reduces current flow. **Thus, the resistance and the length of wire are directly proportional to each** other but both inversely proportional to the current.



Resistance (Ohms)

Length (cm)

b) <u>Temperature:</u>

- The higher the temperature, the higher the value of the resistance. This is attributed to the fact that increased temperatures cause rapid vibration of ions within the wire. This results into more collisions with the electrons. However, temperature increases decreases the resistance of semi-conductors.

c) <u>Thickness (Cross-sectional area):</u>

- The thicker the wire the lower the resistance and the thinner the wire the higher the value of resistance. Thus, the thickness of a conductor is inversely proportional to the resistance. This is so because in a thicker wire there is more space for electrons to pass through hence electrons experience minimal collisions.

d) <u>Type of material from which the wire is made:</u>

- Materials do vary in how they oppose flow of electrons. For instance, copper has low resistance while nichrome has high resistance. This property determines how best the materials are used.

<u>COLOR CODES FOR RESISTANCE:</u>

- This involves use of colored bands to indicate value of resistance.
- **<u>The first color gives the first digit, the second color second digit, third color is a multiplier (it gives number of zeros) and the forth digit if any, gives tolerance.</u>**
- THE tolerance refers to how the actual value differs from the given value of resistance.
- The following are some figures of tolerance:

  None = $\pm$20%   Silver = $\pm$10%Gold =$\pm$ 5%Red = $\pm$2%Brown =$\pm$ 1%.

- The colors black, brown, red, orange, yellow, green, blue, violet, grey and white represent digits from 0 to 9 respectively.

- The colors are encompassed in the following statement: "**Black Boys Raped Our Young Girls But Violet Gave willingly.**"

COLOR	**Black**	**Brown**	**Red**	**Orange**	**Yellow**	**Green**	**Blue**	**Violet**	**Grey**	**White**
DIGIT	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

- For example:

  a. Give the resistance represented by the color code on the following resistor

  Red, Yellow, Red, Silver

  Answer: 2400Ω ± 10%

  b. Use color codes to represent the resistance of a resistor below:

  460000Ω ± 5%

Answer: Yellow, Blue, Yellow, Gold.

PRINTED CODES (STANDARD NOTATION):

- Letters R, K and M are used. R is for unit, K for kilo or thousand and M for mega or million.
- The position of the letter signals presence of a decimal point.
- Tolerance values are: **F = ± 1%, G = ± 2%, J = ± 5%, K = ± 10% and M = ± 20%.**
- Examples:

PRINTED CODES	**RESISTANCE VALUE**
7R6	**7.6Ω**
6K2J	6.2KΩ ± 5%= 6200Ω ± 5%
R8G	0.8Ω ± 2%
4M8K	4.8MΩ ± 10%= 4.8 X 10^6 Ω ± 10%
M7	0.7MΩ = 7 X 10^5 Ω
3RF	3Ω ± 1%

ELECTRICAL POWER:

- This is the rate at which electrical energy is transferred to other forms of energy.
- It can also be defined as the rate of using up electrical energy.
- Thus, power = (Work done)/(Time) = (Energy transferred)/ (Time(taken).
- The SI unit of power is Watt. 1 Watt = 1J/s. 1KW = 1000W.
- **Power = Voltage x current = VI**
- If a bulb has a power rating of 75W, it means the bulb as a transducer, converts 75 Joules of electrical energy into heat energy and light energy.
- Since P = VI and from Ohm's Law V = IR then P = (IR) I = I^2 R and P = V (V/R) = V^2/R

  Given Voltage and Current $P = VI$

  Given Current and Resistance $P = I^2 R$

  Given Voltage and Resistance $P = \frac{V^2}{R}$

- Examples.

a. Calculate the maximum power of an electrical appliance that can be connected safely to 13 A 240V mains socket.
Given I = 13A and V = 240V P = VI = 13A x 240V = 3120W = 3.12 KW.

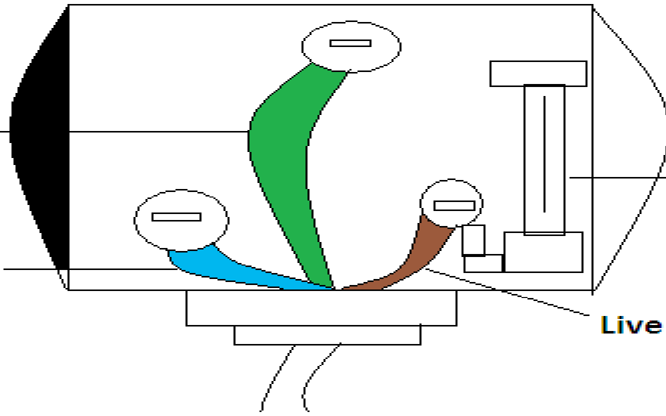
b. A 3KW electric fire is designed to be run on a 250V supply. Assuming it is operating at a correct voltage calculate the current it will draw from the mains and the resistance of the element of the fire.
   - Given P = 3KW = 3000W and V =250V.
     P =VI then I = P/V = 3000W/250V = 12A.
   - $P = V^2/R$ then $R = V^2/P = 250^2/3000 = 20.8\Omega$ or use V = IR then R = V/I = $250/13 = 20.8\Omega$

COST OF EECTRICAL ENERGY:

- The electricity going into a consumer destination passes through a kilowatt- hour meter. This meter measures and records the electrical energy a customer uses in Kilowatt-hours.
- A Kilowatt-Hour is the total electrical energy that is spent for one hour at a constant rate of 1KW or 1000W of power.
- For example a 1000W heater turned on for one hour would consume 1KWh of electrical energy. A 100W lamp left for 10 hours would also consume 1KWh of the electrical energy.
- **The 1KWh of electrical energy is called a "unit"**
- Example: A fridge with a power rating of 150W operates for 12 hours. Work out the cost of using the electricity if 1 unit of electrical energy costs K10.
  Electrical energy = power (KW) x time (hrs) = (150/1000) KW x 12 hrs = 1.8KWh.
  Therefore, there are 1.8 units of electrical energy. Since 1 unit cost K10 then 1.8 units will cost more. **The Cost = 1.8 units x K10/unit = K18.00.**

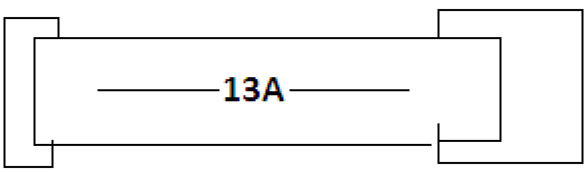
SAFETY OF USING ELECTRICITY:

- It is recommendable to use three pin plugs when using power.
- A three pin pug has a live pinconnected to a live wire, earth pin connected to an earth wire and a neutral pin which is connected to a neutral wire.
- A live wire has highest potential difference, carries current and is connected to a fuse. It is brown in color (old color red)
- A neutral wire is at 0V and it just completes circuits. It is blue in color (old color black)
- An earth-wire is for safety purpose. It is green yellow (old color green). It is connected to a metal chassis of an appliance and the other end is buried in earth. It provides a passage for electrons into the earth in case of short circuits. The earth is a bank of electrons.



A THREE PIN PLUG

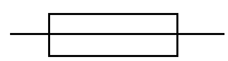
- **A fuse** is a small metal alloy which has a low melting point. It breaks circuit when too much current flows through it hence protecting appliances from damage.
- **Fuse rating** is the description of the highest current value a fuse can allow before melting. Many available fuses have a fuse rating of 13A, 3A, 1A, 10A etc.



Fuse

Cicuit symbol

Or



MAGNETISM:

- Magnets are objects which have the ability to attract other objects. Usually these objects contain iron or steel.
- Materials that get attracted by magnets are Ferro-magnets. Examples of Ferro-magnets are cobalt, nickel, gadolinium, dysprosium etc.

Magnetic poles:

- These are places in the magnets to which magnetic materials are attracted. They are found near the ends and they occur in pairs of equal strength.
- Magnetic attractions are stronger in the poles.
- **North Seeking pole (N-pole):** This always points roughly towards the Earth's North Pole.
- **South Seeking pole (S-pole):** This always points roughly towards the Earth's South Pole.
- **Like poles repel and un-like poles attract each other**.

Types of Magnetic materials:

a. Soft materials:

- These are materials that are magnetized easily but they also lose their magnetism so easily e.g. soft iron.

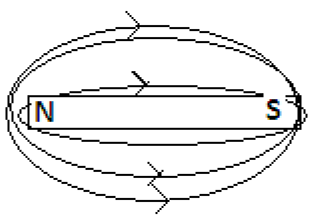
- Magnets produced by soft materials are temporary.

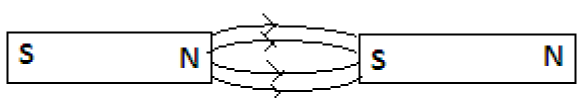
b. **<u>Hard materials</u>**:
- These are materials that get magnetized slowly and slowly they lose their magnetism e.g. hard steel.
- Magnets produced by hard materials are permanent.
- Magnetism that get induced in iron is temporary where as that which gets induced in steel is permanent.
- Magnets can be of different shapes and strength depending on the use. There are bar magnets, horse shoe magnets, loud speaker magnets etc.

<u>Magnetic field:</u>

- This is a region around a magnet where a magnetic force is experienced by an object placed in the region.
- The magnetic field is represented on paper by a set of lines which are referred to as field lines.
- The density of the field lines indicates the intensity of the magnetic field.
- Magnetic field lines can be mapped by **<u>using iron filings or using a small plotting compass</u>**
- Note the following facts:
  - **a.** The pattern of each side is symmetrical.
  - **b.** The magnetic field lines seem to originate from the North Pole to the South Pole.
  - **c.** The field lines are more concentrated at the poles
  - **d.** The magnetic field lines seem to come together at the poles (but not right at the ends).

<u>Examples of magnetic field diagrams:</u>

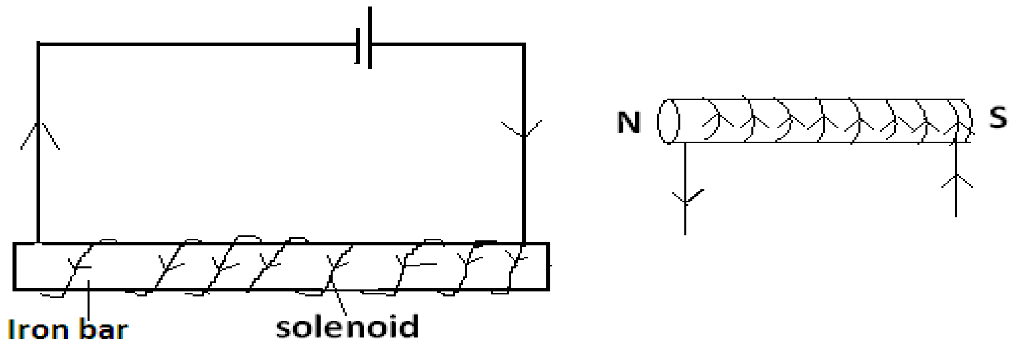




<u>MAGNETIZATION (MAKING OF MAGNETS):</u>

a. **<u>By Electrical Method:</u>**
- This involves placing a magnetic material in a solenoid. A solenoid is a cylindrical coil of wire carrying current.
- Magnets which can be controlled by the flow of electric current are called electromagnets. Their magnetism is temporary and is used in places where strong magnets are needed and permanent magnets would not be suitable.
- Materials which are frequently used in solenoids of electromagnets are **iron** and **nickel alloy** which lose their magnetism once current is switched off.
- <u>The **Polarity**</u> (which side is north or south) can be determined by looking at how the coil has been hooked.

The right hand grip rule predicts which end will be the North Pole.



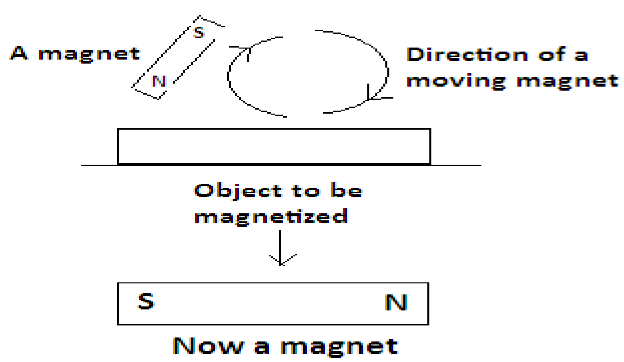
- Reversing the current direction reverse the polarity of the magnet.
- The **<u>Strength of the electromagnets</u>** can be affected by the following:
    i. **<u>number of wire coils:</u>**
    The higher the number of wire coils the stronger the magnet.
    ii. **<u>Size of the current:</u>**
    The larger the current size the stronger the magnet.
    iii. **<u>Distance between the poles:</u>**
    The closer the poles are, the stronger the electromagnet.

b. <u>By Stroking Method:</u>

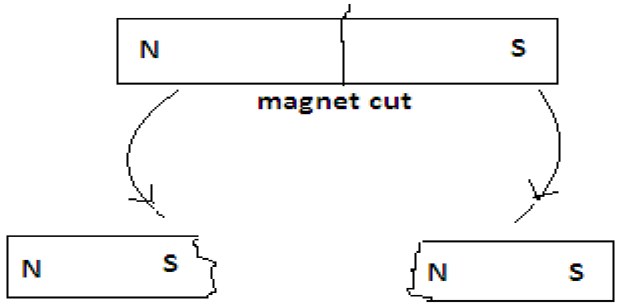
- There are two stroking methods namely;
    i. **<u>single stroking</u>**
    ii. **<u>Double (divided) stroking.</u>**

I. <u>Single stroking:</u>

- Stroking means making gentle caressing movements.
- This method involves moving one bar magnet repeatedly, in the same direction above an object to be magnetized.



- The polarity of the yet to be produced magnet would be in a way that the end will have a pole opposite to the pole near it.
- If a magnet is snapped into half, both halves will have north and north seeking poles and would each be a complete magnet.



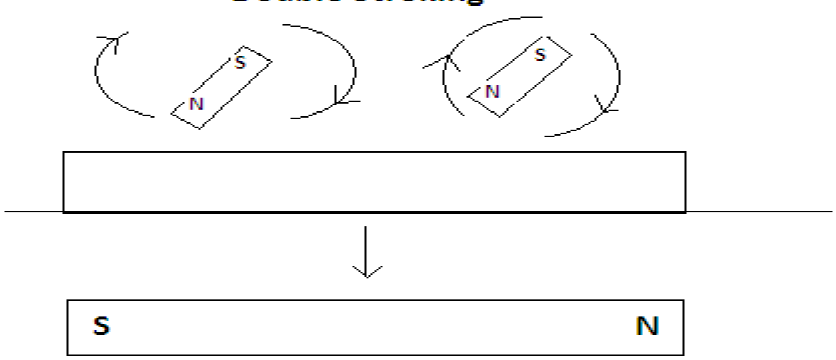
Two new magnets formed

II. **Double stroking:**

- This is done by stroking two magnets from the Centre outwards with unlike poles of the magnets at the same time. The magnet s must be lifted high above the steel at the end of each stroke in both methods.
- The pole produced at the end of the steel where the stroke ends is opposite to that of the stroking pole.

Note:
The above methods technically, cause alignment of small magnets within a magnetic object. These are called domains. In non-magnetic materials these domain are not well arranged. The magnetism effect is canceled out.

Double Stroking



DEMAGNETIZATION OF MAGNETS:
This entails that magnets can lose their magnetism through different ways. Some of them are discussed.

a) **Heating:**
This results into the destruction of the alignment of the tiny magnets (domains).

b) **Hammering (hitting):**
This also causes de-arrangement of the domains inside the magnets.

c) **Use of alternating current:**
This involves placing the material inside a solenoid through which an alternating current is flowing. When the current is slowly reduced to zero, the magnet becomes de-magnetized.

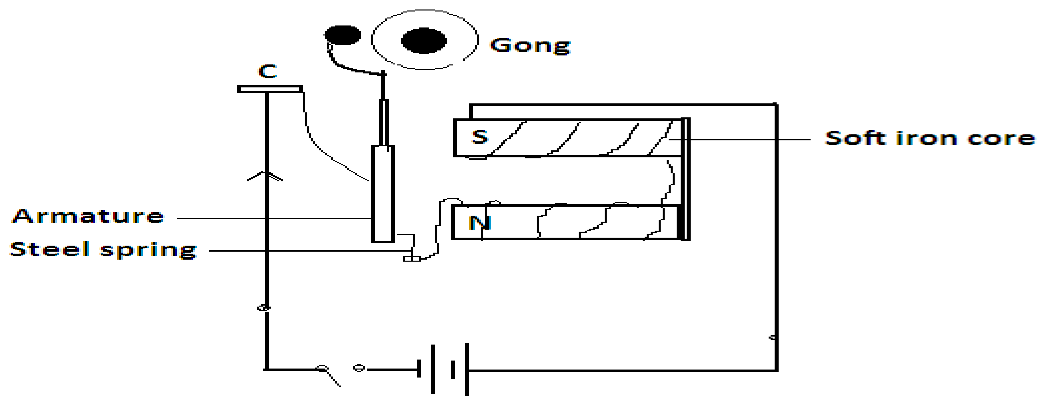
d) **Stopping current flow:**

One, needs electricity for electro-magnets to be produced hence stoppage of current flow leads to loss of magnetism.

The knowledge on how magnets lose their magnetism is vital because one is able to figure out ways of taking care of the magnets. Normally, the magnets have to be kept in a wooden box, and avoid dropping the magnets down.

USES OF ELECTROMAGNETS:

a) **Electric bell:**



AN ELECTRIC BELL

- The soft iron cores are wound so that they have opposite polarity. The soft iron armature is attached to the steel of the spring.
- When a switch is on, the charge flows; the soft iron cores become magnets and attract the armature, ringing the bell in the process.
- As the contact is broken the armature moves down the magnet at C and the current is automatically switched off. The soft iron bars lose their magnetism and the armature is no longer attracted. The steel spring causes the armature to spring back and remake the contact at C. This switches on the current and the cycle is repeated.

b) **Magnetic relay switches**

This device uses one circuit to switch on another. They may also be used to control circuits carrying the currents. This operation hugely depends on the magnetism.

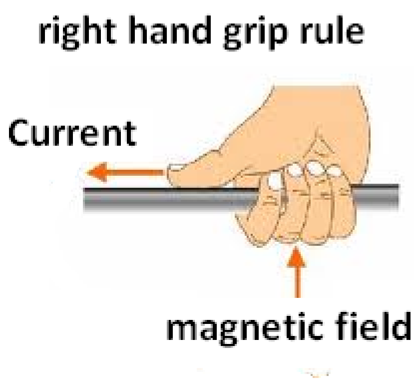
c) **telephone ear piece**

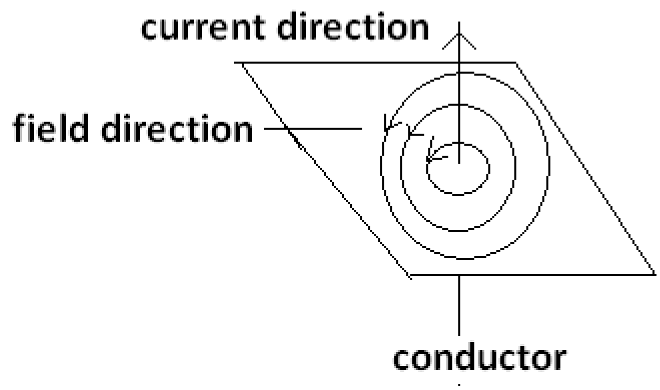
d) **loud speakers**

e) **Lifting of scrap metals.**

FORCE ON A CONDUCTOR IN A MAGNETIC FIELD:

- When an electric current flows through a wire or a cable **a magnetic field** forms around the wire.
- The field or flux pattern around a current carrying wire is a series of concentric circles.
- The direction of the magnetic field can be found by using the **Right Hand Grip rule**. I.e. if **the fingers of the right hand grip the wire with the thumb pointing in the direction of current, the curl of the finger show the direction of the magnetic field.**



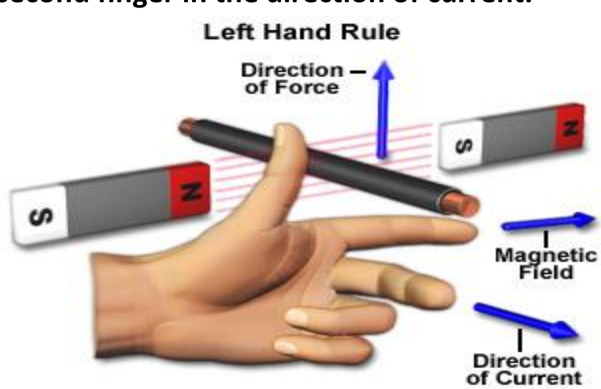


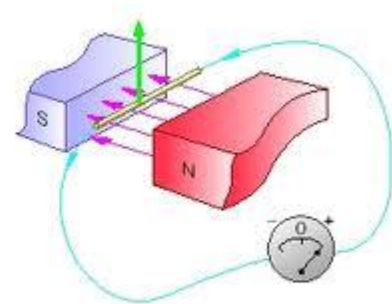
- The direction of the field can also be predicted by the **<u>Maxwell's right handed screw rule</u>**. "**<u>If a right handed screw moves forward in the direction of current (conventional), the direction of rotating of the screw gives the direction of the filed.</u>**
- The field can be made stronger if the wire is formed into a coil (solenoid)
- When a current carrying wire is placed in a magnetic filed it experiences a force.
- The magnitude of the force depends on two factors:

I. **<u>Field strength</u>**:
As the magnetic field strength increases, the force also increases.

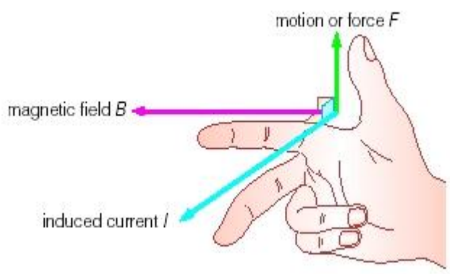
II. **<u>Current size</u>**:
As the current increases so too does the force.

