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FORM ONE NOTES

Introduction to chemistry

By Defn: Chemistry is a science that deals with the composition, structure and properties of matter

Where:

i. ***Matter*** *is anything that has mass and occupies space*. It includes the materials or substances of nature which make up our environment
ii. *The people who study Chemistry are called* ***chemists***. Those who studied Chemistry in ancient times are known as **alchemists**
iii. ***Science*** *is the scientific study of nature*. For example how cooling effect occurs

Scientific Subjects

In order the subject to be a science subject it should involves experiments and practical work. Chemists have to acquire certain skills in order to be successful. These skills include:

i. Careful and thorough observation
ii. Accurate recording of what has been observed
iii. Organizing the observed and recorded information
iv. Repeating tests to make sure observations are accurate
v. Forming conclusions from observations
vi. Predicting possible outcomes of similar experiments

Application of Chemistry

Chemistry is an important subject that is applied in different fields such as agriculture, medicine, manufacturing, education, food and beverage industry, home care and cosmetics industry, among others. This means that Chemistry is applied in

i. Factories
ii. Homes
iii. Hospitals
iv. Laboratories
v. Research centres
vi. Universities

Products made by application of Chemistry

Field	**product**
Agriculture	Fertilizers, pesticides, weed killers, animal vaccines
Medicines	Drugs, vaccines, food supplements
Home care and cosmetics industry	Detergents, beauty products, soaps, shoe polish, toothpaste, disinfectants, insecticides
Food and beverage industry	Soft drinks, common salt, yeast, baking powder, canned food
Manufacturing industry	Paints, chemicals, varnishes, cement ,plastics
Textile industry	Closes, dyes
transport	Fuels, lubricants, oil, grease, coolants, tyres

Importance of Chemistry

Chemistry is an important subject due to its application in our daily life. The follows is important of chemistry in various aspect

i. Agriculture
ii. Food and beverage industry
iii. Medicine
iv. The manufacturing industry
v. Transport
vi. Communication
vii. Home care products
viii. Beauty products

Agriculture

In a process of growing crops and animal keeping, farmers uses many products made by chemists to get better agricultural yields includes

i. **Fertilizers** – used to improve the quality and quantity of crops and yields respectively
ii. **Weed killers** – are chemical substances used to destroy unwanted plants which harm the crops
iii. **Pesticides** – are chemical substances sprayed or sprinkled on crops to destroy pests that leads low or no yields. Also introduces in animal dips to treat animals from ticks etc
iv. **Animal vaccines** – chemical substance used to protect animal from disease
v. **Processed animal feeds** – animal food which mixed with different nutrients component to improve animal health

Food and beverage industry

i. Preservation of food especially those canned or bottled example bear, canned maize etc
ii. Preparation of certain foods such as bread, cakes and sweet

Medicine

In medicine field Vaccines (prevent illnesses) and medicines (treat diseases) are Produced chemically

The manufacturing industry

In industry many material made chemically used to make product. Examples of product are **cement**, plastic container, textiles, chemicals, rubber and paper

Transport

i. Fuels used on transport are produced chemically
ii. The parts used on transport like car engine and tyres are made chemically

Communication

i. Letters, newspaper and magazine are manufactured chemically
ii. Telephones and computer rely heavily on wires which made chemically

Home care products

Product used to make home and its environment which used to clean (soap and detergents), kill insect (disinfectants) and decoration (air fresh and paints) are made chemically

Beauty products

Product used to improve human physical appearance like nail varnish, creams, lotions, perfumes and deodorant are made chemically

Chemistry for careers (professional development)

The skills acquired in chemistry are very valuable in different careers like

i. Doctor
ii. Pharmacist
iii. Chemical engineers
iv. Laboratory technician
v. Nurse
vi. Researcher

Laboratory Techniques and Safety

By defn: *laboratory is a special room or building that designed and used for scientific experiments*. Laboratories have special tools and equipments called **Apparatus**

Feature of Laboratory

The laboratory should have the following

i. Water supply system
ii. Drainage system
iii. Electricity supply
iv. Well illuminated
v. Well ventilated
vi. Door open out ward
vii. Gas supply

Laboratory Rules

By defn: *laboratory rule is the set of regulation governing practical activities in the laboratory*

Parts of laboratory activities

Laboratories rules divided into three parts include

i. Before laboratory activities
ii. During laboratory activities
iii. After laboratory activities