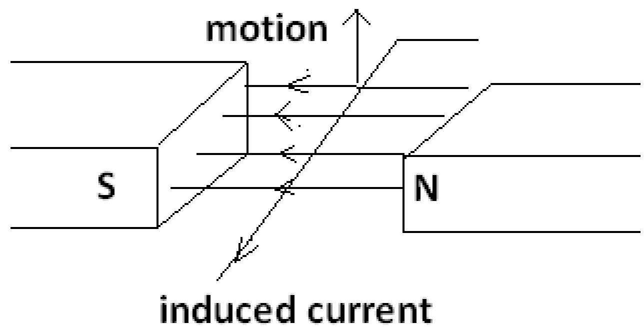
- The direction of the force (which is also the direction in which the wire moves) depends on the direction of the current and direction of the magnetic field.
- The direction of the force can be predicted by **FLEMING'S LEFT-HAND RULE (MOTOR RULE).**
- **The above Left hand motor rule states that " Hold the first finger, second finger and the thumb of the left-hand mutually at right angles so that the First finger points in the direction of the Field, the Thumb in the direction of motion (Thrust) then the second finger in the direction of current."**





Right hand grip rule (dynamo rule)





The rule above gives the direction of induced current.

ELECTRIC MOTOR:

- In a motor current passes through the coil and the resulting force on the coil causes it to rotate. The direction of motion is determined by Fleming's Left hand Rule.
- A split ring (commutator) reverses the direction of current every half the revolution, thus ensuring a continuous rotation.
- The size of the turning couple on the armature of a motor may be increased in the following ways.

I. Increasing the magnetic field strength by using stronger magnets.
II. Increasing the number of turns on the coil
III. Increasing the current size.
IV. Increasing the area of the coil.

- The largest couple act when the coil is moving at right angles to the magnetic field. The greater the couple, the faster is the turning of the motor.
- In electric motor soft materials such as carbon or phosphor bronze "brushes" are used to make contact with the commutator segments as they rotate.
- The brushes tend to wear out with time much more quickly than the harder copper of commutators and as such they must be replaced.

ELECTRO MAGNETIC INDUCTION:

- When loop of wire is moved at right angles through a magnetic field a potential difference is created across the ends of the wire and small current flows.
- The potential difference produced in this way is called induced emf and the current is called induced current.
- **Electromagnetic induction can be defined as production of electric current using magnetism**.

Factors that affect the size of induced emf and current:

i. **Speed of the wire coil:**
The faster the coil moves the greater the emf and current induced.

ii. **Strength of the magnetic field:**

Stronger fields produce large emf and currents.

iii. **Number of turns in the coil:**
Increasing the number of wire passing or cutting through the magnetic field increases the emf and the induced current.

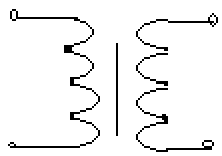
iv. **Area of the coil:**
Increased area of the coil produces high emf and current.

USES OF ELECTROMAGNETIC INDUCTION:

- The ability to produce an emf by changing the magnetic field can be used in different ways like production of electricity using generators and in transformers.

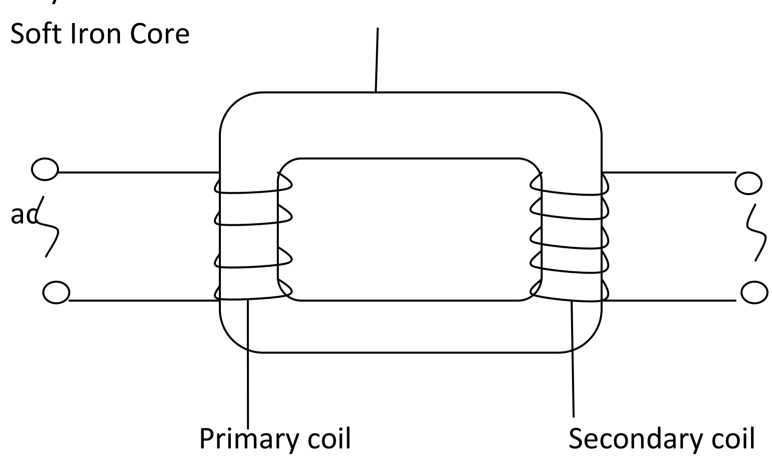
TRANSFORMER:

- It is an electrical device by which alternating current of one voltage is changed to another voltage.
- The circuit symbol of transformer is



HOW A TRANSFORMER WORKS:

- An alternating current is fed into the primary coil and it creates a magnetic field in it. The alternating magnetic field cuts through the secondary coil generating an induced alternating voltage across the secondary coil. The current from the secondary coil is therefore an alternating current.
- As the secondary voltage is made bigger the secondary current gets smaller because the transformer can increase voltage but not power.
- Alternating current (a.c) means current that changes direction of flow. (It goes negative then positive then negative and so on.) The opposite, is direct current, dc which is a one way current.



TRANSFORMER EQUATIONS:

1. This relates the ratio of voltages and number of turns:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$ Where

V_s	Voltage in the secondary coil
V_p	Voltage in the primary coil
N_s	Number of turns in the secondary coil
N_p	Number of turns in the primary coil

2. It gives relationship among currents and voltages in the secondary coil and primary coil of the transformer.

   $$\frac{I_s}{I_p} = \frac{V_p}{V_s}$$ Where $I_s$is the current in the secondary coil and I_p is the current in the primary coil.
3. Assuming that the transformer is ideal (there is no any power loss) then
   Power in = Power out or Power in the primary = Power in the secondary coil.

   Since P =VI then $V_p x I_p = V_s x I_s$

- Efficiency of a transformer refers to how well a transformer works. If loss of power is zero the transformer is ideal or perfect otherwise power loses are inevitable. Usually the power in the primary coil is greater than the power in the secondary coil.
- Efficiency = (Power output)/ (Power input) = (V_sI_s)/ (V_pI_p).
- %efficiency = $\frac{V_s I_s}{V_p I_p} x100\%$

<u>**TURNS RATIO**</u>: This is the ratio of number of turns in the primary coil to the number of turns in the secondary coil
Thus Turns ratio = N_p/N_s.

<u>**TYPES OF TRANSFORMERS**</u>:

- There are two types of transformers which are <u>**step up transformer**</u> and <u>**step down transformer.**</u>
- The <u>Step-up</u> transformer has more turns in the secondary coil than in the primary coil. It also has higher secondary voltage than the primary voltage.
- The <u>Step-down</u> transformer has more turns in the primary coil than in the secondary coil. In addition, there is a larger primary voltage than secondary voltage.

Examples:

1. A transformer with 2000 turns in its primary coil has a primary voltage of 120V. If there are 6000 turns in the secondary coil, work out the secondary voltage, assuming that the transformer is 100% efficient. What type of transformer is this?

Solution:

$N_p = 2000$ $V_p = 120V$ $N_s = 6000$.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow V_s = \frac{N_s}{N_p} x V_p = \frac{6000}{2000} x120V = 360V$$

Type of transformer: Step-up.

2. a. Calculate the number of turns of the secondary of the step down transformer, which would enable a 12V bulb to be used with a 240V a.c mains power, if there are 480 turns on the primary.

   b. What current will flow in the secondary when the primary current is 0.5A? Assume there are no energy loses. (Duncan T, 1977 page 211; 2nd Ed.)

   Solution:

a. N_p= 480 V_s= 12V, V_p = 240V

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \Rightarrow N_s = \frac{V_s}{V_p} xN_p = \frac{12}{240} x480 = 24$$

Thus, there are 24 turns in the secondary coil.

b. I_p = 0.5A

$$V_p x I_p = V_s x I_s \Rightarrow I_s = \frac{V_p I_p}{V_s} = \frac{240x0.5}{12} = 10A$$

3. A 240V mains transformer has an efficiency of 90% and is used to light normally a 12V-36W lamp. Work out

a. The power in the primary coil.
b. The current in the primary coil.

Solutions:

a. V_p = 240V, V_s = 12V P_s = 36W %E= 90%.

$$\%E = \frac{P_s}{P_p} x100\% \Rightarrow \frac{36W}{P_p} x100\% = 90\% \Rightarrow P_p = \frac{36Wx100\%}{90\%} = 40W.$$

b. P = VI

   $P_p = V_p I_p$ therefore $I_p = P_p / V_p$ = 40W/240V = 1/6 =0.17A.

ENERGY LOSSES IN TRANSFORMER:

a. **Copper windings:**
   - The windings of copper wires have some resistance and as such some heat is produced by the currents in the wires.
   - Use of properly designed transformers may help in minimizing the energy loss in this form.

b. Eddy current loses:

- Eddy currents are currents due to fluctuation of magnetic field. The increase and decrease of the magnetic field results in the production of this eddy current since the core is also a conductor. These currents heat the core and energy is lost in the process.
- To reduce the effect of eddy currents the core is made from thin layers of soft iron glued together with an insulating material between the strips.
- So, eddy currents occur whenever pieces of metal are in a changing magnetic field e.g. transformer.

c. Flux leakage:

- All the field lines produced by the primary coil may not 'cut' the secondary coil especially when the core has air gaps or has been poorly designed. This loss of field lines can be minimized by inserting the gap with iron core and ensuring that the transformer is properly designed.

d. **Magnetization and demagnetization of the core**:

- Using soft iron for the design of the core reduces the losses to minimum.

TRANSMISION OF ELECTRICAL POWER:

- Electricity is transmitted at high voltage (high turns) and at low current so as to reduce the heating of cables through resistance.
- This result form the fact that power is given by the equation $P = I^2R$.
- A transformer is used to step up the power station voltage to over a quarter of a million volts. This makes the current smaller. The voltage is stepped down again when it reaches consumer points in towns and villages.

DIFFERENCES BETWEEN DIRECT AND ALTERNATING CURRENT:

1. In direct current (d.c), electricity always flows in one direction (along the same path) while in alternating current (a.c) the current direction changes regularly.
2. Cells and batteries provide d.c while the mains supply is a.c, alternating at frequency of 50 cycles per second (50Hz).

ADVANTAGES OF AC OVER DC:

1. Voltages can be stepped up or down using transformers.
2. AC is easier and cheaper to generate than DC.
3. On a large scale it can be generated more efficiently than the one way DC.

9. ELECTRICTY 2 (ELECTRONICS).

OBJECTIVES:

By the end of this chapter learners should be able to:

- ❖ Explain the meaning of band theory
- ❖ Explain the meaning of semiconductors
- ❖ Discuss uses of semiconductors (diodes, transistors etc).

BAND THEORY:

- When large numbers of atoms are together as they are in a crystal, the energy levels spread into bands.
- Each band contains a large number of levels and these are so close together that in effect, there is a continuous range of energies available to the electrons.
- The energy bands are separated by gaps in which there are no available energy levels.
- If an electron is to take part in the conduction of an electric current it must be capable of being accelerated by an applied voltage and so must be capable of being raised to a slightly higher energy level.
- A material can therefore conduct electricity only if some of its electrons are in a band which does not contain its full quota of electrons.

SEMICONDUCTORS:

- These are materials which conducts electricity partially.
- Their conductivity is higher than that of insulators and less than those of conductors.
- Examples of semiconductors include Silicon (Si), Germanium (Ge), Antimony (Sb), Indium (In), Arsenic (As) etc.
- Electrical resistivity of semiconductors decrease with an increase in temperature.
- Insulators and semiconductors differ only in that all insulators are semiconductors at high temperatures and all semiconductors are insulators at low temperature.
- The conductivity of semiconductors is affected by the presence of impurities.

TYPES OF SEMICONDUCTORS:

1. **Intrinsic semiconductors:**

- These are semiconductors whose conductivities arise due to properties of the atoms in them.
- They are also called pure semiconductors.
- Some electrons in intrinsic semiconductors are held less tightly than other.

2. **Extrinsic semiconductors:**

- These are semiconductors which are obtained by doping.
- **Doping** is the process of adding minute quantities of substances called impurities.
- The importance of doping is that conductivity of the semiconductor is greatly improved.
- The doping process leads to two types of extrinsic semiconductors which are:
    - **N-types semiconductor.**
    - **P-type semiconductor.**

a. **N-type semiconductor:**

- This is a type of extrinsic semiconductors whose conductivity is due to presence of an extra electron.

- It is done by doping a semiconductor with 4 electrons in the valence shell by a penta-valent atom (an atom with 5 electrons in the valence shell).
- If for example, silicon is doped with phosphorous one of the electrons in the phosphorous is not included in the lattice bonding. This results in more free electrons in the semiconductor which in turn increases conductivities several times.
- Since the majority of the charge carries are electrons with a negative charge then these semiconductors are called **n-type semiconductors (n means negative).**

b. P-type semiconductor:

- This is due to absence of electrons which implies presence of a positive hole.
- It is obtained when an atom with four electrons in the valence shell is doped with a tri-valent atom (an atom with 3 electrons in the valence shell).
- For example, when silicon is doped with boron there will be 7 electrons in the lattice bonding and this missing of an electron results in positive holes.
- Since the majority of charge carries are positive holes they are called **p-type semiconductors (p means positive).**
- Impurities which release free electrons are called donors (e.g. arsenic, antimony and phosphorous) and those that receive the free electrons are called acceptors (e.g. indium, gallium and boron).

USES OF SEMICONDUCTORS:

- Semiconductors have got wide application in the electronics industry.
- They are used in designing of diodes, transistors, thermistors and also in integrated circuits.

DIODES:

- A diode is a two terminal, one way device which allows current to flow in one direction.
- The wire nearest the band is a called cathode and the other is called anode.
- The diode conducts when the anode is connected to the anode side of a cell or battery.

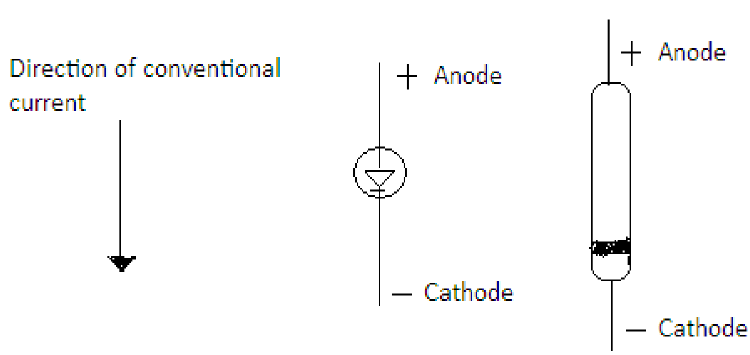
It is then said tobe **forward biased**. The resistance is small and current flows in the direction of the arrow of its symbol.

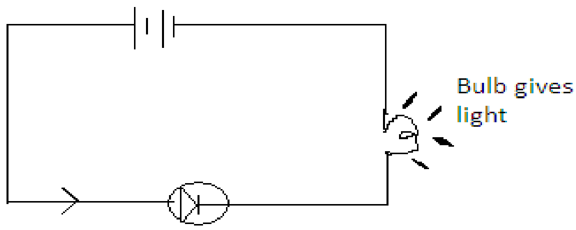
- When the diode is reversed is said to be **reverse biased** and there is a large resistance

and hence no conduction.

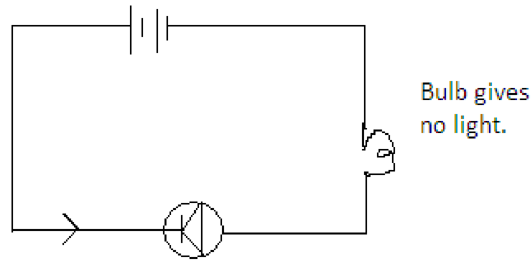
- In diodes, a singe crystal of silicon or germanium is doped in such a way that one half of

it is p-type and the other is n-type.





A diode forward biased.



A diode reverse biased.

USES OFDIODES:

a. As a current rectifier.

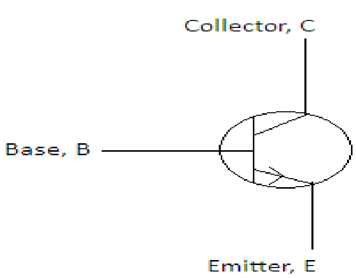
- It allows current to flow in one direction. This process is called rectification.
- Thus, rectification is the conversion of alternating current into a direct current.
- Use of a single diode results into a half wave rectification where by the original current value reduces to half.
- Use of a net-work of diodes called diode bridge leads to a full wave rectification.

b. As a resistor:

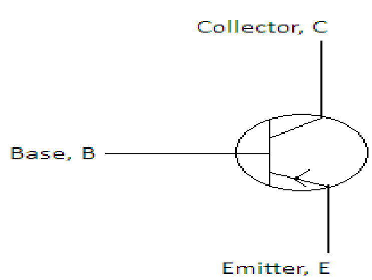
- Diodes can also be used as resistors. They limit current flow. Flow of current depends on how the diode has been connected to terminals of the voltage source which determines whether the diode is forward biased or reverse biased.

USES OF TRANSISTORS:

- A **transistor** is a semiconductor device used to amplify and switchelectronic signals and power.
- It has three connections; **base b, emitter, e and collector, c.**
- Most transistors are silicon n-p-n types. In this one a single crystal of a semiconducting material is doped in such a way that a piece of p-type is sand-witched between two pieces of n-type material.
- The **base-emitter junction** is normally forward biased and **the base collector** is reverse biased when the transistor is in use.
- The following is the circuit symbol of a transistor:



N-P-N
Forward biased



P-N-P
Reverse biased

- In a transistor there are two current paths
  I. base-emitter path
  II. Collector – emitter path.

- There are two types of transistors and these are:
  a. n-p-n type
  b. p-n-p type.
- The transistors are normally used in the following:

a. **<u>as switch:</u>**

- E.g.:
  I. Light sensitive switch
  II. Time-delay switch
  III. Temperature dependent switch
- This is the most important use of transistors. A transistor links circuits connected to each other so that current in one path controls that in the other path. I.e. they can be used as automatic switches such as relay.

  <u>Advantages of transistors:</u>

  Over other electrically operated switches:
  I. They are small
  II. They are cheap
  III. They are reliable
  IV. They have no moving parts
  V. Have indefinite life span once in a well-designed circuit
  VI. Can switch on and off million times in second.

b. **<u>As current amplifier</u>**.

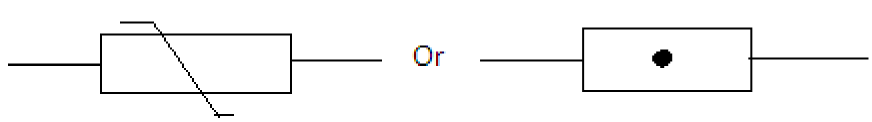
- An amplifier is a device that magnifies the input.
- Electronic amplifiers magnify small input signals and produce large signals. The input might be current or voltage.
- In case of a forward biased (n-p-n) transistor, $I_E = I_B + I_C$.

c. As voltage amplifiers:

- Amplifies are normally used to provide voltage amplification.

THERMISTORS:

- A thermistor a semi-conductor device which changes its resistance as the temperature changes
- As temperature increases the resistance of a thermistor decreases
- This property of the thermistor is used in sensing temperature changes as electronic thermistor in a refrigerator.
- The symbol for a thermistor is

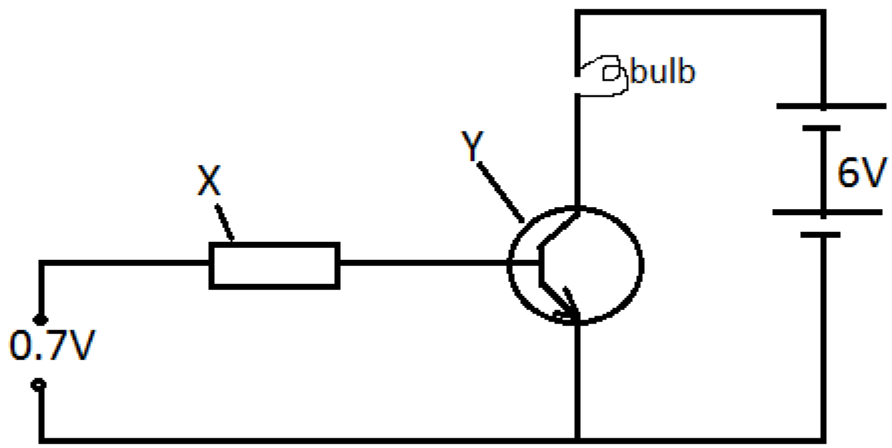


HOW THE TOPICS (ELECTRICITY AND MAGNETISM 1 & 2) HAVE BEEN FEATURED IN THE LAST 4 YEARS OF MANEB EXAMINATIONS

(Find some suggested answers in italics).

2015 No 2

a. **Figure below shows diagram of an electric circuit.**



(i) Name the part labeled X ***Answer: resistor***

(ii) State two uses of the device labeled ***Y Answer: as switch and as amplifier***

(iii) Explain the importance of the small base voltage in the circuit

Answer: it changes the behavior of the transistor (device Y). It removes the blocking effect hence switching it on

(iv) Which device could indicate that the current is flowing in the circuit?

Answer: the bulb

(v) Explain how the device mentioned in 2a(iv) works

Answer: when the small base voltage switches on the transistor current flows and the bulb gives light and when there is no any current in the base of device y, the transistor is off and current no longer flows hence the bulb gives no light.

b. **A transformer steps down voltage from 240V to 120V to operate a hair drier. Calculate the current in the primary coil if the current flowing in the hair drier is 10A**

The question did not give the efficiency of the transformer. Assuming it is 100%

$$V_p I_p = V_s I_s \Rightarrow 240 \times I_p = 120 \times 10$$

then

$$\therefore I_p = \frac{1200}{240} = 5A$$

c. Explain how leakage of magnetic field lines reduces the efficiency of a transformer

Answer: the leakage of field lines affects the voltage in the secondary coil and make it NOT proportional to the voltage in the primary coil

2014 No 6

a.

(i) What are semiconductors?

Answer: These are materials that conduct electricity partially

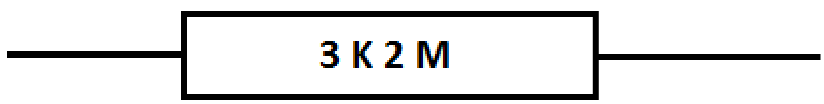
(ii) Name any two elements that can be used to dope silicon

Answer: Boron, phosphorous

b. Why does electrical resistance of metals increase as the temperature of the metal is increased?

Answer*: the increase in temperature causes huge vibration and hitting of free electrons with stationary positive nuclei. This slows down speed/flow of electrons*

c. Figure below shows a resistor whose resistance is indicated in standard notation



Work out its resistance in ohms

$$3.2K\Omega \pm 20\%$$
$$or\,3200\Omega \pm 20\%$$

2013.

6c calculate the current flowing in the primary coil of a 100% efficient transformer that steps down voltage from 240V to 20V if current flowing in the secondary coil is 10A

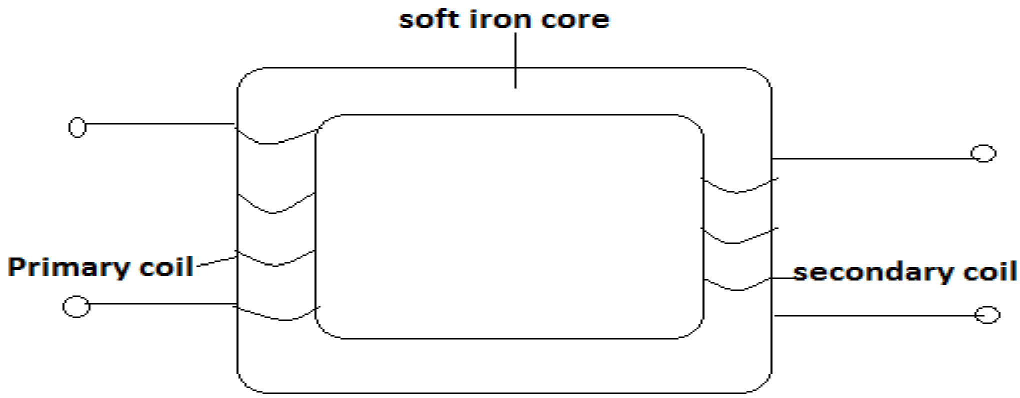
$$V_p I_p = V_s I_s$$
$$240 \times I_p = 20 \times 10$$
$$I_p = \frac{20 \times 10}{240} = 0.83A$$

7.

a. Mention any two factors that affect the efficiency of a transformer

- ***Production of eddy currents***
- ***Leakage of field lined / flux leakage***
- ***Resistance of wire windings***

b. With the aid of a well labeled diagram, explain how a step down transformer works



A step down transformer has more wire turns and higher voltage in the primary coil than in the secondary coil. It has a core made of iron for easy magnetization. When a voltage is applied to the primary coil, it magnetizes the iron core, which induces voltage in the other coil (called secondary coil) by cutting through the wire coils.

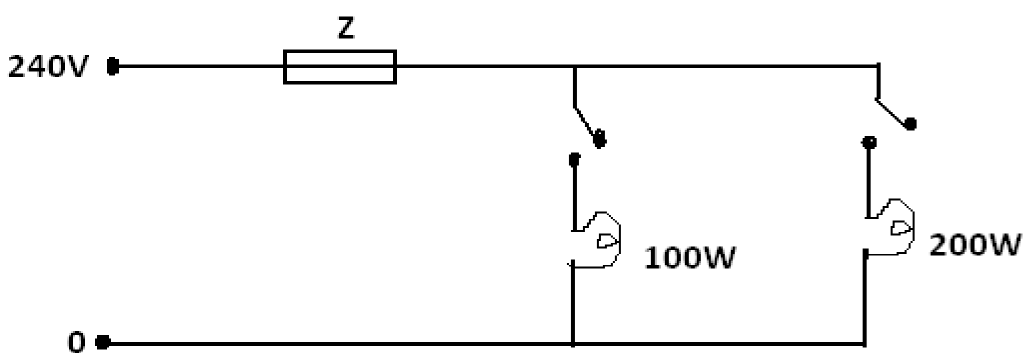
2012 2a State two ways of inducing electromotive force (emf)

- ***I. By moving wires coils up and down at right angles with a magnetic field***
- ***II. By moving a bar magnet into and out of a wire coils.***

b Mention any one application of electromagnet

functioning of an electric bell, designing of magnetic relay switches etc

c Figure below shows an electric circuit.



(i) What is the function of the part labeled Z?

To break the circuit when too much current flows

(ii) State any two advantages of the circuit above

- ***I. Components work independently***
- ***II. If a component is faulty, the other components still work***
- ***III. In case of bulbs, addition of more bulbs has no effect on brightness of the others***

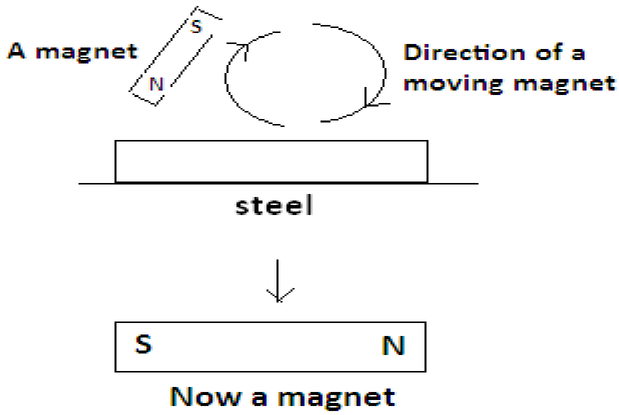
(iii) Which bulb would use more current if both switches were closed? ***The one rated 200W because in a second it will be converting 200J of electrical energy to heat plus light. (Has highest power which is directly proportional to current)***

d Calculate the power dissipated in an electric heater in which 4A of current flows when connected to a 230V supply

$$\boxed{P = VI = 4Ax230V = 920W}$$

8e. Explain how a piece of steel could be magnetized by single touch stroking method.

- This could involve moving one bar magnet repeatedly, in the same direction above the steel.



10.**<u>OSCILLATION AND WAVES</u>**

<u>Topic Objectives</u>

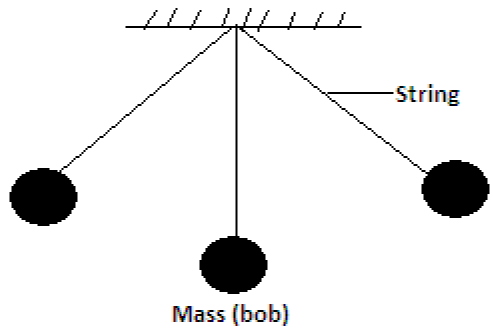
By the end of your interaction with this topic you should be able to:

- explain the term oscillation
- describe the characteristics of an oscillating system
- describe a wave
- Explain characteristics of a wave
- distinguish a transverse wave from a longitudinal wave
- describe wave properties
- use the wave equation in problem solving
- distinguish between a convex lens and a diverging lens
- determine the focal length of a converging lens
- explain image formation by a converging lens
- draw ray diagrams
- apply the lens formula in problem solving
- discuss functions of parts of a camera
- describe how a camera works

- ➢ draw comparison between a camera and an eye
- ➢ discuss parts of a projector and their functions
- ➢ describe how a projector works

Oscillation:

- it refers to a periodic motion in which a body retraces its path at equal time intervals
- It is also defined as a to and fro movement of an object.
- A periodic motion is observed in a simple pendulum which consists of a mass hung at the end of a string. refer to the fig below:



Characteristics of an Oscillating System

Characteristics of an oscillating system defers from properties of the oscillating system hence in this topic the words 'characteristics' and ' properties' should not be used interchangeably. The list of characteristics of an oscillating system includes:

- ❖ Amplitude
- ❖ period
- ❖ frequency
- ❖ wavelength
- ❖ speed

1. **Amplitude, A**
   - This is the maximum displacement reached by an oscillating system from its resting position.
   - the resting position is also known as an equilibrium position
   - The amplitude can be given in meters, centimeters or millimeters.
2. **Period, T**
   - This is the time taken for an oscillating system to complete one oscillation (cycle).
   - It can also be defined as the time taken for one complete vibration
   - The SI unit of period, T is the second (s)
3. **Frequency, f**
   - This is the number of cycles of an oscillating system per second.

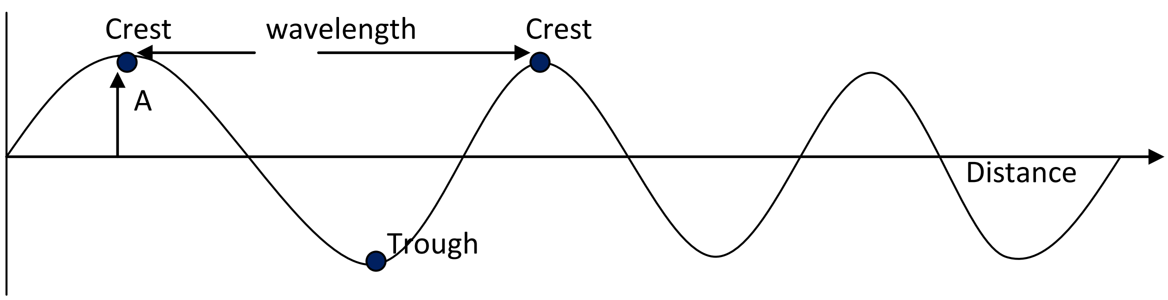
- the SI unit of frequency is the hertz (Hz)
- The period, T and the frequency, f are just reciprocals of each other. i.e. $f = \frac{1}{T} \Rightarrow$

$$T = \frac{1}{f}.$$

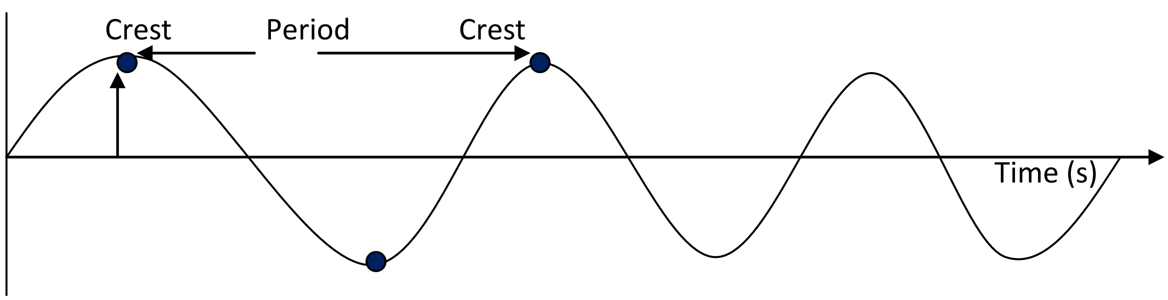
- For example, the escom's electricity is a.c and has a frequency of 50Hz. calculate its period. Solution : $T = \frac{1}{f}$. $\therefore T = \frac{1}{50/s} = 0.02\,seconds$. Note $1Hz = 1cycle/second$

4. **wavelength, λ**
   - This is the distance between two consecutive crests or troughs.
   - It is also defined as the distance between two consecutive particles in phase.
   - A crest is the highest point reached by a vibrating particle while a trough is the lowest point reached by the same.
5. **speed, v**
   - This is the distance moved by a crest or a trough or any point on the wave in one second. It's normally given in meters per second.

The figure below shows parts of a wave



Displacement against distance. A is the Amplitude



Displacement against time

WAVE EQUATION

If a particle spends t seconds in moving from one point to the other then the speed, v will be as follows:

$speed = \frac{dis\tan ce}{time}$ Now consider the distance from one crest too the next which is the wavelength and time taken from one crest to next which is the period then Speed= wavelength/period. I.e. $v = \frac{\lambda}{T}$ Since $T = \frac{1}{f}$. Then $v = \frac{\lambda}{\frac{1}{f}} \Rightarrow v = f\lambda$

Where v = speed in m/s

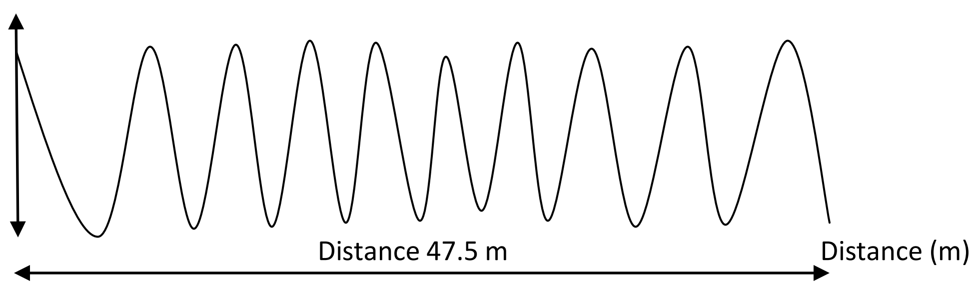
λ = wavelength in m

f = frequency in Hz

T = period in seconds.

Example 1

a.



I. Calculate the wavelength of the wave represented above.

II. If the period of the wave above is 10 seconds, what is the speed of the wave?

Solution:

I. there are $9\frac{1}{2} = 9.5$ complete waves hence wavelength = $\frac{47.5m}{9.5} = 5m$

II. $v = f\lambda$. Need to find the frequency. $f = \frac{1}{T} = \frac{1}{10s} = 0.1Hz$ thus

$$v = 0.1Hz x 5m = 0.5m/s$$

Example 2

A wave travels a distance of 50 cm in 5 seconds and the distance between two successive troughs is 2.0 m

Calculate

a. Velocity

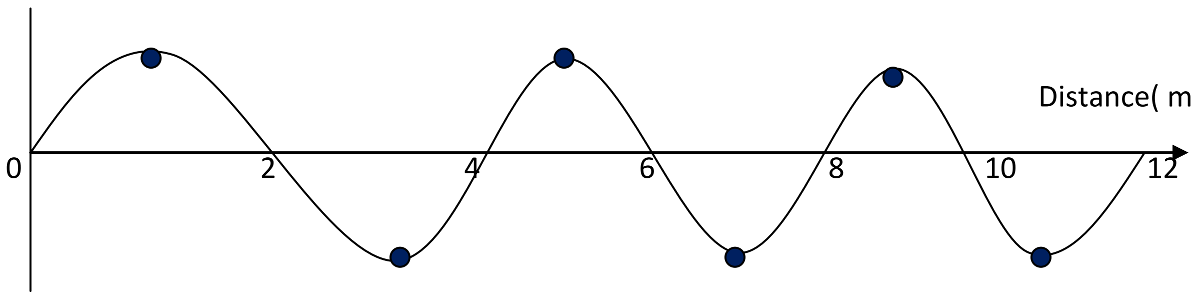
b. Frequency of the wave

Solution

a. $v = \frac{distance}{time} = \frac{0.5m}{5s} = 0.1m/s$

b. $v = f\lambda \Rightarrow f = \frac{v}{\lambda} = \frac{0.1m/s}{2.0m} = 0.05Hz$

Example 3.



Displacement against distance in meters

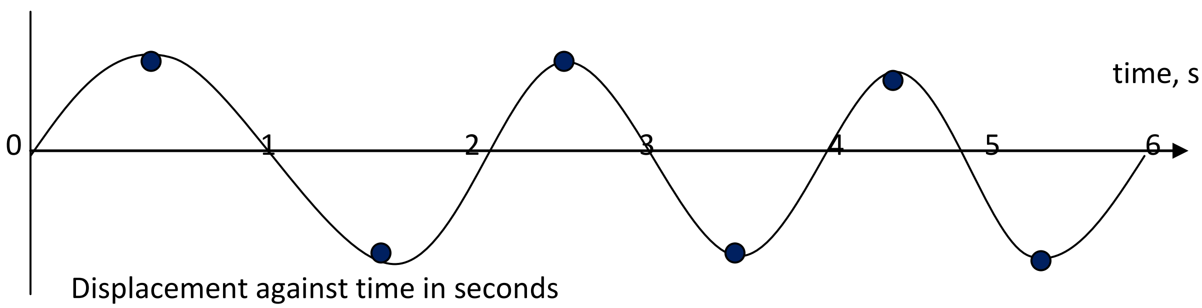
Work out the following:

a. wavelength
b. Speed of the wave if its frequency is 2Hz.

Solution

a. The wavelength is the distance from one crest to the next hence the wavelength is 4m.
b. $v = f\lambda = 2Hz x 4m = 8m/s$

Example 4.



Displacement against time in seconds

a. find the frequency of the wave
b. If the wave is traveling at 5 m/s, what is its wavelength?

Solution

a. Need to find the period. It is the time taken for a wave to complete one cycle. (From a crest to the next) then Period = 2 seconds.

   Therefore $f = \frac{1}{T} = \frac{1}{2s} = 0.5Hz$

b. $\lambda = \frac{v}{f} = \frac{5m/s}{0.5m} = 10m$

- the energy transmitted by waves depends on frequency and amplitude
- in the absence of friction, oscillating systems obey the principle of conservation of mechanical energy (PE + KE)
- However, all oscillating systems lose energy and their vibrations dieaway and are called damped oscillations.
- Examples of oscillating systems include: a simple pendulum, a spiral spring, a ruler (cantilever), a watch, a swinging rope etc.
- A wave, like all other oscillations have characteristics such as amplitude, period, frequency, wavelength and velocity (speed).

Factors That Affect Frequency of Some Oscillating Systems.

a. simple pendulum

  I. **The length of the pendulum**
  The shorter the length the higher the frequency and vice-versa
  II. **material from which the pendulum is made**
  III. **amplitude**
  The smaller the amplitude the higher the frequency and vice-versa

Note: the mass of a bob does not affect frequency. When doing experiments on these, only one factor should be changed the rest have to be controlled.

b. Spiral spring

  I. **Mass on spring**
  The higher the mass hung at the end the smaller the frequency.
  II. **Material from which the spring is made.**
  Some materials make a spring stiffer or weaker and this affect how they oscillate.

Note: Length of spring and amplitude changes do not affect the frequency of the oscillating system.

c. Cantilever

  I. **mass on end**
  The smaller the mass the higher the frequency and vice-versa
  II. **the material from which the cantilever is made**
  III. **length of the cantilever**
  The shorter the length the higher the frequency and vice-versa

Amplitude changes **do not** affect the frequency of a vibrating cantilever

CLASSIFICATION OF WAVES

- The classification depends on the criteria used. if one considers media for transmission then the waves are classified as
  a. mechanical waves
  b. Electromagnetic waves.

a. mechanical waves:

- These are waves that require a medium for transmission. Examples of media are water, air etc.
- Examples of waves in this category are: water wave, sound waves, waves in a stretched string, seismic waves which travel through earth's crust.
- When a mechanical wave travels from some point A to some point B, it is because a disturbance of some kind at A has caused particle to become displaced.
- The displaced particle drugs its neighbor with it so that it too gets displaced and has a similar effect on the next particle. This continues until the disturbance reaches point B.

b. <u>Electromagnetic waves:</u>

- These are waves which do not require a medium for transmission.
- It is as a result of vibration of a particle in a magnetic and electric fields.
- Examples of electromagnetic waves include radio waves, x-rays, microwaves, infra-red, ultraviolet, gamma rays, light waves etc.

Electromagnetic spectrum:

This is a list of electromagnetic waves arranged in accordance to their frequencies and wavelength.

The table below shows examples of electromagnetic wave, their frequencies and uses.