Laboratory Rules Before laboratory activities

i. Do not enter the laboratory without the permission or presence of the teacher or laboratory assistant
ii. Dress appropriately for the laboratory activities. Do not wear loose or floppy clothing. Tie back long hair. Roll up long sleeves. Do not wear shorts, or walk barefoot or in sandals
iii. Keep the windows open for proper ventilation.
iv. Master the location of all exits

Laboratory Rules During laboratory activities

i. Read instructions carefully before you start any activity
ii. If you do not understand something, ask your teacher before proceeding
iii. Read the labels on **reagent bottles** carefully to make sure you have the right substance. Do not interchange labels
iv. Do not eat, drink, smoke, play or run in the laboratory
v. Do not taste or smell chemicals unless advised on how it should be done
vi. Use the **fume chamber** when carrying out experiments where harmful gases and vapours are produced
vii. Only perform the intended experiments. Do not set up your own experiments or interfere with someone's experiment.
viii. Do not spill liquids on the floor
ix. Report any breakages or accidents to the teacher or laboratory assistant immediately
x. When heating substances, direct the mouth of the test tube away from you or others. Do not point burners or hot substances towards yourself or other people
xi. Use lighter or wooden splints to light burners. Do not use papers. Always strike the match before turning on the gas tap
xii. In case of a gas leak, turn off all the gas taps and open the windows. Leave the room immediately
xiii. Do not touch any electrical equipment with wet hands
xiv. Do not use dirty, cracked or broken apparatus
xv. Turn off any gas or water taps that are not in use
xvi. No chemical or equipment should be removed from the laboratory
xvii. Replace covers and stoppers on the container after you are through with the chemicals
xviii. Keep inflammable substances away from naked flames
xix. Wash off any chemical spillage on your skin or clothes with plenty of clean water
xx. Do not taste things during experiments

Laboratory Rules After laboratory activities

i. Appropriately dispose of any wastes Use the litter bins, not the sink, to dispose of solid waste. Do not return unused substances to their original containers
ii. Clean up the equipment and store it safely
iii. Turn off gas and water taps.
iv. Clean the working surfaces, benches and sinks
v. Wash your hands with soap and running water.

Laboratory Safety measure

By Defn: *laboratory safety is the condition in which measures of risk avoided during laboratory activities*

List of Laboratory Safety Measures

The laboratory safety measures includes

1. Laboratory should well ventilated and his door should open outward
2. Fire extinguishers should be fitted in an accessible position with using instruction
3. Laboratory floors should not polished to avoid slippery
4. Cabinets and drawer must present for storing apparatus
5. All apparatus should checked regularly to ensure they are safe to use
6. Emergence exit should present and easy to access and use
7. The laboratory should be equipped with working fire extinguishers and other working fire equipment with clear instructions on how to use them in case of a fire
8. **Cupboards**, **storage cabinets** and **drawers** should have locks
   Reason: This is to ensure one does not accidentally get into contact with harmful substances or interfere with equipment
9. All chemicals should be **well-labelled**
   Reason: prevent accidental use of the wrong substance
10. Emergency exits should be present and easy
11. There should be a **manual or instruction guide** on how to treat spills of different chemical substances.
12. Any chemical spills should be cleaned immediately
13. The **fume chamber** should be labelled. It should be kept in good working condition to minimize unexpected gas leaks or emissions
14. Gas cylinders should be labelled, stored well and supported. They should be in good working condition at all times.
15. laboratory should contain **First Aid kits**
16. Refrigerators and freezers used should be labelled '***For chemical use* only**'
    Reason: avoid contamination of other substances. They should be clean and free of any spills
17. Equipment for monitoring contamination should be installed to give alerts of any possible dangers.
18. Chemicals that easily react with each other should never be stored together
19. Containers for chemicals should be checked regularly to ensure they do not leak. They should have stoppers or covers which should be secured when the chemicals are not in use
20. Stored chemicals should be inspected regularly to ensure they have not expired.
21. All apparatus should be checked regularly to ensure they are safe for use
22. All persons using the laboratory should ensure they wear appropriate protective clothing to minimize exposure to hazards to access and use.