DIVISION	FREQUENCY	USES
Radio waves	3×10^4 to 3×10^9	Radio communication
microwaves	3×10^{10}	Radar, cooking
Infra-red	10^{11} to 10^{14}	Heating, night sights
Visible light rays	5×10^{14}	Stimulates the retina, initiates photosynthesis
Ultraviolet (UV)	10^{15}	Promote chemical reaction. used in photography
X-rays	3×10^{18}	Used in medicine to I. locate borne fractures II. destroy cancer cells III. locate imperfections in welding and casting
Gamma rays	3×10^{19}	To sterilize medical equipment & destroy cancer cells

If one looks at how the waves are propagated then we would have the following types of waves:

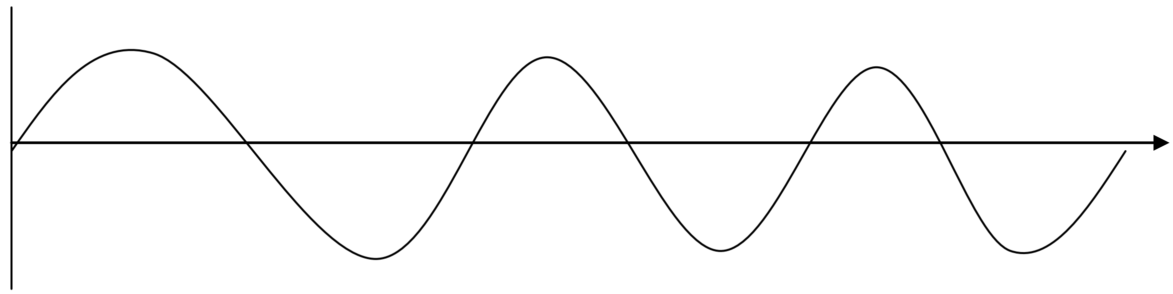
<u>Types of waves</u>

a. Transverse

b. Longitudinal waves

a. <u>transverse waves:</u>

- These are waves in which the displacements are perpendicular to the direction of travel or propagation.
- Examples are water waves, light waves and all the electromagnetic waves
- Their general shape is as follows:



b. Longitudinal Waves
   - these are waves in which the displacements are parallel to the direction of the propagation
   - examples are**: Sound waves, Tsunami waves, waves in a slink, internal water waves, spring oscillations**
   - Both types of waves can best be demonstrated by a long steel spring called a slinky.

Similarities between transverse and longitudinal waves:

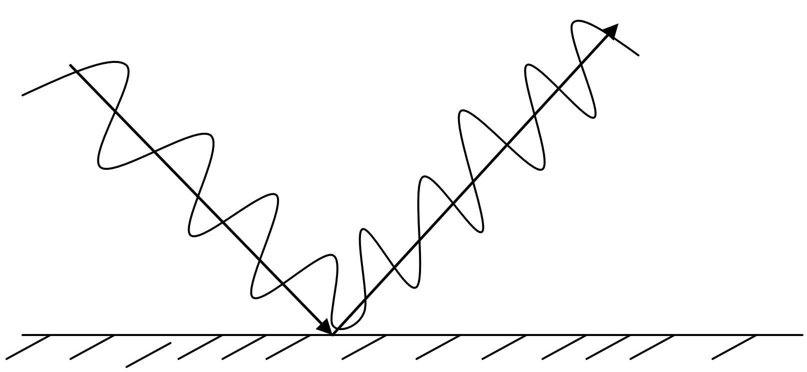
1. both waves can be represented by sine waves
2. both can be reflected
3. they can be refracted
4. both get involved in interference
5. both can be diffracted

Differences between transverse and longitudinal waves:

1. Transverse waves can be polarized (confined on the same plane) while longitudinal waves cannot be polarized.
2. In transverse waves particles vibrate perpendicularly to the wave direction while in longitudinal waves particles vibrate parallel to the wave propagation.
3. Transverse waves include all the electromagnetic waves while no any electromagnetic wave is longitudinal.

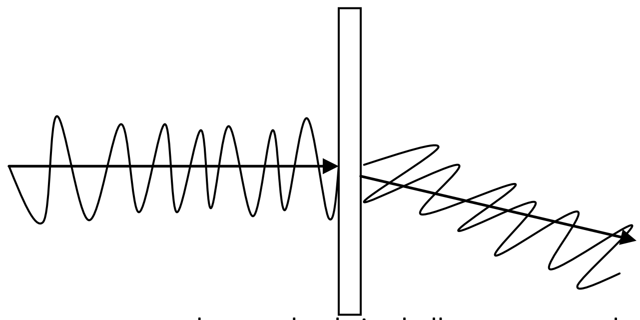
PROPERTIES OF WAVES:

a. Reflection of Waves:
- This is the bouncing back of waves when it meets a barrier
- When a wave gets reflected the angle of incidence is equal to the angle of refection.

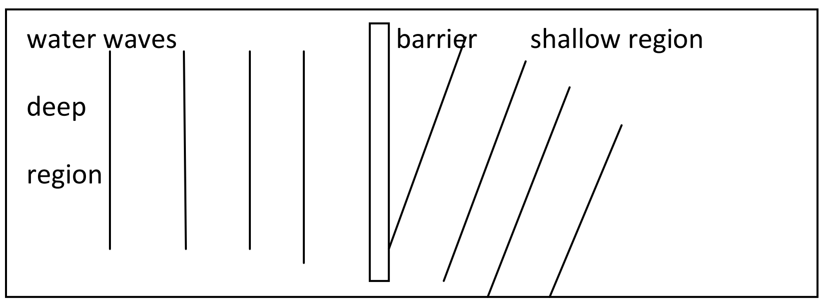


b. Refraction of Waves:

- This is the bending (deviation) of waves when they cross boundary between two different media.
- During refraction the wavelength and speed of the waves change so too with the direction. Frequency remains constant



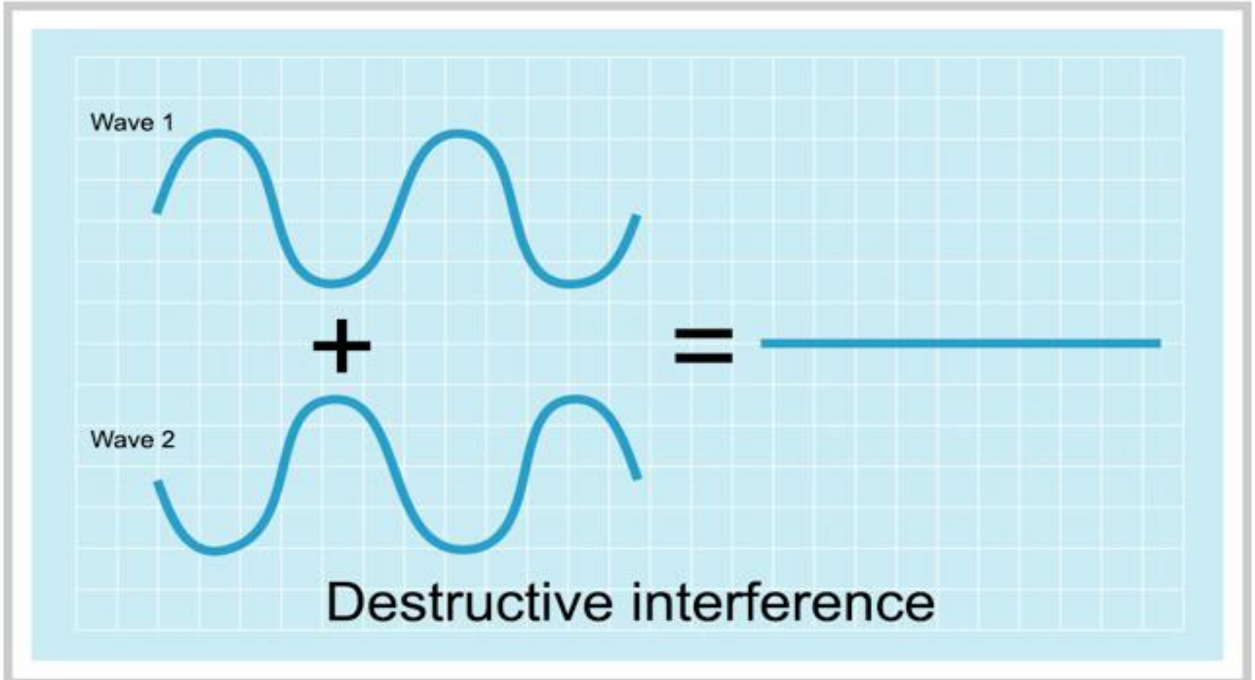
- Water waves travel more slowly in shallow waters and as a result they are refracted towards the normal as they enter shallow region. This is so because since $v = \lambda f$ and f remains constant while λ decreases leading to decrease in velocity in shallow waters.

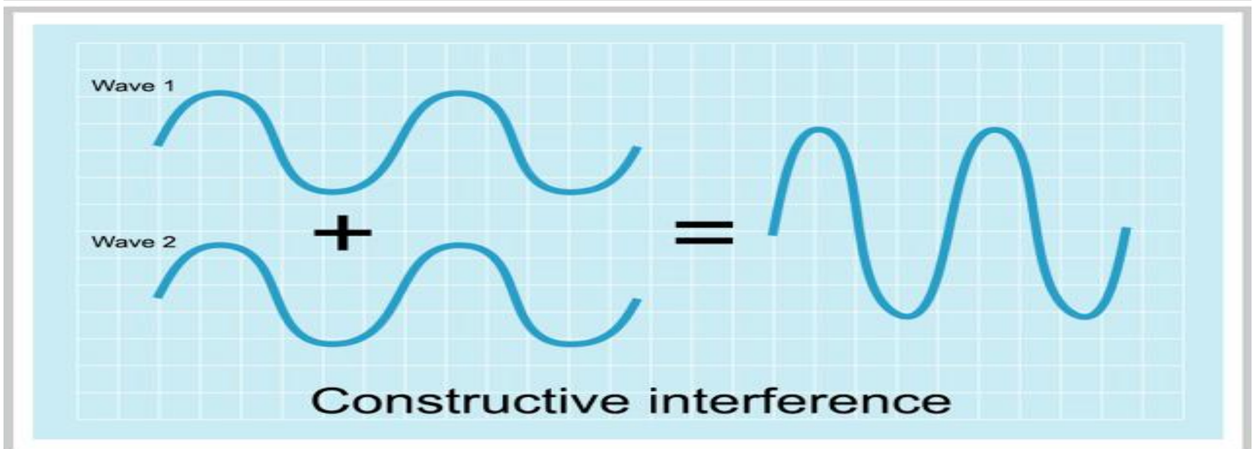


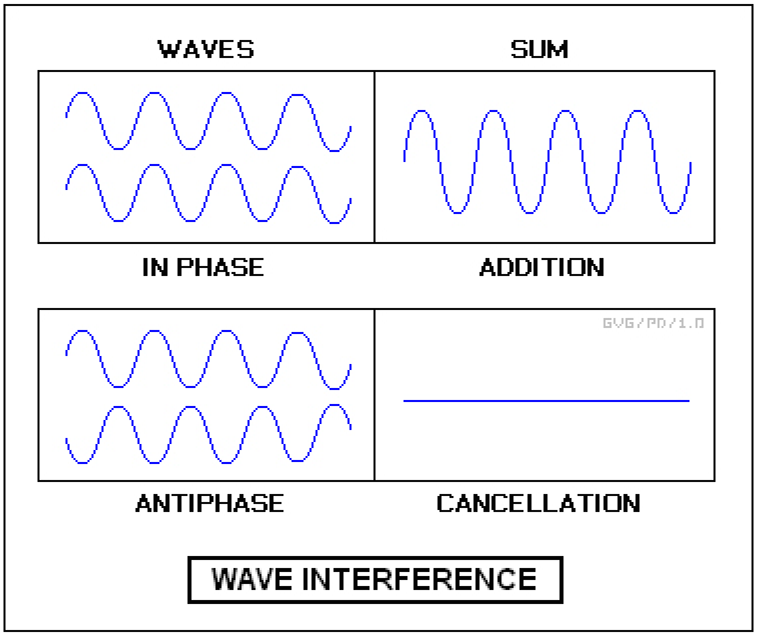
The figure illustrates bending of water waves when they move from deep regions to shallow regions.

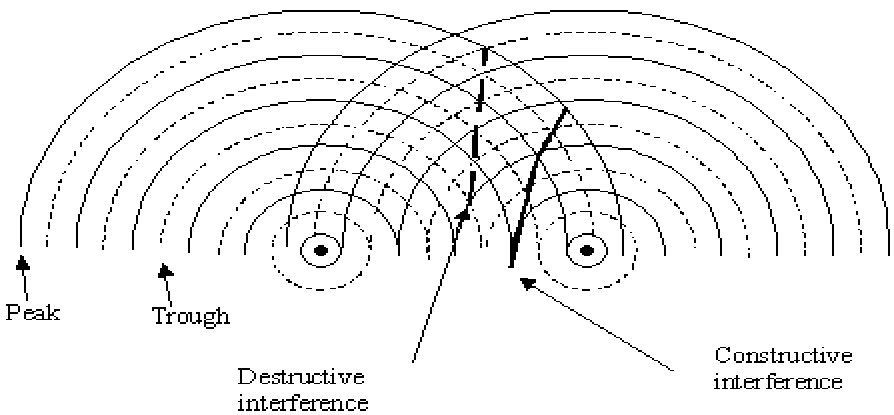
c. <u>interference or superposition of waves</u>

- It is the addition (superposition) of two or more waves which results into a new wave pattern
- If a crest meets a crest or a trough meets a trough then there is a constructive interference and the wave produced has large amplitude.
- In other words constructive interference occurs when the waves are in a phase.
- If the waves are out of phase the destructive interference occurs.
- Destructive interference occurs when a crest meets a trough.


Wave 1
+
=
Wave 2
Destructive interference

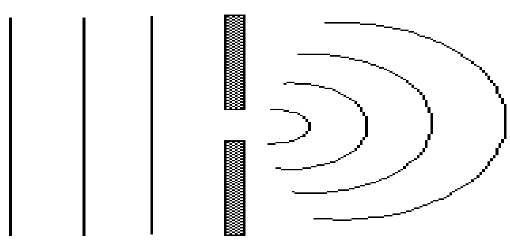

Wave 1
+
=
Wave 2
Constructive interference





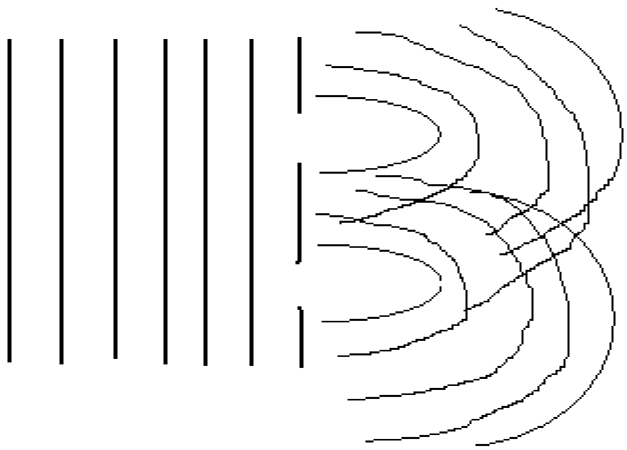
d. <u>Diffraction</u>

- This is the bending (deviation) of waves in a single media when it passes through a narrow aperture.
- During diffraction there is no change in wavelength or speed but amplitude increases.
- The size of the slit (gap) affects how a wave spreads out.
- If the slit is narrow the waves curve more and there is a linear propagation if the gap is made wider.



Diffraction

If there are two gaps then two wave properties will be observed and these are diffraction and interference. Refer to the figure below.



Diffraction and interference

LIGHT AS AN EXAMPLE OF ELECTROMAGNETIC WAVES

- A light is a transverse wave
- It travels at the speed of 3×10^8 m/s.

LENSES

- A lens is a grass or a plastic prism with curved surfaces.
- It can be converging or diverging

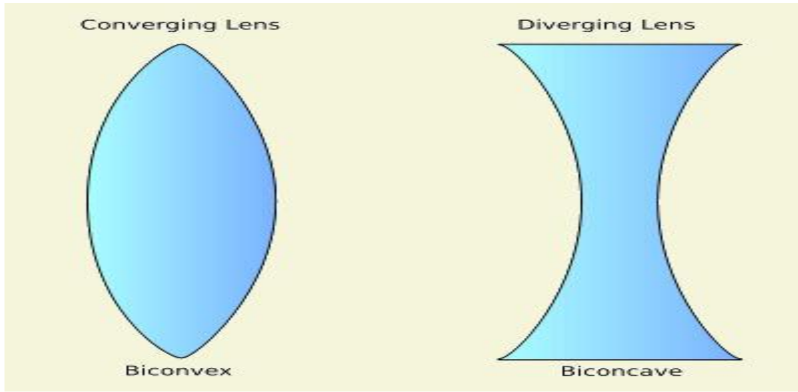
a. Converging lens.

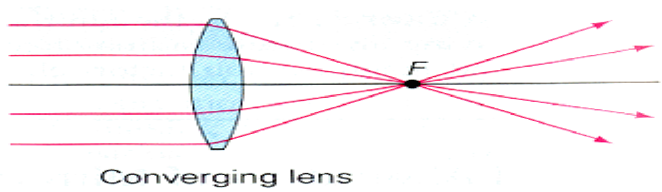
- they cause light rays to come to a similar position
- They are also called convex lens.
- They are thicker on the middle and narrow on the sides.

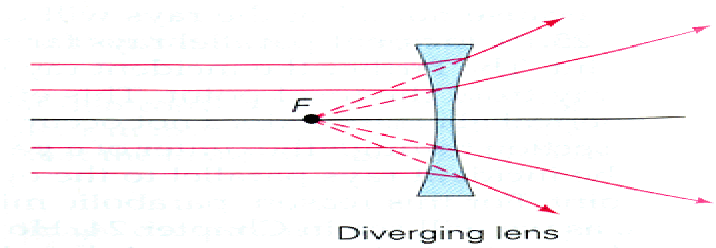
b. diverging lens

- They cause light rays to spread out.
- They are also known as concave lens.
- They are narrow on the middle and wider on the edges.

Convex lens (converging lens)	**Concave (lens) (diverging lens)**
Their Focal length is positive	Their focal length is negative
After refraction, Light rays meet(appear to meet) at one point	After refraction, light rays move away from one another
The image they form can be real, virtual, magnified or diminished depending on the object distance	They always form an image which is virtual and diminished
Used to correct long sight	Used to correct short sight







Important terms:

1. PRINCIPAL FOCUS (FOCAL POINT), F of a converging lens is that point on the principal axis of the lens to which light rays parallel to it converge after refracting at the surface of the lens.
2. PRINCIPAL AXIS of the lens (converging or diverging) is the line which passes through the centre of the lens surface.
3. FOCAL PLANE is an imaginary plane through F which is perpendicular to the principal axis.
4. REAL IMAGE is one through which rays of light actually meet.
   A real image
   - Can be cast onto a screen.
   - Is always inverted.
5. VIRTUAL IMAGE is the one from which rays of light only appear to have come from.
   A virtual image
   - Cannot be cast onto a screen.
   - Is always upright.
6. FOCAL LENGTH (f) is the distance from the lens to the principal focus.
7. IMAGE DISTANCE (V) is the distance from the image to the lens.

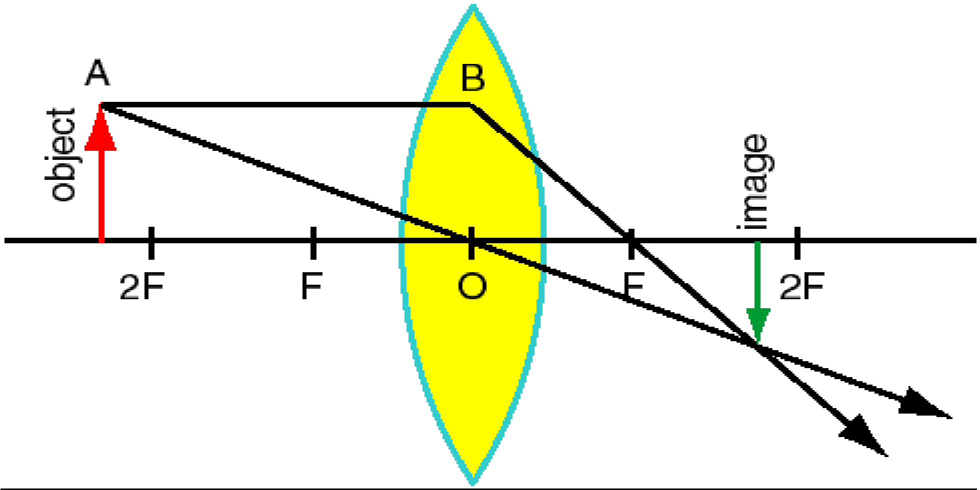
8. OBJECT DISTANCE (U) is the distance from the lens to the object.
9. OPTICAL CENTRE is the middle part of a lens.

RAY DIAGRAM.

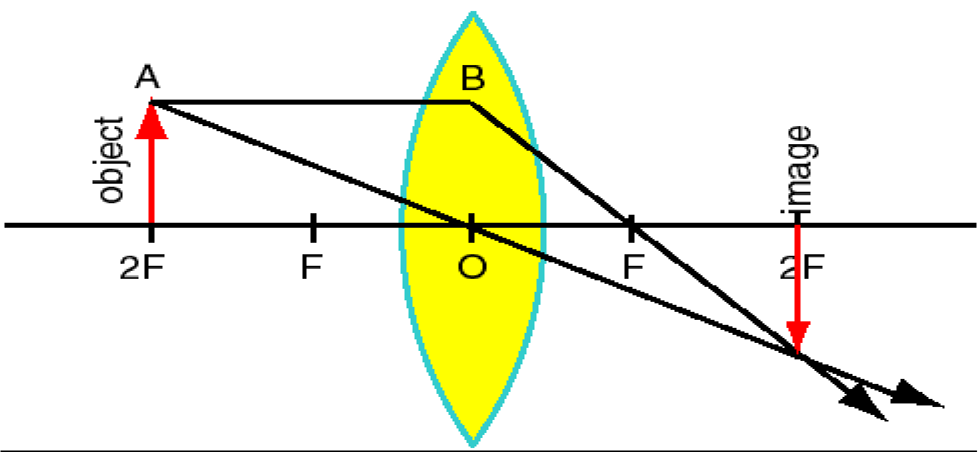
Important ray path:

- All the rays of light that leave a single point on an object meet at the same image point.
- A ray, through the optical centre of the lens is un-deviated.
- A ray, parallel to the principal axis, passes through (appear to leave or come from F)
- A ray, through (or heading towards) F, emerges parallel to the principal axis.

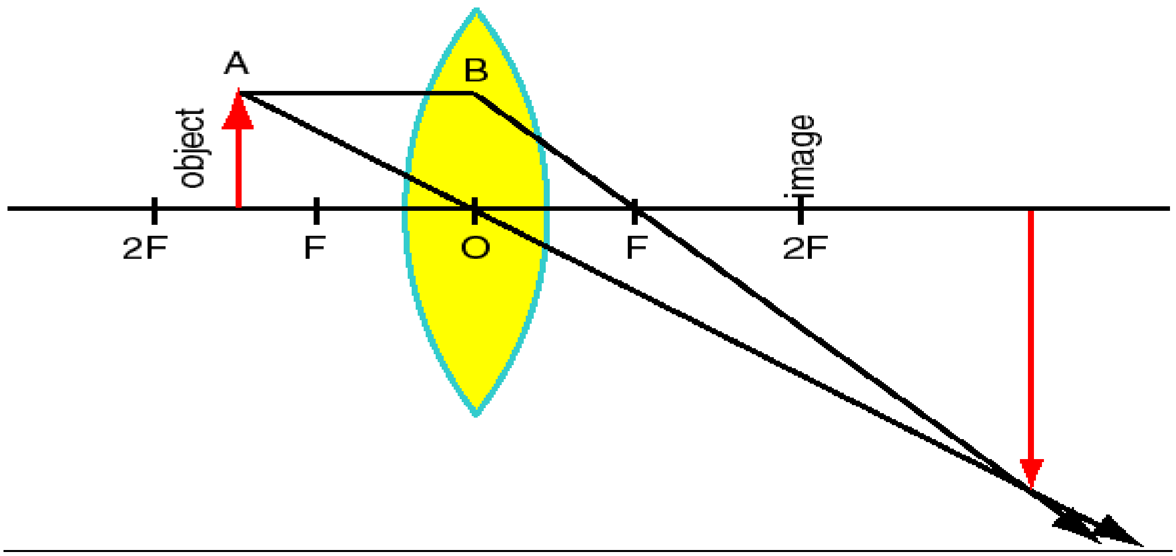
1) **Object beyond 2F, image between F and 2F, real, inverted and diminished.**



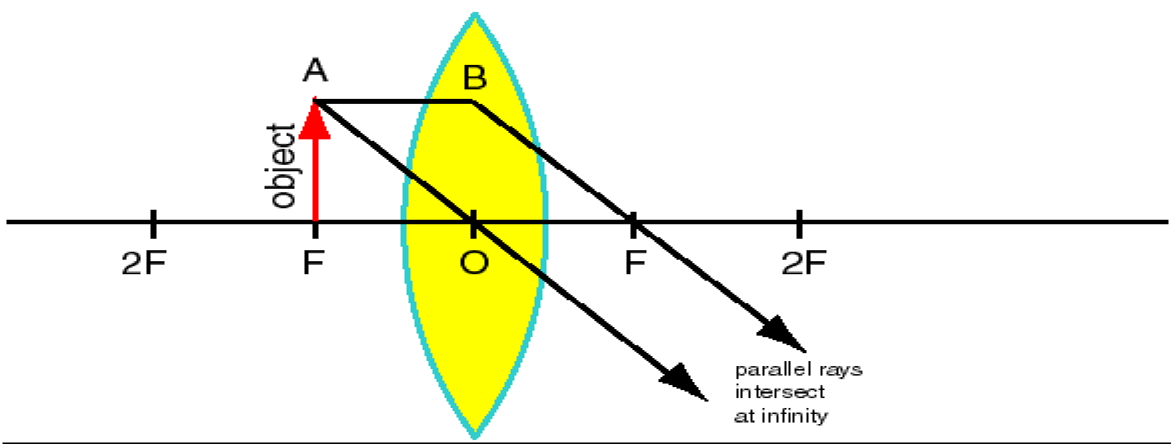
2) **Object at 2F, image at 2F, real, inverted and of the same size as the object.**



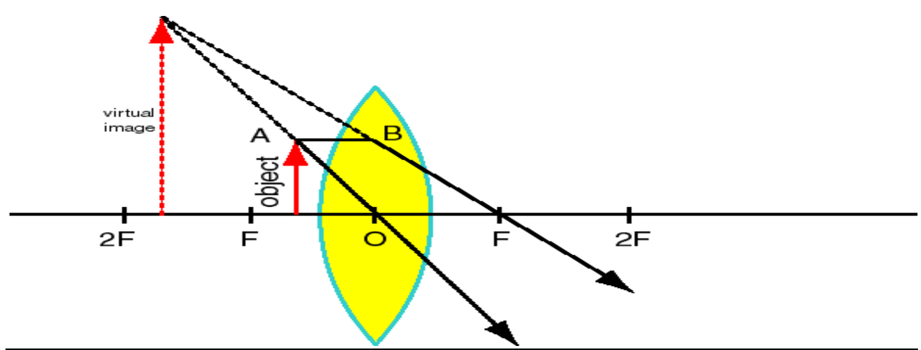
3) **Object between 2F and F, image is beyond 2F, real, inverted and magnified.**



4) **Object at F, no image formed since light rays meet at infinity.**



5) **Object between F and O, image virtual, upright and magnified and is on the same side as the object.**



THE LENS FORMULAR

- This is given by $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$ **w**here u = object distance, v = image distance and f = focal length of the lens.
- The focal length of a converging lens are positive, those of a diverging lens are negative.
- Distance from the lens to real images is positive whereas the distance from the lens to the virtual image is negative.

MAGNIFICATION

- Magnification of an object is given by $m=\frac{v(imgedis\tan ce)}{u(objectdis\tan ce)}=\frac{imageheight}{objectheig\,ht}$
- Formation of an image by a diverging lens, for all positions of the objects, the image is virtual, erect and smaller than the object and is situated between the object and the lens.

Examples

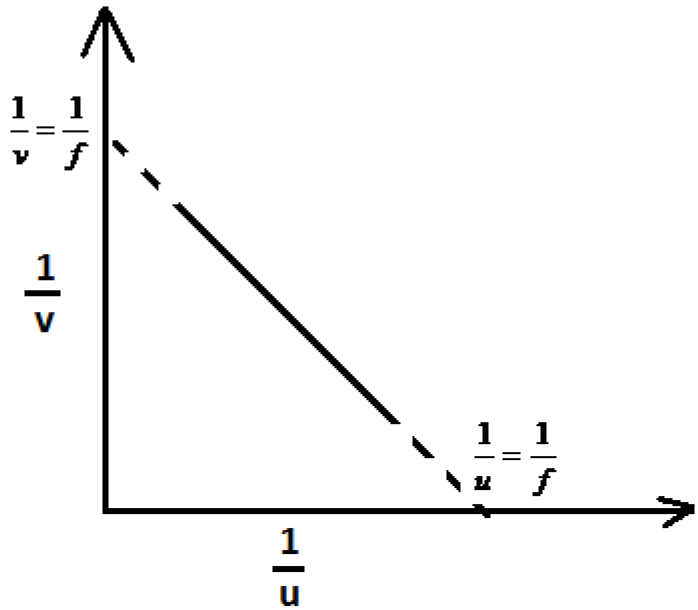
1. An object 9cm high is placed 24cm in front of a converging lens and real image is formed 8cm away from the lens find
   a. Size of the image
   b. The focal length of the lens

a. $$\frac{v(imgedis\tan ce)}{u(objectdis\tan ce)}=\frac{imageheight}{objectheig\,ht}$$
$$\frac{8}{24}=\frac{h_2}{9}\Rightarrow h_2=\frac{8\times 9}{24}=3cm$$

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$
b. $$\frac{1}{24}+\frac{1}{8}=\frac{1}{f}=\frac{1+3}{24}=\frac{4}{24}\Rightarrow f=\frac{24}{4}=6cm$$

EXPERIMENTAL DETERMINATION OF FOCAL LENGTH OF A CONVERGING LENS:

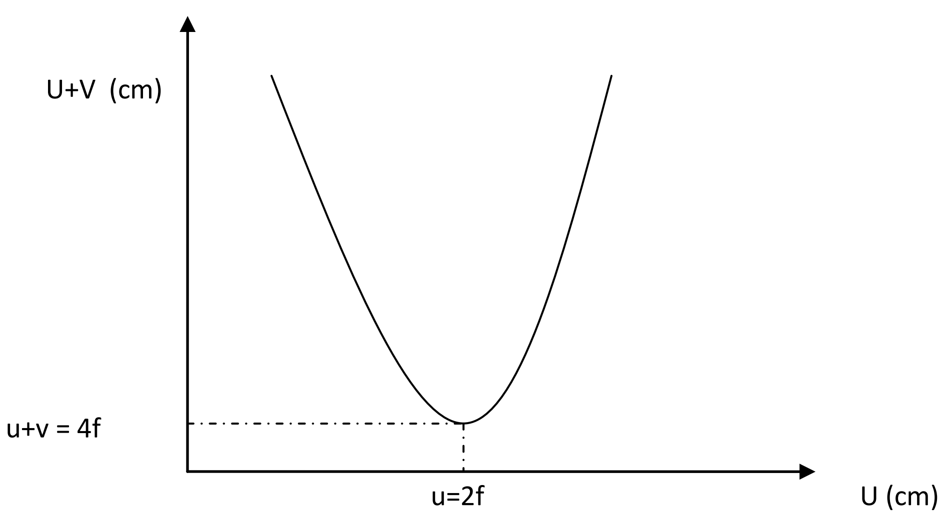
1) Distance Object Method.
   - Position the lens so that it produces a sharply focused image of a distant object (e.g. a window or a screen.
   - The distance between the lens and the screen or the window is roughly taken to be the focal length of the lens.
2) Light Experiments.
   - By using an illuminated object and a screen, obtain a number of values of U and the corresponding values of V.
   - The graph of $\frac{1}{U}$ against $\frac{1}{V}$ is plotted and each intercept of the graph is equal to $\frac{1}{f}$ and hence f is found.



E.g. consider the values given in the table below:

U (cm)	V (cm)	$\frac{1}{U}$ (cm^{-1})	$\frac{1}{V}$ (cm^{-1})
12.5	49.9	0.080	0.020
15.0	29.9	0.069	0.033
20.0	20.0	0.050	0.050
25.0	16.7	0.040	0.060
30.0	14.7	0.033	0.068
35.0	13.7	0.029	0.073
40.0	13.0	0.025	0.077

- When corresponding values of u and v are collected as In method 2, the graph of (U+V) against U can also be used to find the focal length of a lens.



Example

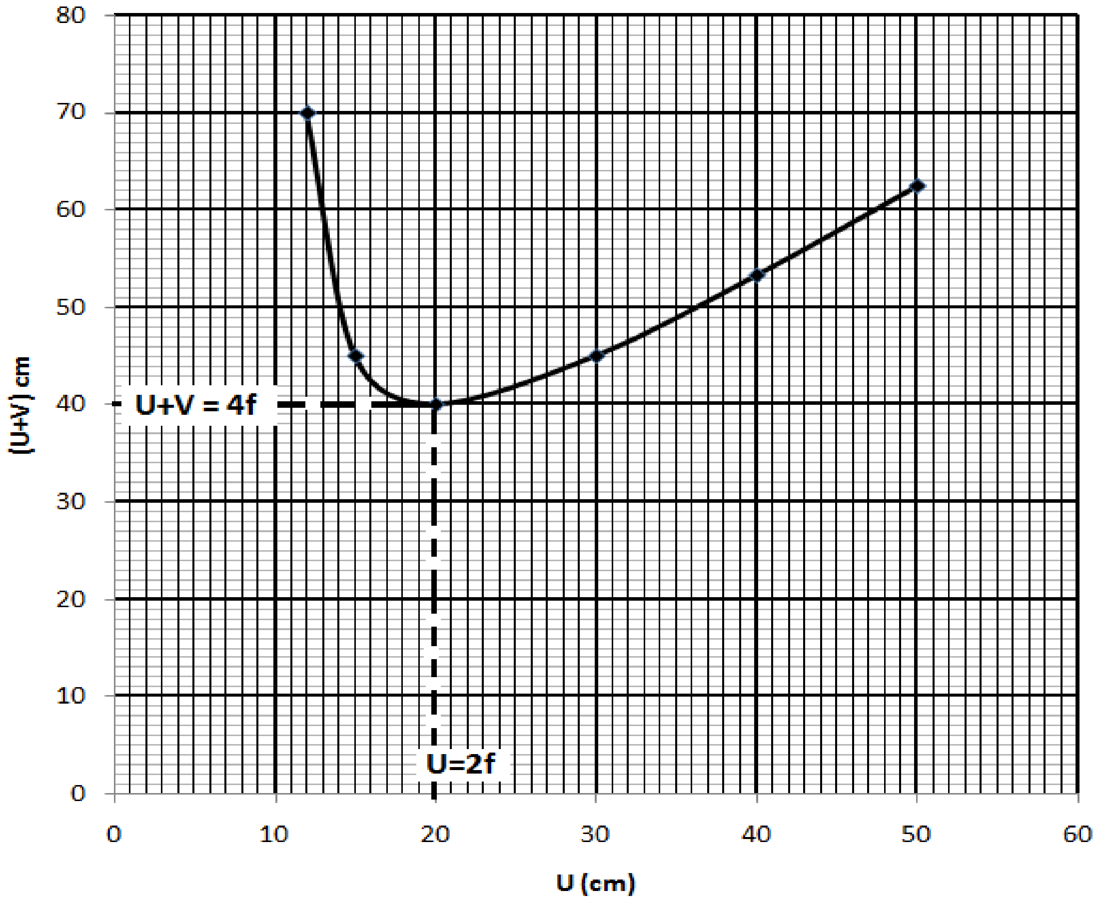
In an experiment to determine focal length of a convex lens, the following data was obtained

Object distance (cm) U	**Image distance (cm) V**	**(U+V) cm**
12	58	
15	30	
20	20	
30	15	
40	13.3	
50	12.5	

(i) Complete the table under column of (U+V)

ii. Using the graph paper provided, Plot a graph of (**U+V) against U**

Object distance (cm) U	**Image distance (cm) V**	**(U+V) cm**
12	58	70
15	30	45
20	20	40
30	15	45
40	13.3	53.3
50	12.5	62.5



$$2f = 20 \Rightarrow f = \frac{20}{2} = 10cm$$

Focal length *or*

$$4f = 40 \Rightarrow f = \frac{40}{4} = 10cm$$

- Other methods are:
  3) Plane mirror method (self-conjugate foci)
  4) Displacement method.

OPTICAL INSTRUMENTS:

- These are instruments which depend on light for their functioning.
- Examples are: camera, projector, binoculars, and microscope.

THE CAMERA:

- This is a device whose main function is to provide a dark place to hold a film.
- Camera is a light-tight box in which a convex lens forms a real image on a film.

some parts of a camera

I. Iris diaphragm

- This works as the eyes-iris does. Normally the diaphragm is closed. When a picture is to be taken in dark area, the diaphragm opens up to provide a large hole called aperture. The aperture is the pupil of the eye.

II. The shutter

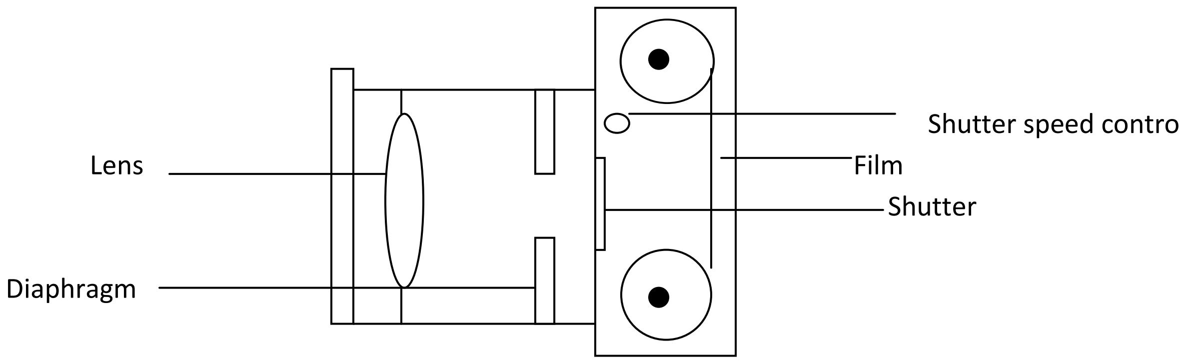
- This controls the light entering the camera by opening and closing the aperture at different speeds.

III. Photographic film

- This is where the images are focused just like on the retina of the eye.

IV. The lens

- This refracts light.
- It brings the images to focus on the film no matter what the distance of the object is, or whether it is in the center of the scene or towards the edge.



Picture of a camera and how the lens refracts light

SIMILARITIES BETWEEN A CAMERA AND AN EYE:

CAMERA	EYE
Has a light sensitive film	Has a light sensitive retina
Has a converging lens	Has a converging lens
Inside surface is black	Inside surface is back
Light controlled by shutter diaphragm	Light controlled by the iris of the eye
Lens forms real, diminished and inverted image	Lens forms real, diminished and inverted image

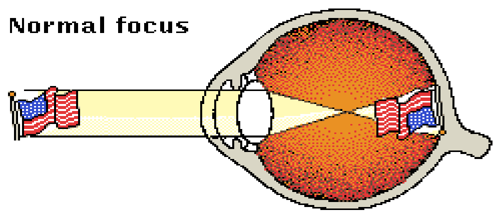
DIFFERENCES BETWEEN A CAMERA AND AN EYE:

CAMERA	EYE
Focal length of lens is fixed	Focal length of the lens can be altered
Closed except when taking a picture	Pupil normally open
Image distance changes	Image distance fixed

EYE DEFECTS:

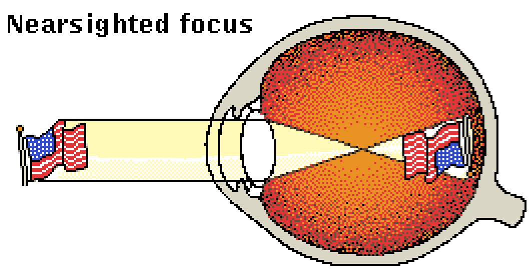
Accommodation:

- It is the automatic adjustment in focal length of the natural lens of the eye.
- There are two types of eye defects which are: short sight and long sight.



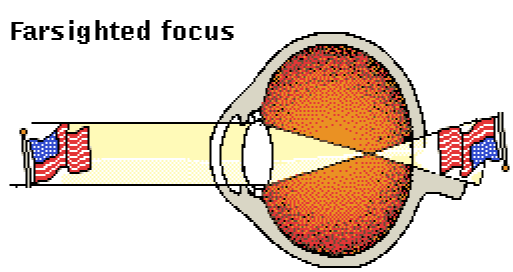
Short Sight (myopia):

- Ability to see near objects clearly.
- The image of a distant object is focused in font of a retina due to long eye balls.
- It is corrected by using spectacles with diverging lens.