First Aid

By Defn: *First aid is the help given to a sick/injured person before getting professional medical help*

Importance of First Aid

1. It helps to preserve life
2. It prevents the victim's condition from becoming worse
3. It promotes recovery by bringing hope and encouragement to the victim
4. It helps to reduce pain and suffering
5. It prevents infection

First Aid Kit

By Defn: *first aid kit is the small box contains items that are used to give help to a sick person*. Usual labelled as "**FIRST AID**" and stored in a safe and easily accessible place

Items Found In First Aid Kit

Items	**Uses**
First Aid Manual	Contains guidelines on how to use the items in the first aid kit
antiseptic	Cleaning wound to kill germs
Soap	washing hands, wounds and equipment
cotton wool	Cleaning and drying wounds

Disposable sterile gloves	Preventing direct contact with victim's body fluids
Liniment	Reducing muscular pain
Painkillers	Relieving pain
Adhesive bandage (plaster)	Covering minor wounds
Bandage	Keeping dressings in place and immobilizing injured limbs
Thermometer	Measure body temperature
Sterile gauze	Covering wounds to protect them from dirty and germs
Safety pins, clips and tape.	Securing bandages or dressing.
Scissors and razor blades	Cutting dressing materials.
Petroleum jelly	Smoothening and soothing skin
Torch	Source of light
Whistle	Blow to call for help
Gentian violet	For fungal infection of the skin and mouth. Also used for the treatment of serious heat burns

Causes of Laboratory Accident

i. Slippery floor
ii. Incorrect use and handling of apparatus
iii. Gas leakages from faulty gas taps
iv. Fires
v. Failure to follow the right experimental procedures and laid down safety rules

First Aid Procedure

When accident occur we have to help the victim by following the follows procedures, consider the follows accidents

i. Burns
ii. Suffocation
iii. Choking
iv. Bruises
v. Shock
vi. Electrical shock
vii. Fainting
viii. Bleeding
ix. Poisoning
x. vomiting

Burns

By defn: *Burns is an injuries resulting contact with heat or harmful chemicals*. Burns cause by liquids or vapour is called **scalds**

Effect of burns

Burns cause blisters on skin and if severe the skin becomes charred and peels off

Procedure to follow in giving first aid

i. Lay the victim down and protect the burnt area from coming contact with ground, if possible
ii. Gently pour cold water on the burn for about 10 minutes to cool it and reduce pain
   Note: if the burn is severe, immediately call for medical help
iii. Check the breath and pulse and prepare to resuscitate the victim, if necessary
iv. Gently remove any Jewellery, shoes or burnt clothing from the injured area
   Note: loosen any tight clothing. Do not remove any sticking clothing to the skin
v. Cover the burn with sterile gauze and wrap it loosely to avoid pressure on the skin
   Note: do not use fluffy cotton. Bandage the wound reduce pain and infection
vi. Give the victim a pain reliever and treat them for shock
vii. Seek medical help immediately

Caution!

i. Do not ice as it further damages the skin
ii. Do not apply ointment or butter to the burn since this prevents proper healing
iii. Do not break any blisters as this can cause infection
iv. Burns to the face and in the mouth or throat are serious as they cause rapid inflammation of air passage and may cause suffocation. In such case seek medical help immediately

Suffocation

When dealing with a victim of electric shock, remember to take the following action

Choking

By defn: *Chocking is the blockage of the upper part of the airway by blood or other object*

Sign of chocking

Defaulting in speaking and breathing

Procedure to follow in giving first aid

- i. Encourage the victim to cough up the object
- ii. If the subject remain stuck, give firm but gentle taps between the shoulder blade
- iii. If the object is still stuck, perform the **Heimlich manoeuvre (procedure)**. This the procedure involve the following
  - a. Stand behind the victim
  - b. Grasp fist placed near the top of the victim's stomach
  - c. Make quick upwards thrusts to dislodge the object
  - d. Repeat the thrusts until the object comes out

Bruises

By defn: *Bruise an injury appearing as an area of discoloured skin on the body*. It caused by a blow or impact break/bust underlying blood vessels

Procedure to follow in giving first aid

- i. Apply a cold compress on injure for (20 – 30) minutes to reduce swelling and speed up recovery
- ii. If bruise is on leg/foot and covers large area, keep the leg elevated if possible for first 24 hours
- iii. After 48 hours , apply a warm wash cloth for 10 minutes, three times a day to increase blood flow to the affected area and thus speed up healing

Shock

By defn: *shock is a condition in which the body system is unable to take enough blood to the vital organs*. Vital organs include heart, lungs and brain

Symptoms of shock

- i. A victim has the follows symptoms
- ii. Fast pulse rate
- iii. Pale skin, lips and fingernails
- iv. Skin becomes cool and moist
- v. Limbs may tremble and become weak