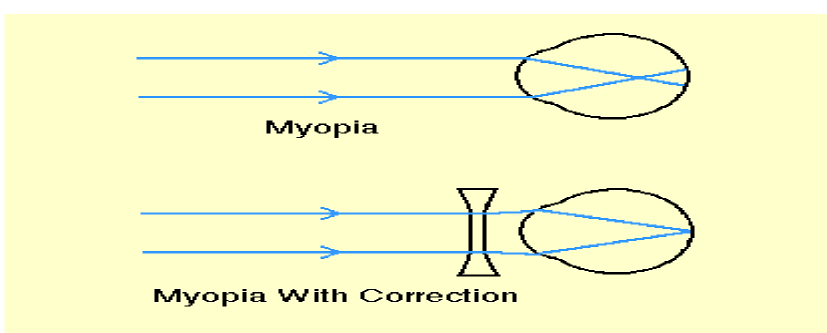


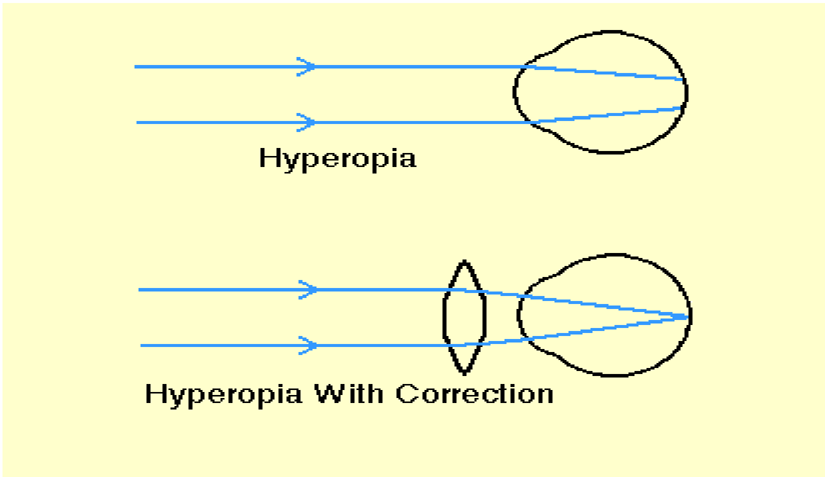
Long sight (hypermetropia or hyperopia)

- Ability to see distant object but failing to see near ones.
- It happens due to short eye balls. The image is focused behind retina.



- A spectacle with convex (converging) lens corrects the problem.
- Note that if a person holds a book at arms length then he/she is long-sighted.

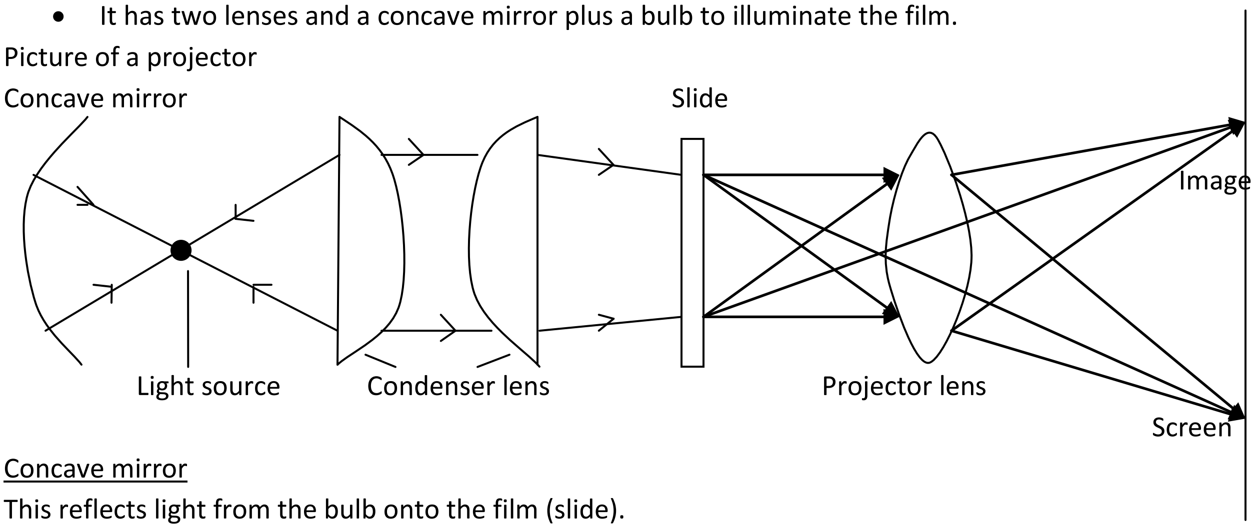




THE PROJECTOR:

- This is a device which is used to form a magnified image of a small object (such as a photographic slide) on a screen placed at several meters away from the lens.
- It has two lenses and a concave mirror plus a bulb to illuminate the film.

Picture of a projector



<u>Concave mirror</u>

This reflects light from the bulb onto the film (slide).

<u>Condenser Lens (Condensing Lens)</u>

This is used to

- converge light and
- Concentrates as much light as possible on the film so that it is very bright and evenly lit.

<u>Projection Lens:</u>

- It is used to produce considerable, focused, magnified, real and inverted images of the film.
- The distance from the lens to the film must be between F and 2F.(Just outside F)
- The projector lens has a longer focal length than the condenser lens.
- Upright images are produced by placing the film (object) upside down.

To increase magnification one can do the following:

Increase image distance, V and decrease the object distance, U. This can be achieved by

- Moving the projector lens nearer to the film or object.
- Moving the film/object nearer to Projector lens.
- Moving the screen away from the projector lens.

HOW THE TOPIC HAS BEEN FEATURED IN THE LAST 4 YEARS OF MANEB EXAMINATIONS

(Find some suggested answers in italics).

2015 N0 4

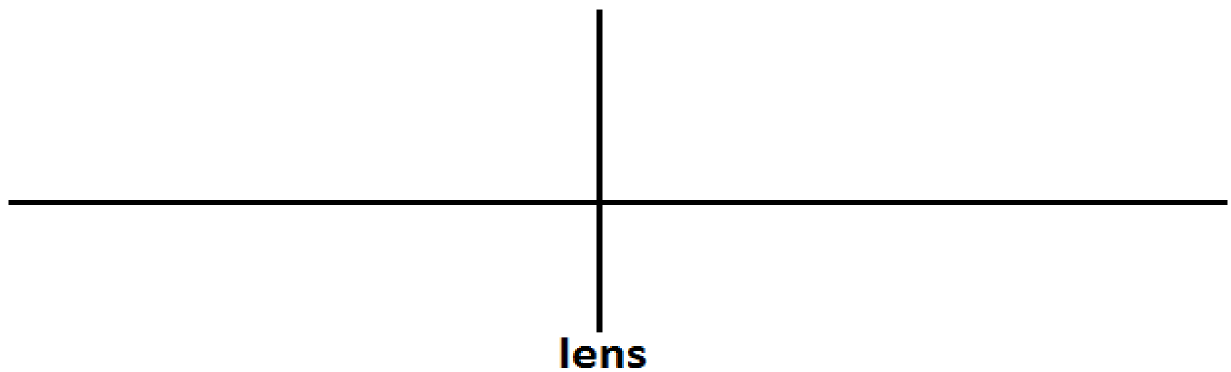
a. **Mention any two properties of waves**

   Answer: reflection, refraction, interference and diffraction

b. **(i)State any two differences between convex and concave lenses**

Convex lens	Concave lens
Thick in the middle than edges	Narrow in the middle
Light rays are bent inwards	Light rays are bent outwards

(ii) Draw a ray diagram to show the position of an image 4cm high placed 10 cm from a convex lens of focal length 5 cm. (use a scale of 1 cm to represent 2 cm)

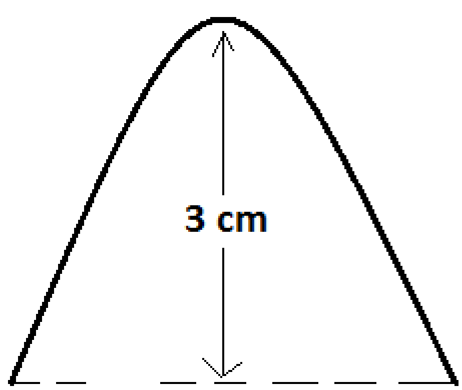


(iii) Calculate the magnification of the image

Answer: $mg = \frac{v}{u} = \frac{10}{10} = 1$

c. **Figure below shows two waves travelling in opposite directions**

(i) Draw a diagram to show what happens when the two waves meet



(ii)Draw a diagram to show what happens when the two waves pass each other

(iii) What property of wave is demonstrated in 4c(i)?

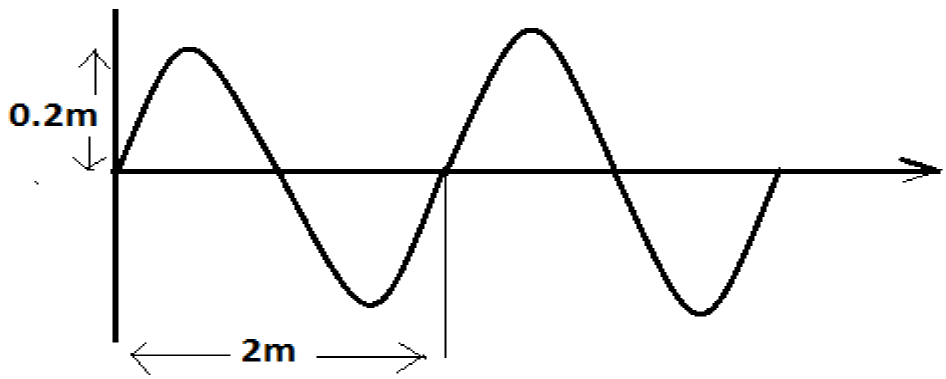
<u>Answer: Interference</u>

2014 6

d. Mention any three characteristics of waves

- ***Speed, Frequency, Wavelength, Amplitude, Period***

e. Figure below is a diagram showing a wave



(i) What is the amplitude of the wave**?**

<u>Answer: 0.2m</u>

(ii) What type of wave is shown in the diagram?

<u>Answer: Transverse wave</u>

(iii) Calculate the frequency of the wave is its speed is 8m/s

$$v = f\lambda$$

$$f = \frac{v}{\lambda} = \frac{8m/s}{2m} = 4Hz$$

8a explain how a slide projector works

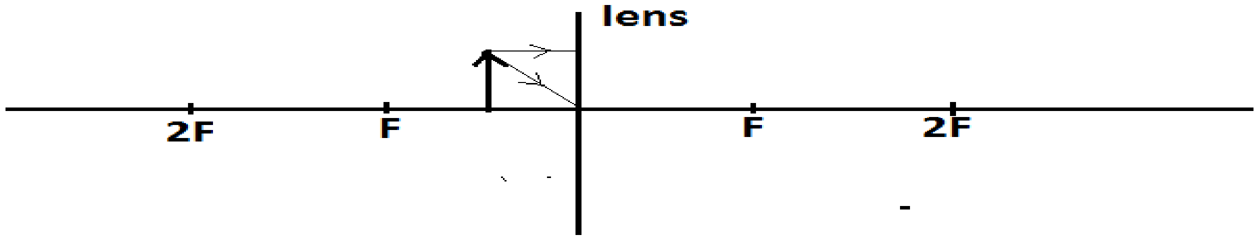
It produces a real magnified image through functions of a small bulb which provides light; condenser lens which converges and concentrates light onto a film. It has a projector lens which refracts light and focuses it on the screen where the image is formed. The slide (film) is put up-side down in order to obtain an upright image and furthermore, the slide is put between F and 2F in order to get a magnified image.

2013

a. Mention two differences between convex and concave lenses

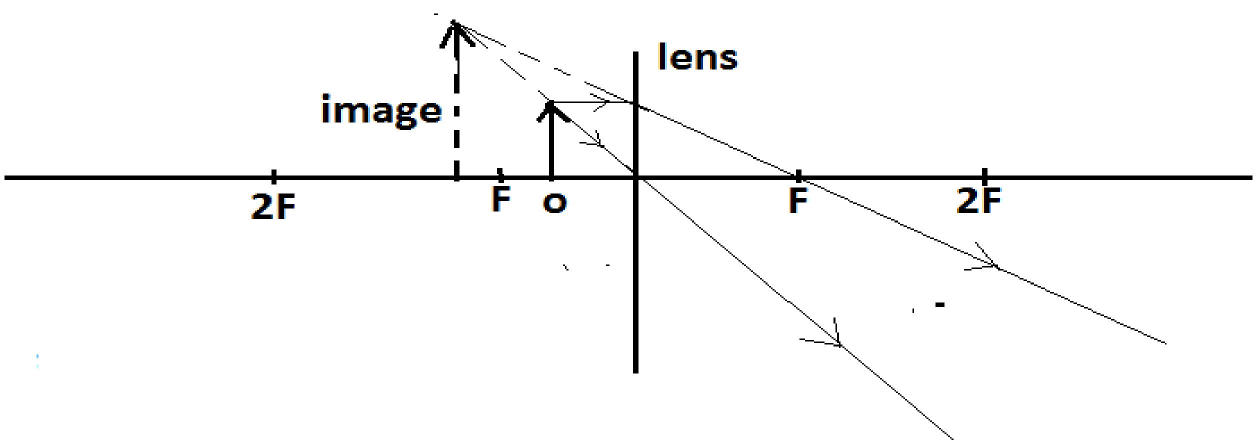
Convex lens (converging lens)	**Concave (lens) (diverging lens)**
Their Focal length is positive	Their focal length is negative
After refraction, Light rays meet(appear to meet) at one point	After refraction, light rays move away from one another
The image they form can be real, virtual, magnified or diminished depending on the object distance	They always form an image which is virtual and diminished
Used to correct long sight	Used to correct short sight

b. Figure below shows part of ray diagram



(i) Complete the ray diagram to locate the position of the image

The answer below is not to scale. Exact position would be obtained by accurate drawing.



(ii) State the nature of the image formed

Image would be virtual, upright and magnified

c. Mention any two similarities between the human eye and a camera

CAMERA	EYE
Has a light sensitive film	Has a light sensitive retina
Has a converging lens	Has a converging lens
Inside surface is black	Inside surface is back
Light controlled by shutter diaphragm	Light controlled by the iris of the eye
Lens forms real, diminished and inverted image	Lens forms real, diminished and inverted image

d. **Why are radio waves classified as transverse waves?**

Answer: because particles vibrate perpendicularly to the direction of the wave

2012 4

a. Define "oscillation"

It is defined as a to and fro movement of an object

b. (i) What type of a wave is produced by a vibrating string? ***Transverse wave***

(iii) Calculate the frequency of a wave with a wavelength of 2m and speed of 6m/s

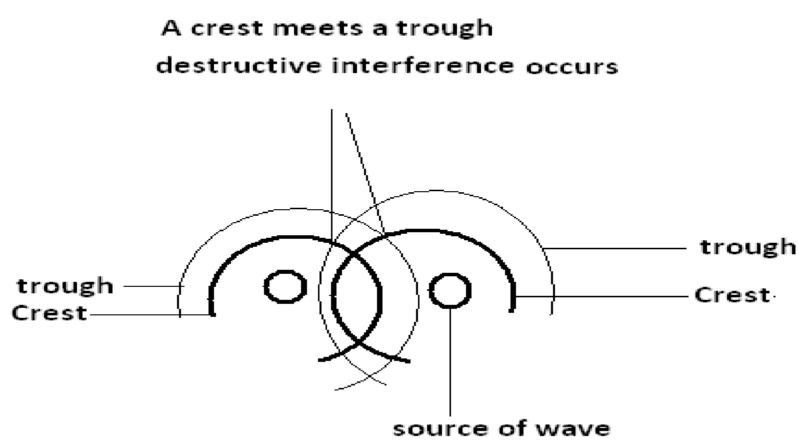
$$v = f\lambda \Rightarrow f = \frac{v}{\lambda} = \frac{6m/s}{2m} = 3Hz$$

c. State the difference between "interference" and "diffraction" of waves. ***Diffraction is the bending (deviation) of wave in a single media when it passes through a narrow gap while interference is the addition (superposition) of two or more waves which results into a new wave pattern***

8.

a. With the aid of a well labeled diagram, explain how destructive interference in water waves occurs.

Water waves, which are circular in nature spread out from a source and overlap (interference). If a crest of one wave meets trough of another wave then the destructive interference occurs.



b. Explain why waves refract when travelling from one medium to another. ***It's due to a decrease in speed. The wavelength reduces but the frequency remains constant.***

11. NUCLEAR PHYSICS

By the end of this chapter learners should be able to:

- Name constituent particles of the atomic nuclei
- Express composition of a particular nucleus in standard notation
- Describe isotopes
- Explain what is meant by radioactivity
- State characteristics of radioactive substances
- Describe alpha and beta particles and gamma rays
- Describe detection of radiation
- Explain the meaning of radioactive decay
- Distinguish between natural and induced radioactivity
- Explain and use the idea of half-life
- Describe safety precautions during handling and storing of radioactive substances
- Distinguish between nuclear fission and nuclear fusion.
- Describe the use of radioactivity

STRUCTURE OF AN ATOM

An atom is a basic unit of matter which contains other three sub-atomic particles. These are protons, electrons and neutrons. The table 1 below summarizes their location, mass and type of charge.

PARTICLE	SYMBOL	LOCATION	MASS	CHARGE
Electron	E	Shell	0	negative
Neutron	N	nucleus	1amu	zero
proton	P	nucleus	1amu	positive

Note: the mass of an electron is almost zero (negligible) as compared to the mass of the proton. amu means atomic mass unit. The shell is also called an energy level.

STANDARD NOTATION

The standard way of expressing composition of an atom involves showing mass number, atomic number and element symbol. Refer to the following:

${}^{A}_{Z}X$ where A is the atomic mass or mass number

Z is the atomic number. It gives the position of an element in the periodic table and it is equal to the number of protons.

Mass number, A = Atomic No. + No. of neutrons

Therefore, No. of neutrons = Atomic mass – Atomic number
i.e. **No. of neutrons = A – Z**. Refer to the following example:

Given the following: $^{27}_{13}Al$. Determine

a. The mass number
b. Atomic number
c. Number of neutrons
d. Number of electrons.

Solution:

a. The mass number = A = 27
b. Atomic number = Z = 13
c. No. of neutrons = A – Z = 27 – 13 = 14
d. No. of electrons = No. of protons = Atomic number = 13

ISOTOPES

These are atoms of the same element having the same atomic numbers but different mass numbers. The difference in mass numbers is due to difference in number of neutrons.

- ✓ For example the nuclides $^{16}_{8}O$, $^{17}_{8}O$ and $^{18}_{8}O$ are isotopes of oxygen while $^{23}_{11}Na$ and $^{24}_{11}Na$ are isotopes of sodium.
- ✓ Isotopes have similar chemical properties due to the same number of electrons.
- ✓ Isotopes can be **stable** or **unstable**
- ✓ Stable isotopes are isotopes in which the number of both neutrons and protons are about equal and are within tolerable levels or comparable ratios e.g. $^{16}_{8}O$, $^{17}_{8}O$ and $^{18}_{8}O$
- ✓ Unstable isotopes are those in which there are two many neutrons for the protons and vice- versa. E.g. $^{238}_{92}U$, $^{226}_{88}Ra$ and $^{90}_{38}Sr$
- ✓ Other examples of isotopes include those of hydrogen which are: Hydrogen $^{1}_{1}H$ also called Protium, Deuterium $^{2}_{1}H$ or $^{2}_{1}D$ and Tritium $^{3}_{1}H$ or $^{3}_{1}T$

RADIOACTIVITY OR RADIOACTIVE DECAY

- This is the spontaneous disintegration of unstable nucleus to acquire a more stable state.
- Radioactivity happens in order to equalize or normalize its proton neutron ratio.
- A radioactive substance is the one that breaks in order to gain a stable form.
- Examples of radioactive substances are: Uranium $^{239}_{92}U$, Radium $^{226}_{88}Ra$, Polonium $^{210}_{84}Po$
- During radioactive decay, energy is released. In addition, several particles are emitted which include alpha, beta and gamma rays.
- Nuclear radiation is the energy released when radioactivity occurs.
- Take note that a particle can still be undergoing decay but without releasing energy.

TYPES OF DECAY PARTICLES

ALPHA (α- PARTICLE)

- It is a radioactive emission identical to a helium nucleus
- The following is its symbol: ${}^{4}_{2}\alpha$ or ${}^{4}_{2}He$

Characteristics of alpha radiation

- This consists of two protons and two neutrons
- As already mentioned, it is identical to a helium nucleus
- When a nucleus undergoes α- decay it loses four nucleons, two of which are protons. Therefore
  I. Its mass number (A) decreases by 4
  II. Its atomic number (Z) decreases by 2.

i.e. $${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

(Parent) (Daughter) α – particle (decay product)

Example: consider the decay of Uranium- 238

$${}^{238}_{92}U \longrightarrow {}^{234}_{90}Y + {}^{4}_{2}He$$

Properties of Alpha particles

1. It is the most highly ionizing particle. I.e. it knocks off electrons in an atom and makes it charged. This is attributed to the high charge they have (+2)
2. It can penetrate about 5 cm of air because of its relatively large mass.
3. It can be deflected by electric and magnetic fields. (It bends in these fields). This is so because of its positive charge and any charge creates a magnetic and an electric field.
4. It is positively charged(has a charge of +2)
5. Move at a low speed as compared to the speed of light (due to its large mass).

Other examples of α-decay include the following:

$${}^{222}_{86}Rn \xrightarrow{\alpha} {}^{218}_{84}Po + {}^{4}_{2}He$$

$${}^{218}_{84}Po \xrightarrow{\alpha} {}^{214}_{82}Pb + {}^{4}_{2}He$$

BETA (β- PARTILCE)

- It is a radioactive emission identical with an electron.
- Its symbol is as follows: ${}^{0}_{-1}\beta$ or ${}^{0}_{-1}e$

Characteristics of beta radiation

- These are simply high energy and fast moving electrons emitted by any given species of nucleus. The nucleus has too many particles to be stable.