Effect of shock

- i. If it develops the victim may experience
- ii. Nausea and even vomiting
- iii. Become restless, anxious, aggressive and finally unconscious

Procedure to follow in giving first aid

- i. Control sources of shock
- ii. Lay the victim down in a shock position. If victim vomiting turn him/her to the side
- iii. Loose tight clothing, laces and belts
- iv. Maintain the victim body temperature using a warm covering
- v. Prepare to resuscitate the victim if necessary
- vi. Seek medical help immediately

Electric Shock

Electrical shock occur when a person comes into contact with electricity

Procedure to follow in giving first aid

- i. Put off the main switch
- ii. Break contact between victim and electrical sources by using dry wooded stick or insulator material
- iii. Check whether the victim is breathing. If breathing stopped begin resuscitation
- iv. If the victim breathing but unconscious put him or her in the recovery position
- v. Administer First Aid for burns, shock or other injuries sustained by the victim
- vi. Seek medical help

Caution!

- i. Do not touch the victim who still in contact with electric current
- ii. Do not go near the area if you suspect that the area has high voltage electricity. Instead call for professional help immediately

Fainting

By defn: *Fainting is a sudden loss of consciousness cause by lack of sufficient blood and oxygen to the brain*. Victim feels **weak**, **sweats** finally **falls down**

Procedure to follow in giving first aid

- i. Take the person to a cool place or under a shade of plenty air

ii. Loosen or remove any tight clothing from the victim
iii. Let him/her lie on his back with his legs raised higher than the head
iv. Dip a clean handkerchief in water and press on his forehead.
v. Give him/her clean water to drink when he regain consciousness
vi. If not, take the victim to the nearest hospital

Bleeding

By defn: *Bleeding is the loss of blood and usually occurs from a visible wound or internal organ*

Procedure to follow in giving first aid

Procedure of bleeding may be

i. Light bleeding (small cut or wound)
ii. Severe bleeding (large cut or wounds)
iii. Noise bleeding

Light bleeding

i. Place the victim in a comfortable resting position
ii. Elevate the injured part
iii. Wash your hands using soap and cleaning water.
iv. Put on your gloves
v. Wash your wounds using salt water or antiseptic and clean cloth
vi. Cover the wounds or cut using sterile gauze. Gently clean the surrounding skin and dry it using sterile dressing
vii. Dress the wound and bandage it
viii. If bleeding continue, take the person to hospital

Severe bleeding

i. Let the victim lay under a shade or allow her to sit comfortably
ii. Wash your hands using soap and clean water
iii. Put on your gloves
iv. Prevent further blood loss by applying pressure over the wound using a folded but clean handkerchief or cloth
v. Use another cloth to secure the first one in place
vi. Take the injured person to hospital

Noise bleeding

i. Lessen clothing around the neck and chest
ii. Let the victim sit with the head tipped slightly forward
iii. Have the victim pinch their nose and ask them to breathe through the mouth for a few minutes
iv. Place a wet piece of cloth at the back of the victim neck
v. When bleed stop, gently clean the nostril
vi. If bleed continue, take the victim to hospital

Poisoning

By defn: *Poison is any substance that can harm the body if swallowed, inhaled or absorbed into the body*. Poison includes laboratory chemical, drug, medicine etc.

Sign of poison

i. Nausea
ii. Vomiting
iii. Abnormal cramps
iv. Pain
v. Difficulty in breath
vi. Diarrhoea
vii. Abnormal skin colour

Procedure to follow in giving first aid

i. Call for medical assistance immediately
ii. Find out what cause the poison
iii. If poison is in eye
    a. Wash eye with a lot of clean water
    b. Ask victim to blink as much as possible
    c. Do not rub the eye
iv. If poison is in skin
    a. Remove any clothing from affected part
    b. Wash affected area thoroughly with a lot of clean water
    c. Do not apply any ointment
v. If poison swallowed
    a. Induce vomiting if the poison is non-corrosive (medicine and soap) by putting your finger in victim's throat
    b. Do not Induce vomiting if the poison is corrosive (kerosene, bleach, detergent, laboratory acid, disinfectant etc)
vi. If poison has been inhaled
    a. Move the person to plenty of fresh air
    b. Make sure you protect from inhaled the poison

Vomiting

By Defn: *Vomiting is the removal of the contents of the stomach through the mouth*

Result of vomiting

i. Food poisoning
ii. Drinking contaminated water
iii. Inhaled poisonous fumes or over eating