- In the emission of beta particles one of the element's neutrons transforms to a proton and an electron. The proton remains in the nucleus.
- Beta rays are streams of high energy electrons.
- When a nucleus undergoes β- decay
    - I. <u>Its mass number (A) does not change</u>
    - II. <u>It atomic number (Z) increases by 1</u>

In general,

$$ {}^{A}_{Z}X \xrightarrow{\beta} {}^{A}_{Z+1}Y + {}^{0}_{-1}e $$

Example:

I. $ {}^{27}_{14}Si \xrightarrow{\beta} {}^{27}_{15}P + {}^{0}_{-1}e $ ii. $ {}^{214}_{82}Pb \xrightarrow{\beta} {}^{214}_{83}Bi + {}^{0}_{-1}e $

<u>Properties of Alpha particles</u>

1. Produces much less ionization than alpha particle. It's due to its relative low charge.
2. It can penetrate 500cm of air as well as 2mm of aluminum since it is lighter as compared to alpha particle.
3. They are negatively charged
4. They are easily deflected by both electric and magnetic effects (Due to the negative charge they have).
5. They move at about 0.9 x the speed of light ($3x10^8$m/s)

GAMMA (γ -RAYS)

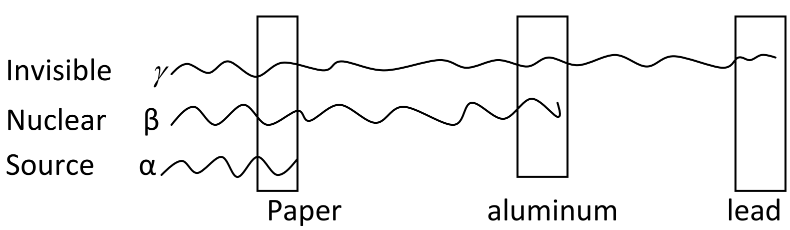
- It is a radioactive emission of very short wavelength of electromagnetic radiation.
- Its symbol is ${}^{0}_{0}\gamma$ or γ

<u>Properties of gamma rays</u>

1. They produce very little and weak ionization effect because their charge is zero.
2. They are very penetrating. Thus, they are able to penetrate through about 4cm of lead and their intensity is reduced by thick concrete. This is due to the fact that they are very light and move at a high speed, a speed of light.
3. They are not deflected by magnetic and electric fields because they do not carry any charge.
4. They have no mass and charge
5. Have a speed as that of light

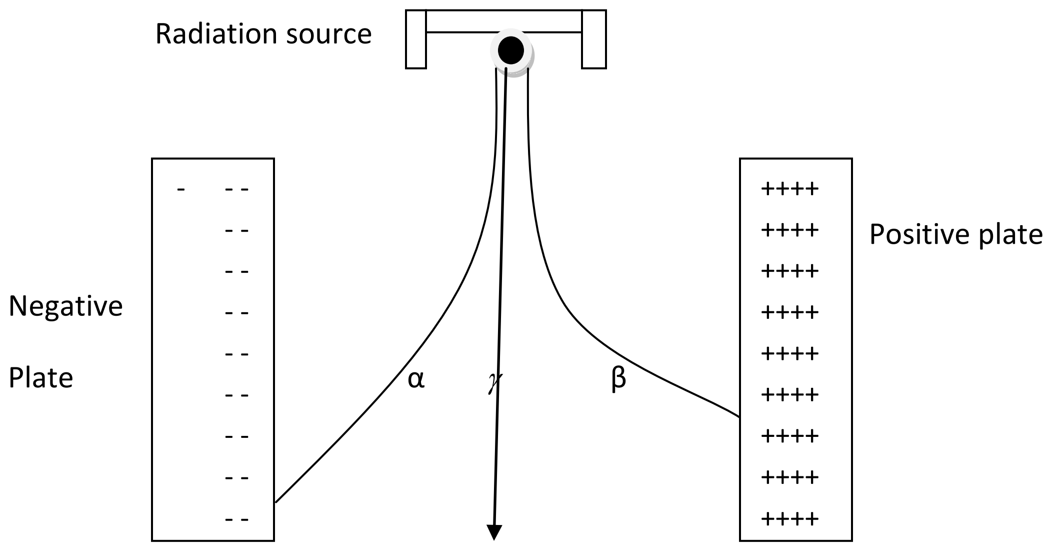
<u>COMPARING THE LEVEL OF PERNETRATION</u>:

Figure below shows relative penetration power among the three types of radiation.



DESCRIBING DEFLECTION IN AN ELECTRIC FIELD

Figure below shows radiation passing through an electric field.



The alpha particles get attracted to the negative plate since they are positively charged and unlike charges attract each other. The same applies to the beta particles which are attracted towards the positive plate since they have a negative charge. Gamma rays are not affected in the field since they do not possess any charge to warrant either repulsion or attraction. Note that beta particles bend more than alpha particles because beta particles have a smaller, if not a negligible mass as compared to that of alpha (helium) particles.

TYPES OF RADIOACTIVTY

Radioactivity can either be natural or artificial (induced)

a. Natural radioactivity

   This happens without human interference and involves mostly nuclides whose atomic numbers are more than that of lead $^{207}_{82}Pb$

   Examples of nuclides which can undergo natural radioactivity are uranium-238, thorium-234, radium-226 etc.

b. Artificial or induced radioactivity

   This is done by exposing a stable naturally occurring nuclide to different atomic particles inside a nuclear reactor. The different particles used in this bombardment are: neutrons, protons, hydrogen isotopes etc.

Take note that the induced radioactivity leads to production of energy and different radioisotopes.

Next part gives examples of how induced radioactivity can be achieved;

1. <u>Neutron bombardment</u>

- When a stable non-radioactive uranium 238 is bombarded by a neutron particle a radioactive uranium-239 is obtained

$$^{238}_{92}U + ^{1}_{0}n \longrightarrow ^{239}_{92}U$$

2. Alpha bombardment

$$^{19}_{9}F + ^{4}_{2}\alpha \longrightarrow ^{22}_{11}Na + ^{1}_{0}n$$

$$^{14}_{7}N + ^{4}_{2}\alpha \longrightarrow ^{17}_{8}O + ^{1}_{1}H$$

- A proton or neutron gets emitted in the process.
- Description of a proton bombardment is also done as above.

SOURCES OF RADIATION:

Sources of radiation can be categorized into two namely:

a. Natural sources
b. Artificial (human) sources

a. Natural sources of radiation

Three major sources of naturally occurring radiation are:

- **Cosmic radiation**

  This comes from the sun and outer space and consists of positively charged particles as well as gamma radiation.

- **Terrestrial radiation**

  These are natural sources of radiation in the ground rocks, building materials and drinking water supplies. Examples under this category include: Uranium, radium, thorium and radon gas. The radon gas is as a result of decay of natural uranium in the soil. The radon which emits alpha radiation rises from soil under the houses and can build up in homes.

- **Internal sources**.

  Our bodies also contain natural radio nuclides. Potassium 40 is one example.

b. Artificial (Human) sources

The following information briefly describes example of human made sources of radiation.

- Medical radiation sources

  Examples include x-rays which have some similar properties to gamma rays.

- consumer products

  Examples include TV's, older luminous dial watches, some smoke detectors etc.

- Atmospheric testing of nuclear weapons.

  This leads to residues of radioactive substances as a result of testing nuclear weapons in the atmosphere and water bodies.

DETECTING RADIATION

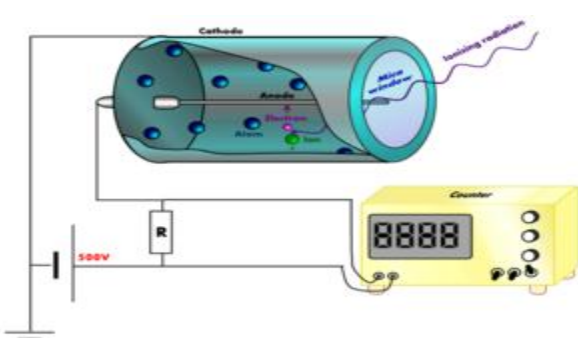
There are a number of instruments used to detect radiation .this part describes some of the widely used detectors.

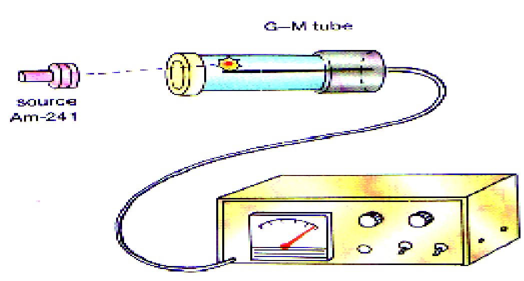
I. By photographic plates.
   - Once a photographic is exposed to radioactivity it gets fogged.
   - The fogging of the photographic film is a measure of radioactivity to which they have been exposed
   - It was this phenomenon which lead to discovery of radioactivity by the scientist Henri Becquerel in 1896.

II. By scintillation counter
   - There are substances such as zinc sulphide which phosphoresce when affected by radioactivity.
   - As each particle from the radioactive source hits ‘the phosphor’ a flash of light is emitted
   - In scintillation counter, each flash of light gives rise to a pulse of current
   - A digital counter records the pulse of current.

III. Spark counter
   - It makes use of ejection (release) of electrons from the surface of metals when light falls on them
   - Sparks happen where radioactive particles ionize the air. (this is normally the case with the alpha and beta particles which have the ionizing power)

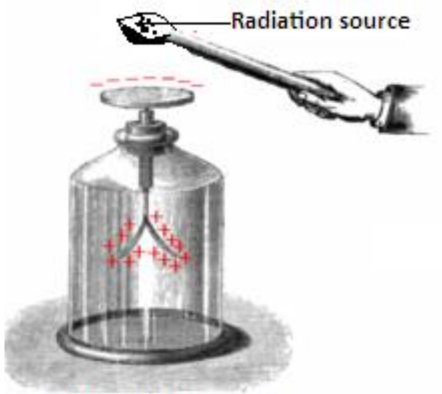
IV. Geiger- Muller Tube
   - When a particle enters inside this tube it causes ionization of argon gas and a flow of charge takes place
   - The pulse of current caused by the flow of charge can be amplified and the pulse is counted electronically by a scale or a rate meter.





V. Gold Leaf Electroscope
   - A charged electroscope gets discharged when a radiation source (held in forceps) is brought near the cap of the electroscope.
   - Radiation knocks electrons out of surrounding air molecules leaving them as positively charged ions. This is called ionization

- The positive air ions are attracted to the cap if the electroscope is negatively charged and vice versa. This, in any case, causes the charge on the electroscope to be neutralized.



Gold Leaf Electroscope

Other radiation detectors are:

- Bubble chamber
- Wilson cloud chamber
- Solid state detectors
- Match counter

DECAY CURVES AND HALF-LIFE

The number of parent nuclei decreases exponentially with time and as a result it is known as the exponential law of radioactive decay.

The radioactive decay is measured in activity per second or number of disintegrations per second but the SI unit of radioactivity is called Becquerel, Bq.

The equation of decay is as follows:

$N = N_0 e^{-\lambda t}$ ……equation 1 where N is the amount remaining

N_0 is the original amount of nucleus

e is an exponent (used when talking about natural logs)

t is the time taken for the decay

λ is the decay constant. OR the equation 2 which is

$$N = N_0\left(\frac{1}{2}\right)^{\frac{T}{t}}$$ Where T is the time for decay and t is half-life. N and N_0 are as above

HALF-LIFE:

This is the time taken for half of the nuclei to remain or time taken for half of the atoms in a sample to decay. E.g. if before decay there were 60 grams of a radioactive sample, then after half-life there would be 30 grams. After a further half-life there would be 15g then 7.5g and so on.

Since after half-life the amount remaining (N) is half the original amount (N_0) then it can be stated as follows: at $t = T_{1/2}$ $N = N_0/2$ then equation 1 becomes $N_0/2 = N_0 e^{-\lambda T_{1/2}}$

$\Rightarrow 1/2 = e^{-\lambda T_{1/2}}$

$\Rightarrow \ln ½ = -\lambda T_{1/2}$

$\Rightarrow T_{1/2} = 0.6931/\lambda$

Example 1.

Given that a radioactive particle of Bismuth-210 has a half-life of 5 days. If originally there is 80grams of Bismuth-210 determine the amount that would remain after

a. 5 day
b. 15 days

Solution:

Time in days	0	5	10	15
Amount remaining	80g	40g	20g	10g

a. 40g b. 10g

By use of formula; a. N=? N_0 = 80g t=5days, T= 5 days.

$$N = N_0\left(\frac{1}{2}\right)^{\frac{T}{t}} = 80g\left(\frac{1}{2}\right)^{\frac{5}{5}} = 40g$$

b

$$N = N_0\left(\frac{1}{2}\right)^{\frac{T}{t}} = 80g\left(\frac{1}{2}\right)^{\frac{15}{5}} = 80g\left(\frac{1}{2}\right)^{3} = 80g\left(\frac{1}{8}\right) = 10g$$

OR

N=? N_0 = 80g t=5days. Need to find decay constant λ.

Using $T_{1/2} = 0.6931/\lambda$ then$\lambda = 0.6931/T_{1/2}$therefore, λ = 0.6931/5 = 0.13862

$$N = N_0 e^{-\lambda t} = 80 \times e^{-0.13862 \times 5} = 40g$$

$$\text{b. } N = N_0 e^{-\lambda t} = 80 \times e^{-0.13862 \times 15} = 10g$$

The table below shows some elements and their half-lives

ELEMENT	HALF-LIFE
Thorium	10^{10} years
Radium-226	1602 years
Bismuth-210	5 days
Polonium-214	3 minutes
Iodine 131	8 days
Iodine 128	25 minutes
Carbon 14	5730 years
Boron 12	0.02 years
Radon 220	52 seconds

Example 2

If 6.25g of radioactive sample was found to remain after 208 seconds of radioactivity calculate the half-life of the sample if the original activity was 100 grams.

N_0 = 100g, N = 6.25g T = 208 second, t = ?

$$N = N_0\left(\frac{1}{2}\right)^{\frac{T}{t}} \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{T}{t}}.$$

Thus $\dfrac{6.25}{100} = \left(\dfrac{1}{2}\right)^{\frac{208}{t}} = \dfrac{1}{16} = \left(\dfrac{1}{2}\right)^{\frac{208}{t}}$

Therefore

$$\left(\frac{1}{2}\right)^{\frac{208}{t}} = \left(\frac{1}{2}\right)^{4} \Rightarrow \frac{208}{t} = 4 \Rightarrow t = \frac{208s}{4} = 52\,\text{seconds}.$$

In another way, N_0 = 100g, N = 6.25g t= 208 seconds $T_{1/2}$ = ?

Using the equation $N = N_0 e^{-\lambda t}$ we have 6.25= 100x $e^{-\lambda x\, 208}$

$\Rightarrow$ 6.25/100 = $e^{-\lambda x\, 208}$

$\therefore$ Ln (6.25/100) = $^{-}\lambda$x 208

$\therefore$ λ = Ln (6.25/100)/(-208) = 0.0133

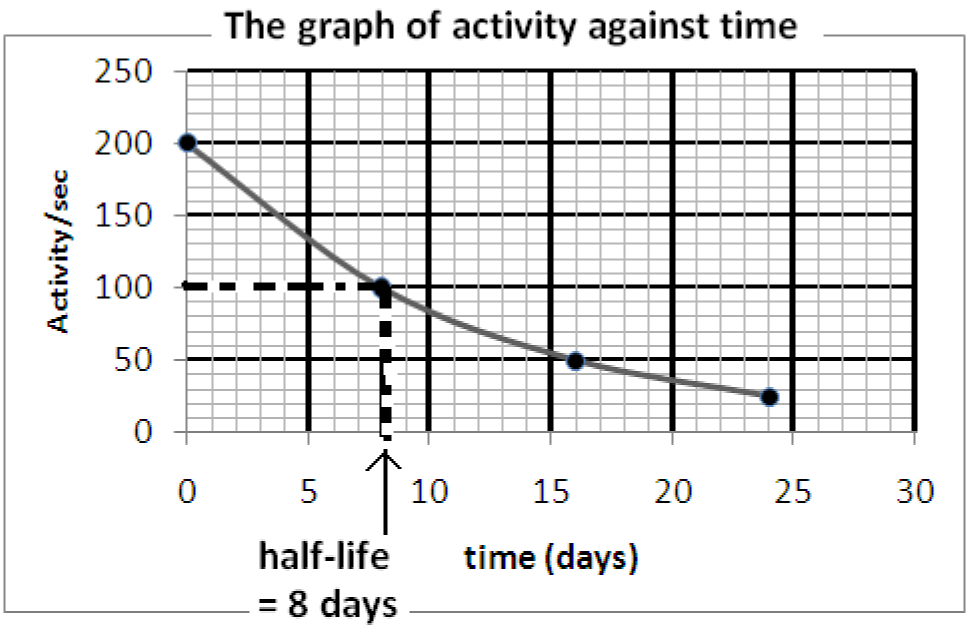
Now $T_{1/2}$ = 0.6931/λ = 0.6931/0.0133= 52 seconds

Graphical way of determining the half-life

The following table shows values for the decay of radioisotope iodine -131

Time (days)	0	8	16	24
Activity/ second	200	100	50	25

Plot a graph of **activity against time**. Use your graph to find the half-life of the iodine-131 clearly showing how you get it on the graph.



DANGERS, SAFETY PREACAUTIONS, AND STORAGE OF RADIOACTIVE SUBSTANCES:

Dangers:

- ✓ Beta and gamma rays can cause radiation burns(redness and sore on the skin)
- ✓ It can also cause delayed effects like cancer and eye cataract
- ✓ Low dosage over periods can cause fetal deformities, leukemia, bone cancer and other forms of cancer.

Safety Precautions

- ✓ Hold the radioactive substance using forceps.
- ✓ Never hold a radioactive substance near one's eyes
- ✓ Put the substances in lead boxes when not in use
- ✓ Avoid ingestion of the radioactive substance

- ✓ Limit the amount of radiation you receive from x-rays and ultraviolet
- ✓ Reduce time of contact with the radioactive substance
- ✓ Never smoke near a radioactive source
- ✓ Keep food away from places where radiation is used
- ✓ Used sources must be dumped in concrete tanks

NUCLEAR FISSION AND FUSION

Nuclear fission

- ✓ It is the disintegration of a heavy nucleus into two lighter nuclei.
- ✓ Energy is released during nuclear fission
- ✓ An example is the bombardment of uranium $^{235}_{92}U$ by slow neutrons

$$^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{236}_{92}U \longrightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3^{1}_{0}n + energy$$

- ✓ Nuclear fission gives out a huge amount of heat which is used to turn water into steam. The steam is used in turn to drive turbans for electricity
- ✓ The energy released by the fission of a single uranium atom is about 200 Mev, and about 80% of this goes into providing the kinetic energy of the two fission fragments which are often radioactive.
- ✓ Nuclear reactors makes use of controlled fission reaction to provide heat at a steady rate
- ✓ The atomic bomb makes use of uncontrolled fission reaction
- ✓ The energy from nuclear reactors is used to make steam for the turban in conventional power station.

Nuclear fusion

- ✓ This is the amalgamation (combination)of two light nuclei to produce a heavier nucleus
- ✓ Like in fission, energy is released.
- ✓ An example is the fusion of two deuterium nuclei to produce a helium-3

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n + energy$$

- ✓ Reactions of this type(the conversion of hydrogen to helium) are the sources of the sun's energy
- ✓ The explosion of a hydrogen bomb is as a result of a nuclear fusion.

COMPARISON BETWEEN NUCLEAR FISSION AND NUCLEAR FUSION

	NUCLEAR FISSION	NUCLEAR FUSION
1	**It is the breaking of a heavy nucleus to produce lighter ones**	**It is the amalgamation (combination)of two light nuclei to produce a heavier nucleus**
2	**It is a chain process**	**It is not a chain process**

3	**It results into production of many radioactive particles**	**It results into production of few radioactive particles**
4	**Less energy is needed to activate the process**	**High energy is needed to kick start the process**
5	**Releases fewer energy**	**Releases higher amounts of energy**
6	**Does NOT normally occur in nature**	**It normally occurs in nature (like in the stars e.g. sun**
7	**Its progress can be controlled**	**It's very difficult to control its progress**
8	**Leaves many radioactive wastes (causes pollution)**	**Leaves no trace of radioactive wastes hence NO pollution**

USES OF NUCLEAR RADIATION (RADIOACTIVITY)

1. Carbon 14 dating
   - It is used in archaeology to estimate age of an organism that died sometime back.
   - Living matter takes in carbon in form of CO_2 from the atmosphere. When an organism dies the intake of CO_2 stops. This causes carbon-14 content to start decreasing as a result of radioactivity. However, the caron-12 content stays constant and therefore from the moment of death the rate of carbon-14 to carbon-12 decreases
   - When a tree is cut down and burnt radioactive decay of charcoal begins. The longer the charcoal was formed the lower is its radioactivity.
2. Tracers
   - In agriculture it is used to study uptake of fertilizer in plants. E.g. radiophosphosrous-32
   - Radioactive carbon-14 is also used in the study of photosynthesis.
   - Detecting leaks in underground pipes by adding a tracer to the fluid in the pipe. Eg radioactive iodine-131 is used to detect leaks in water and fuel lines.
   - Note that tracers with short half-lives are used to avoid accumulation of the radioactive substances which can pollute the environment and causes different undesirable effects. It also assists in getting instant (immediate) results.
3. Thickness monitoring
   - The thickness of metal sheet, paper, rubber and plastics can be monitored during manufacturing by passing it between beta or gamma source and a suitable detector
   - The thicker the sheet the grater the absorption
   - Also in the industries they use radiation to check whether packets and containers have been correctly filled.
4. Medical (radiotherapy)

- Cancer cells can be destroyed by gamma radiation. Gamma rays are most penetrating
- Deep lying tumors can be treated by planting radium-226 or ceasium-137 inside the body close to the tumor
- Radioactive iodine 131 is used in persons suffering from diseases of the thyroid gland. It may also be injected into the blood stream to detect tumors
- Iron -59 is used to monitor red blood cells production in bone marrow
- Sodium-24 is used to monitor blood flow and detect blood clots and destruction in blood vessels.