Procedure to follow in giving first aid

i. Give the victim lots of clear fluid(oral rehydration drink)
ii. Get medical assistance if
   a. Persistent vomiting
   b. Victim vomiting blood
   c. Victim has high fever
   d. Victim is very dehydrated (observed mouth and skin become very dry)

Laboratory Apparatus

By Defn: *laboratory apparatus is the special equipment that used in the laboratory*

Used of Laboratory Apparatus

They are used for various purposes such as

i. Heating
ii. Testing
iii. Measure
iv. Filtering
v. Grinding
vi. Holding
vii. Storage
viii. Scooping
ix. Safety

Heating

The following apparatus are used when heating substance. Consider the table below

Items	Uses
Spirit lamp	used for heating substance
Bunsen Burners	used for heating substance
Boiling tube	Used to heat substance
Tripod stand	providing a platform for heating for stability
Wire gauze	For providing equal distribution of heat while burning
Crucible	Container used to heat substance to very high temperature
Evaporating dish	Heat and evaporate liquid and solution
Deflagrating spoon	Used to heat small amount of substance inside gas jar

Testing

The following apparatus are used when testing substance. Consider the table below

Items	Uses
Beaker	container used for holding, heating and mixing liquids
Test tube	Used for holding chemical for heating for short time Used to test some simple chemical reaction
Dropper	Used to add liquids drop by drop
Flasks	For holding liquids during experiment
Watch glass	Used as • Evaporate surface • Hold substance • Cover for beaker
Gas jar	• Used to collect gas • Used with deflagrating spoon to burn
Thistle funnel	Used to add reagents into flasks

Measure

The following apparatus are used when Measure substance. Consider the table below

Items	Uses
Measuring cylinder	For measuring **volume** of liquids
Thermometer	For measuring **temperature** of substances
Triple beam balance	Measuring **mass**
Measuring syringe	• Suck in • Measure specific **volume** of liquids/gas
Pipette	Transferring and measure specific but small **volume** of liquids
Burette	measuring **volume** of

	liquid
Electronic balance	measuring **mass** in more precise values
Stop watch	Measure accurately **time**

Filtering

The following apparatus are used when filtering. Consider the table below

Items	**Uses**
Filter funnel	Used to separate solid from liquids
Filter paper	Placed in filter funnel to separate solid from liquids

Grinding

The following apparatus are used when grinding substance. Consider the table below

Items	**Uses**
Mortar and pestle	Used for crush/grinding things

Holding

The following apparatus are used when holding substance. Consider the table below

Items	**Uses**
Test tube rack	Placing test tubes
Test tube holder	Holding a test tube while heating
Retort stand and clamp	Hold apparatus e.g. Burettes
Tongs	Hold hot substance and apparatus

Storage

The following container are used when storage substance. Consider the table below

Items	**Uses**
Reagent bottles	Store different chemicals
Plastic wash bottle	Store distilled water

Scooping

The following apparatus are used scooping substance. Consider the table below

Items	**Uses**
Spatula	Scooping small quantity of powder

Safety

The following apparatus are used for Safety during experiment. Consider the table below

Items	**Uses**
Safety goggles	Protect eyes from chemical spill, strong light and harmful vapour

Nb:

After experiment apparatus should be cleaned and return/stored to their position

Warning Signs

Warning sign is the symbol established to ensure safety in the laboratory and in other field like goods or commodities. This signs should obeyed to avoid accidents, include the follows

i. Toxic
ii. Irritant/harmful
iii. Flammable
iv. Oxidizing agent
v. Corrosive
vi. Radio active
vii. Danger of electric shock
viii. Fragile
ix. Explosive
x. Careful
xi. Keep away from water

Toxic

Toxic symbol means that a substance is dangerous and can cause death within a short time. Toxic substances containing poisonous ingredients, Example of toxic substance is **jik**, **mercury** etc.

Diagram:

Toxic Substance Enter the Body Through

i. Ingestion (by eating and drink)
ii. Inhalation (by breathing)
iii. By injection (by syringe, bite or insect)
iv. Contact (by touching)

Irritant/Harmful

Harmful symbol means that a substance is dangerous and can affect our health for long time. Example of harmful substance is alcohol, paint, insecticide, tobacco, ammonia etc, mercury etc

Diagram of harmful

Diagram of Irritant

This substance can annoy parts of the body

Flammable

Flammable symbol means that the substance can catch fire easily. For example gasoil, kerosene, petrol, butane, methane, spirit, nail polish remover, turpentine etc

Diagram:

Oxidizing Agent

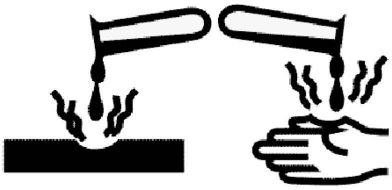
Oxidizing agent symbol means that the substance can speed up the rate of burning. For example oxygen gas, chlorine gas, fluorine gas and hydrogen peroxide

Diagram:

Corrosive

Corrosive symbol means that the substance cause gradual change if contact with various materials. For example concentrated sulphuric acid, concentrated hydrochloric acid, concentrated nitric acid, concentrated sodium hydroxide, concentrated ammonia etc

Diagram:



Radio Active

Radioactive symbol means that the substance emits harmful radiations that penetrate human body and cause damage. For example uranium, plutonium etc

Diagram;

Danger of Electric Shock

Danger of electric shock symbol means that the substance has high voltage which should not touch.

Diagram:

Fragile

Fragile symbol means that the substance should handle with care to prevents them from breaking. For example glass etc.

Diagram:

Explosive

Explosive symbol means that the substance can erupt/explode easily. Always sore in a special container

Diagram:

Nb:

Never store explosive material in glass container because when explode pieces of glass would fly all over and injure people

Careful

Careful symbol that is the caution advice you to be carefully

Diagram:

Keep Away From Water

Keep away from water symbol that is the caution advice you to keep item away from the water. For example computer, mobile phones, radio etc

Diagram:

Heat sources and flame

In this topic we will study source of Heat and flame

Heat

By Defn: *Heat is the condition of being hot*

Source of heat

Heat can be obtained in two ways

i. Natural source of heat
ii. Artificial source of heat

Natural source of heat

By Defn: *Natural source of heat is the kind of heat in which cannot made by human*. For example heat from the **sun**

Artificial source of heat

By Defn: *Artificial source of heat is the kind of heat in which made by human*. For example heat from the **spirit lamp**, **Kerosene stove**, **Bunsen burner** and **gas stove**

Nb:

i. Heat is the energy
ii. All chemical processes (reaction) whether combination or decomposition involves heat energy

Heat sources in the laboratory

In the laboratories is the different source of heat which can be used in the chemistry laboratory for various purposes. For example

i. spirit lamp
ii. Kerosene stove
iii. Bunsen burner
iv. gas stove

Flame

By Defn: *flame is a zone of burning gases that produces heat and light*. It is the visible glowing part of a fire

Diagram:

Nb:

i. Flame formed due to burning of fuel
ii. The colour and temperature of flame depend on the type of fuel burning and the source of the flame
iii. In order flame to happens the component of **fire triangle** should be completed which is **fuel**, **oxygen** and **heat**

Types of flame

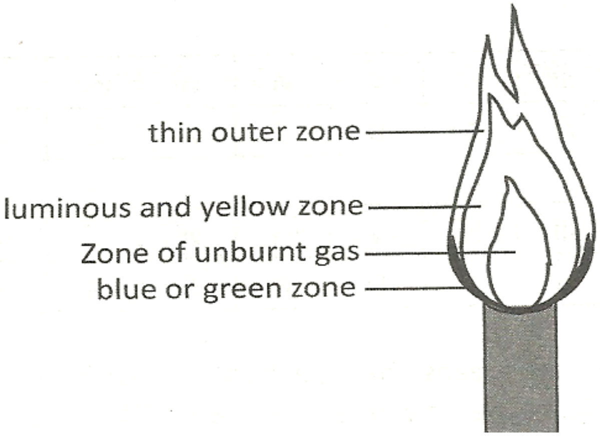
They are two main types of flame includes

i. Luminous flame
ii. Non luminous flame

Luminous flame

By Defn: *Luminous flame is the flame with yellow colour, produces soot and does not give more heat*. It produced when the oxygen supply is usually not enough to complete burn up the fuel

Diagram:



Parts of Luminous Flame

It consists four parts includes

i. Thin outer zone
ii. Luminous and yellow zone
iii. Zone of unburnt gas
iv. Blue or green zone

Why produce soot?