5. Sterilization/food preservation
    - Gamma rays can be used to kill bacteria on such thing as hospital blankets and certain foods. Surgical (medical) equipment can be sterilized more effectively by radioactivity than boiling.
6. Power generation (Energy source)
    - Power is produced at nuclear reactors. The obvious example is the use of uranium-235 in fuel nuclear power stations to produce energy. This energy source is called nuclear energy.
    - There are, however, other portable power sources which use radioactive materials.
    - Some satellites contain radioactive material which are decaying naturally and giving enough energy to remain hot throughout long space flight.
    - The great merit in this type of power station is the small fuel consumption. A few kg of uranium are sufficient to produce hundreds of megawatts of power for a whole day.

NUCLAR REACTORS

A nuclear reactor produces and controls the release of energy from splitting of atoms of certain elements.

Energy released is used as heat to produce steam which drives turbines.

Some Major Components of a nuclear reactor:

Fuel

Uranium is the basic fuel. Usually pellets of uranium oxide (UO_2) are arranged in tubes to form fuel rods. The rods are arranged into fuel assemblies in the reactor core.

Moderator

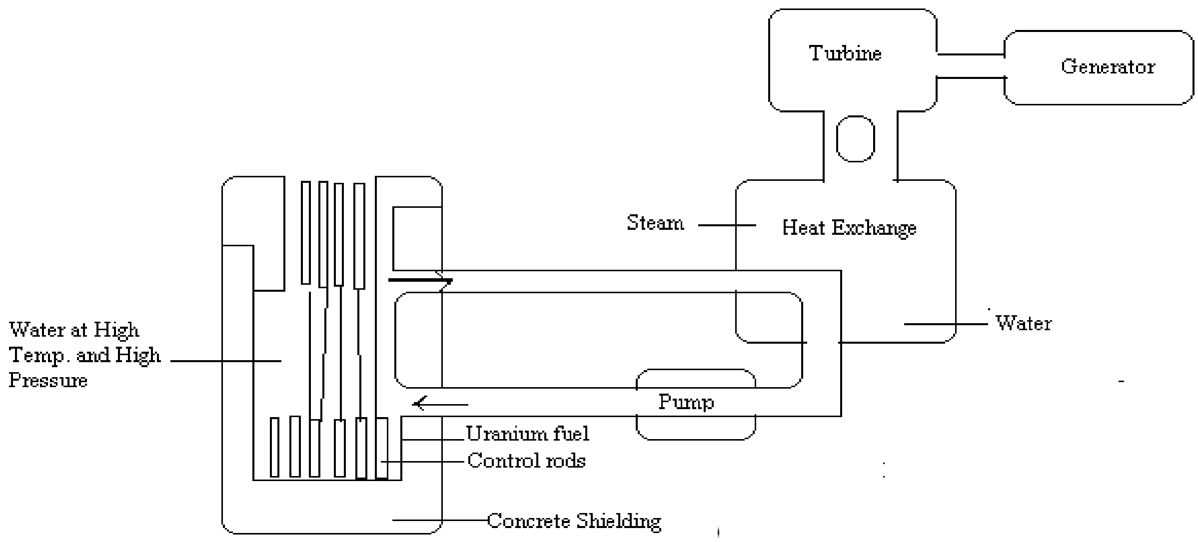
This is material in the core which slows down the neutrons released from fission so that they cause more fission. It is usually water, but may be heavy water or graphite.

Control rods

These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the core to control the rate of reaction.

Coolant.

A liquid or gas that circulates through the core so as to transfer the heat from it. . In light water reactors the water moderator functions also as primary coolant.



Nuclear Reactor

2015 No

6c

i. **Mention any two properties of beta particles**

Answer: are negatively charged, are more penetrating than alpha, are less ionizing than alpha, get deflected in magnetic and electric fields etc

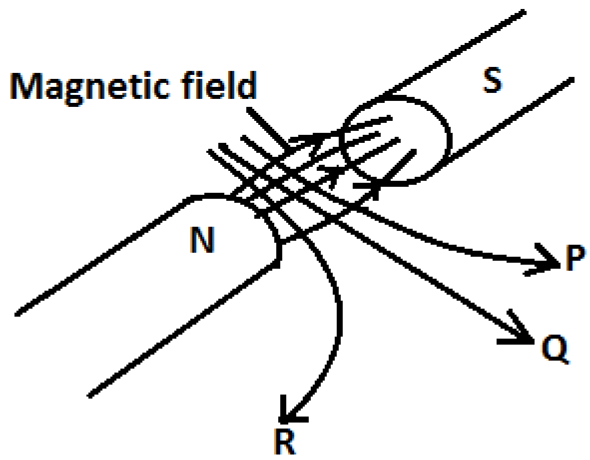
ii. **State any two safety precautions when handling radioactive substances**

Answer: handle with forceps, use minute amounts when doing experiments, keep it away from eye and skin

iii. **Explain how radioactivity could be induced**

Answer: it could be induced by exposing radioactive nuclei to a fast moving particle eg a neutron, alpha etc. The accelerated particle excites the nucleus to undergo radioactivity.

d. figure 4 is diagram showing the effect of magnetic field on nuclear radiation



Identify the type of radiation P, Q and R

<u>Answers: P: is alpha radiation Q is gamma radiation and R is beta radiation</u>

2014

7

a. The equation below shows nuclear decay of carbon $\left({}^{14}_{6}C\right)$ and cobalt $\left({}^{60}_{27}Co\right)$

$$1.\left({}^{14}_{6}C\right)\longrightarrow \_\_\_\_\_\_\_\_\_\_\_\_ + {}^{14}_{7}N$$

$$2.\left({}^{60}_{27}Co\right)\longrightarrow\left({}^{60}_{27}Co\right) + \_\_\_\_\_\_\_\_\_\_\_\_$$

(i) Complete the equations

$$1.\left({}^{14}_{6}C\right)\longrightarrow {}^{0}_{-1}e + {}^{14}_{7}N$$

$$2.\left({}^{60}_{27}Co\right)\longrightarrow\left({}^{60}_{27}Co\right) + {}^{0}_{0}\gamma$$

(ii) Which equation represents gamma emission? ***Answer: Equation 2***

(iii) Why has $\left({}^{60}_{27}Co\right)$ not changed its atomic mass and atomic number in the daughter nuclide?

Answer***: it's because gamma emission is not a particle but form of energy with zero atomic number and mass number hence no change to*** $\left({}^{60}_{27}Co\right)$

b. State any three properties of a beta particle

Answer:

- ***Have a negative charge***
- ***Gets deflected in magnetic and electric field***
- ***Are more penetrating than alpha***
- ***Have a less ionization power than alpha***
- ***Move at relatively higher speed than alpha***

c. What do A and Z stand for in the following nuclear notation?

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

A: ***atomic mass or mass number***

Z: ***atomic number***

d. The half-life of sodium-24 is 15hours. If the initial count rate is 240 counts/second, calculate the count rate after 30 hours

$$t = 15hrs, N_0 = 240c/\sec, T = 30hrs$$

$$N = N_0\left(\frac{1}{2}\right)^{\frac{T}{t}} = 240\left(\frac{1}{2}\right)^{\frac{30}{15}} = 240 \times \frac{1}{4} = 60counts/\sec$$

2013

7.

a. State any two safety measures when handling radioactive substances at a school
- ***Use small amounts when conducting experiments***
- ***Handle with forceps***
- ***Avoid bringing samples close to one's mouth and eye***
- ***Keep them away from food stuffs***

b. Mention two particles that are produced when a neutron disintegrates

Answer: Protons and electrons

c. Explain how gamma emission occurs

Gamma emissions are simply packets of energy released by decay of atomic nuclei as they move from a high state of instability (with high energy) to a low level of stability (less energy).

d. A radioactive substance with an activity of 30 counts/second is disintegrating. Calculate the number of disintegrated atoms after 10 minutes

Time = 10 minutes = 60 x 10 = 600 seconds

If in 1 second, 30 atoms disintegrates then in 600 seconds it would be more

Number of disintegrated atoms = 600 x 30 = 18 000

2012 6d

(i) Name two types of radioactivity. ***Natural radioactivity and artificial (induced) radioactivity***

(ii) Define "half-life" of a radioactive element

This is the time taken for half of the radioactive element to decay

(iii) Mention any three properties of alpha particle

1. ***It is the most highly ionizing particle. I.e. it knocks off electrons in an atom and makes it charged. This is attributed to the high charge they have (+2)***
2. ***It can penetrate about 5 cm of air because of its relatively large mass.***
3. ***It can be deflected by electric and magnetic fields. (It bends in these fields). This is so because of its positive charge and any charge creates a magnetic and an electric field.***
4. ***It is positively charged(has a charge of +2)***
5. ***Move at a low speed as compared to the speed of light (due to its large mass***).

8d .Explain any two uses of nuclear radiation. ***Source of energy. This is done in nuclear reactors. Uranium is normally used. Used in sterilization of medical equipment. Gamma rays are best used because of high penetration.***

PRACTICE QUESTIONS (ANSWERS TO SELECTED QUESTIONS ARE PROVIDED)

1. The following represents the radioactive decay of throrium-232. A, Z and X are unknown.

   $$^{232}_{90}\text{Th} \longrightarrow {}^{A}_{Z}\text{X} + {}^{4}_{2}\alpha$$

   a. What type of radiation is being emitted?
   b. What are the values of A and Z?
   c. Use the periodic table to determine what X is
   d. Rewrite the above equation replacing A, Z and X with numbers and symbols you have found.
   e. What are the decay products?
2. When a radioactive sodium-24 decays, magnesium -24 is formed. The following is an incomplete equation for the process.

   $$^{24}_{11}\text{Na} \longrightarrow {}^{24}_{12}\text{Mg} + \underline{\qquad\qquad}$$

   Assuming that only one charged particle is produced
   a. What is the mass number of this particle?
   b. What is the relative charge of this particle?
   c. What type of particle is it?
3. The half-life of Iodine-128 is 25 minutes. If the activity of a sample of iodine-128 is 800becquerels (800 Bq). What would you expect the activity to be after
   a. 25 minutes
   b. 50 minutes
   c. 100 minutes
4. Give two uses of radioactive tracers and explain why it is important to use tracers with short half-lives.
5. The symbol $^{35}_{17}\text{Cl}$ represents one atom of Chlorine

State the names, numbers and locality of the different particles found in one of these chlorine atoms.

6. The phosphorous-32 is a radioactive isotope. It can be used to prove that plants absorb phosphorous from the soil around them.

a.

I. The stable isotope of phosphorous has a mass number of 31. Sate the structural difference between the atoms of phosphorous-31 and phosphorous-32.

II. Explain why both isotopes of phosphorous have identical chemical properties.

b. Phosphosrous-32 is a beta-emitter with a half-life of 14 days.

I. What is a beta emitter?

II. The atomic number of phosphosrous-32 atom is 15. State the new values of the atomic and mass numbers of the atom just after it has emitted a beta particle.

c. State three safety precautions which should be adopted when doing experiments with radioactive phosphorous-32.

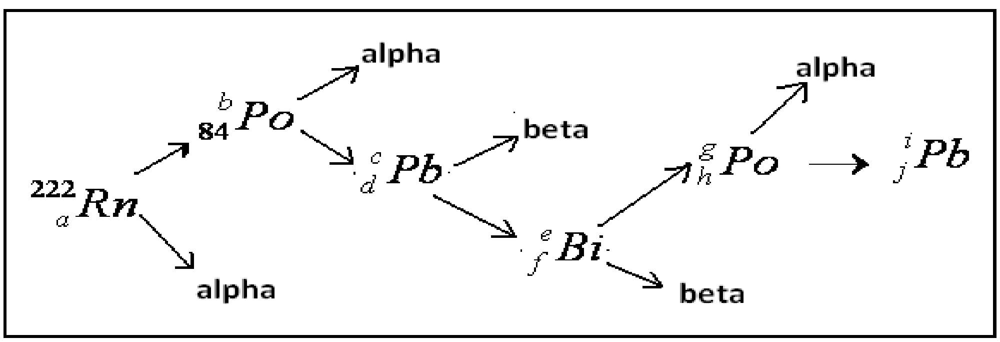
7. A milk sample containing **Iodine-131** was found to have an activity of 1600 units per liter. The activity of the sample was measured every 7 days and the results are as shown below

TIME (days)	0	7	14	21	28	35
ACTIVITY (units per day)	1600	875	470	260	140	77

a. Draw a graph of activity against time.

b. Estimate the half-life of iodine 131 and show on the graph how you arrive at your answer.

8. Fig below shows how radon decays.



(**Identify the values of a, b, c, d, e, f, g, h, I and j**

9. Write down the nuclear equation for the following fro the following

a. Conversion of ${}^{13}_{6}C$ to ${}^{14}_{6}C$

b. Conversion of ${}^{30}_{15}P$ to ${}^{30}_{14}Si$

10. A radioactive series is shown below. Copy and fill the missing words and numbers.

$${}^{210}_{80}A \xrightarrow{a} {}^{b}_{78}B \xrightarrow{c} {}^{206}_{d}C \xrightarrow{alpha} {}^{e}_{f}D \xrightarrow{beta} {}^{g}_{h}E \xrightarrow{i} {}^{198}_{j}F$$

Note: there are 10 question marks for you to answer.

11. Bismuth sample with a half-life of 5 days was left to disintegrate. It was observed using a Geiger Muller Counter that after 25 days from the start of decay the activity of Bismuth sample was 10counts/second. Calculate the original counts of the Bismuth sample.

.

12. Complete the following nuclear equations

    a. $\_\_\_\_\_\_\_\_ + {}^{4}_{2}He \longrightarrow {}^{30}_{15}P + {}^{1}_{0}n$

    b. $\_\_\_\_\_\_\_\_ + {}^{2}_{1}H \longrightarrow {}^{13}_{7}N + {}^{1}_{0}n$

    c. $\_\_\_\_\_\_\_\_ \longrightarrow {}^{82}_{36}Kr + {}^{0}_{-1}e$

    d. ${}^{66}_{29}Cu \longrightarrow \_\_\_\_\_\_\_\_ + {}^{0}_{-1}e$

    e. ${}^{0}_{-1}e + \_\_\_\_\_\_\_\_ \longrightarrow {}^{7}_{3}Li$

13. Write **four** properties of each of the following
    a) Alpha decay
    b) Beta decay
    c) Gamma radiation
14. By giving an example of each in form of equation distinguish nuclear fusion from nuclear fission
15. Highlight **six** uses of nuclear radiation or radioactivity.
16. Mention **five** precautionary measures of handling radioactive materials.

Write down **four** ways of detecting nuclear radiation

ANSWERS TO SELECTED QUESTIONS

1.

a. Alpha radiation
b. A= 238 -4 = 228 and Z = 90-2 = 88
c. X is Radium
d. $${}^{232}_{90}Th \longrightarrow {}^{228}_{88}Ra + {}^{4}_{2}\alpha$$
e. Alpha particles and radium

2.

a. 0
b. -1
c. A beta particle

3.

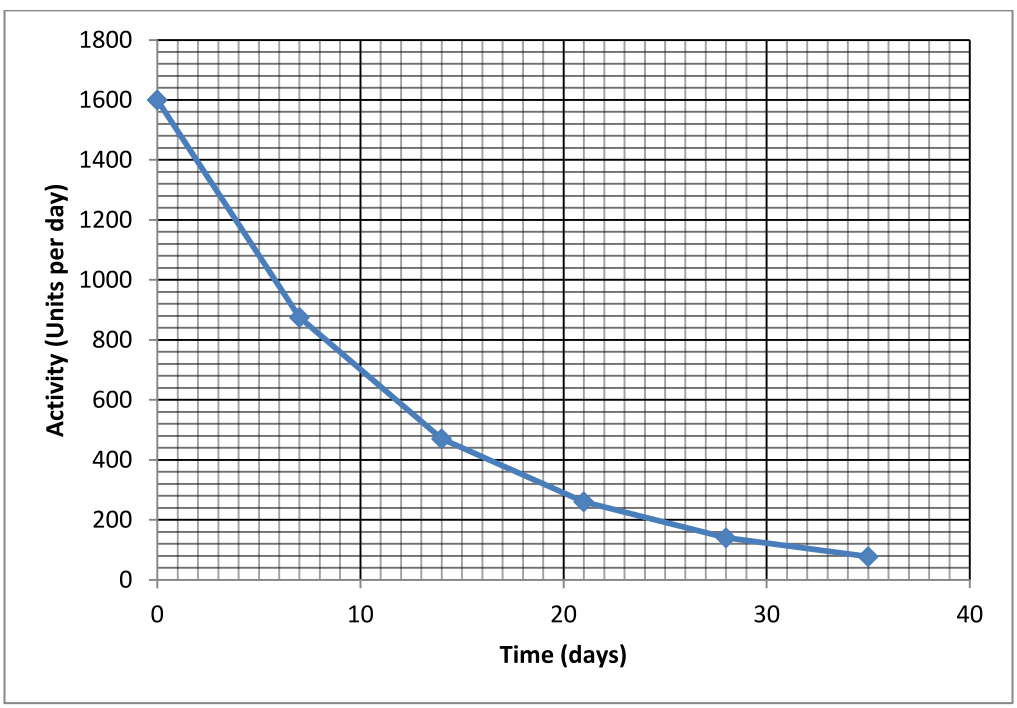
a. 400Bq
b. 200Bq
c. 50Bq

4. To detect uptake of nutrients by the plants and to detect cracks in pipes. It is important to use tracers with short half-lives because it assists in avoiding accumulation and over stay of the substances in the environment which can be hazardous to the living things. It also assists in getting quick results.
5.

Name of particle	locality	number
Electron	Shells/energy levels	17
Proton	nucleus	17
neutron	nucleus	18

6.
   a. (i)The atoms will defer in the number of neutrons that will be contained in their nucleus.
      (ii) The isotopes have identical chemical properties due to same number of electrons and protons.
   b. (i) It is a substance that releases a beta particle when it undergoes radioactive decay.
      (ii) Mass number will be 32 and the atomic number will become 16
   c. Refer to the notes.

7a. **THE GRAPH OF ACTIVITY AGAINST TIME**



7. b. 8 days
8.

a	b	c	d	e	f	g	h	i	j
86	218	214	82	214	83	214	84	210	82

9.

a. $$^{13}_{6}C + ^{1}_{0}n \longrightarrow ^{14}_{6}C$$

b. $$^{30}_{15}P + ^{0}_{-1}e \longrightarrow ^{30}_{14}Si$$

10.

a	b	c	d	e	f	g	h	i	j
Alpha	206	Beta	79	202	77	202	78	Alpha	76

11. Use the table below

Time (days)	25	20	15	10	5	0
Amount remaining	10cts/sec	20cts/sc	40cts/sec	80cts/sec	160cts/sec	320cts/sec

Therefore the original count was **320 counts per second**

Or using the formula as shown on the next page

$$N = N_0\left(\frac{1}{2}\right)^{\frac{T}{t}} \Rightarrow 10c/s = N_0\left(\frac{1}{2}\right)^{\frac{25}{5}} = N_0\left(\frac{1}{2}\right)^{5}$$

Thus

$$10c/s = N_0\left(\frac{1}{32}\right) \Rightarrow N_0 = 32x10c/s = 320counts/\sec$$

12.

a	b	c	d	e
$^{27}_{13}Al$	$^{12}_{6}C$	$^{82}_{35}\mathbf{Br}$	$^{66}_{30}Zn$	$^{7}_{4}Be$

REFERENCES:

1. Wallis, K (1992) *Physical science for Malawi Book 1 &2*, Zomba; Chancellor College
2. Duncan, T. (1983). *Physics for Today and Tomorrow*, 2nd Ed. London: John Murray
3. Gallagher, R .M and Ingram, P. (1997). *GCSE CHEMISTRY*. Oxford: Oxford University Press.
4. Gallagher, R.M (2000), *Complete Chemistry*, Oxford: Oxford University Press.
5. Odian, G &Blei, I (1994) Schaum's Outline of Theory & Problems of General, Organic, and Biological Chemistry: Mac Graw Hill Companies: New York
6. MIE (2001), *Malawi Senior Secondary Teaching Syllabus, Physical Science (3-4),*Zomba: MIE
7. Malawi National Examinations Board, Maneb- Physical Science Examination Past papers.
8. Murigi, M. etal (2007)K K.C.S.E Golden Tips Physics, Moran Publishers