It produces soot because oxygen supplied is not enough to complete burn up the fuel

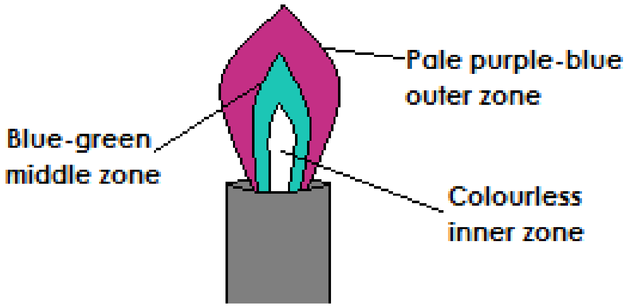
Why produce less heat?

It produces less heat because oxygen supplied is not enough to complete burn up the fuel

Non luminous flame

By Defn: *Non Luminous flame is the flame with blue colour does not produce soot and give more heat*. It produced when the oxygen supply is usually enough to complete burn up the fuel

Diagram:



Parts of Non Luminous Flame

It consists three parts includes

1. Colourless inner zone
2. Blue-green middle zone
3. Pale purple-blue zone

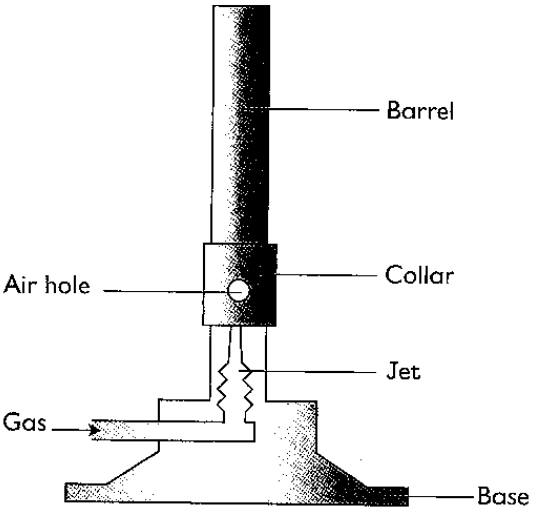
Different between Luminous flame and Non luminous flame

Luminous flame	**Non luminous flame**
Yellow in colour	Blue in colour
Produces soot	Does not Produces soot
Produce less heat	Produce more heat
Has a wavy flame	Has a triangular flame
Burns quietly	Burns with a roaring noise

Bunsen burner

By Defn: *Bunsen burner is a laboratory heat source consisting of a vertical metal tube connected to a gas source*

Diagram:



Parts of Bunsen burner

1. **Barrel** – round pipe whereby oxygen and gas burn at its top
2. **Air hole** – it allow air (oxygen) to support burning of gas
3. **Collar** - it turn around the barrel in order to vary size of air hole
4. **Jet** – gas pass through it to barrel
5. **Gas** – fuel which burnt to produce flame
6. **Base** – give stability to Bunsen burner

How Bunsen produce luminous flame

It produce luminous flame when collar turn to reduce size of air hole to results not enough air (oxygen) to complete burn up the fuel

How Bunsen Produce Non Luminous Flame

It produce luminous flame when collar turn to increase size of air hole to allow enough air (oxygen) to complete burn up the fuel

Uses of Luminous flame

1. It used for light

Uses of Non luminous flame

1. It used for heating purpose
2. It used for Flame test of certain chemical substance
3. It used for welding
4. It used for cooking

The scientific procedure

Scientific Investigation

By defn: scientific method is a set of techniques used by scientists to investigate a problem/answer question. Also called *scientific procedure or scientific investigation or scientific methods*

Steps of a Scientific Method

The following is the steps followed when carrying out a scientific investigation

i. Identify the **Problem**
ii. Formulation the **hypothesis**
iii. Experiment and **observe**
iv. Data collection and **analysis**
v. Data **interpretation**
vi. Draw a **conclusion** from data

Identify Problem

In this step the physicist makes a puzzling observation. For example **does temperature affects the solubility of common salt in water?**

Formulation of Hypothesis

A hypothesis is an intelligent guess that tries to explain an observation. Example **does not temperature affects the solubility of common salt in water?**

Experiment and observe

By defn: *An experiment is the test under controlled conditions*. The aim of experiment is to test whether hypothesis is true or false. It based on variable to test hypothesis

By defn: *variable is the condition in which changes to obtain set of values*

Types of Variable

There are three types include

i. Dependent variable
ii. Independ variable
iii. Controlled variable

Dependent Variable

By defn: *Dependent variable is the condition (depend other factor) to measure or observed to obtain the results*. For example **solubility**

Independ Variable

By defn: *Independ variable is the conditions (does not depend other factor) manipulate to obtain the results*. For example **temperature**

Controlled Variable

By defn: *Controlled variable is the condition may changes (kept constant) to obtain the results*. For example **amount of water**

Data Collection and Analysis

It Concern recording what you have observed during experiment. Always kept in the table for example

Temperature	solubility
10	200
20	400
30	600
40	800

Data Interpretation

In this step we look trend or patterns and explain why they occur that way. For example **from the table above when temperature increase also solubility increase**

Draw a Conclusion

In this step, it concerning about summary of the experiment. It includes a statement that either proves or disproves the hypothesis. For example **in our experiment change in temperature affects solubility of common salt**

Application of Scientific Procedure

i. **carrying out experiment**: to study what happens and gain new knowledge
ii. **project work**: to find information on subject/problem
iii. **Field study/work**: to test hypothesis. A field study also called field work

Significance of the Scientific Procedure

i. It helps us to solve scientific problems
ii. It helps us to gain new knowledge
iii. It helps us to conduct project work
iv. It helps us to carry out field study
v. It helps us to solve problems or answer scientific questions

Matter

By defn: matter is anything that has mass and occupies space. Matter can be change state with vary in temperature. Example of matter is **stones**, **vegetation**, **air**, **food**, **water** and **our bodies**

State of Matter

Matter exist in three physical states include

i. Solid state
ii. Liquid state
iii. Gas (vapour) state

Structure of matter

Matter is made up of tiny particles. The particles are either **atom** or **molecules**

Atom

By defn: *atom is the smallest part of an element, which can take part in chemical reaction*. For Example Sodium atom (Na), hydrogen atom (H) etc

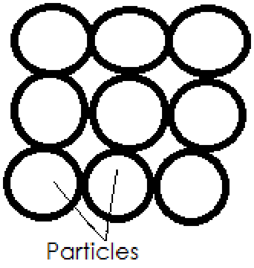
Molecules

By defn: *a molecule is a group of atoms*. For Example water molecule (H_2O), hydrogen molecules (H_2)

Solid State

By Defn: *Solid substance has definite shape and definite volume*. Particle in solid substance are closely packed together. For Examples of solid substances are **Ice**, **firewood**, **metal, Wood**, **Stone**, **Books**, **Shoes**, **Plastic** etc

Diagram



NB:

i. The particles vibrate in fixed position
ii. The particle are not free to move because they held by strong inter particle force

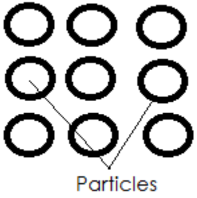
Properties of Solid Matter

i. Particles are closely packed together
ii. Has definite shape and volume
iii. Has strongest inter-particle force
iv. Particles are not free to move
v. Has high density due to small volume
vi. Particle move very slow

Liquid State

By defn: *Liquid substance has fixed volume but variable in shapes*. Particles in liquid are slightly father apart. For example **water**, **kerosene**, **milk** etc

Diagram



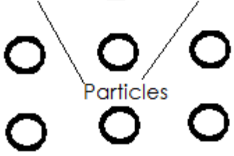
Properties of Liquid Matter

i. Particles are slight father apart
ii. Have definite volume
iii. Have not definite shape
iv. Has medium density due to medium volume
v. Has medium motion
vi. Inter-particle force is weak

Gas State

By defn: *Gas has not definite shape or size. Particles are moving so fast and are so far apart that they do not interact with each other at all*. For example **oxygen gas**, **hydrogen gas**, **nitrogen gas** etc

Diagram:



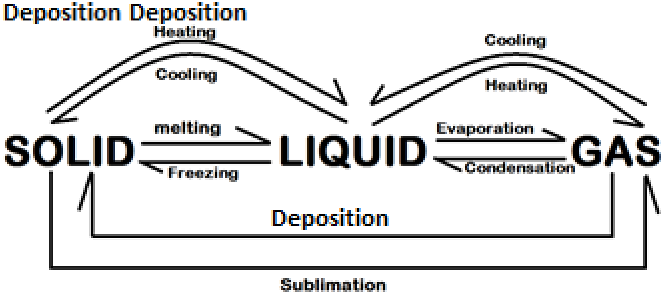
Properties of Gas Matter

i. Has not definite shape
ii. Has not definite volume
iii. Has largest inter particle distance
iv. Has low density due to largest volume
v. Has weakest inter particle force
vi. Particle move at high speed

Change of State in Matter

Matter can change solid, liquid and gas and vice versa. Consider the diagram below.

Diagram:



Melting

By defn: Melting is the change of state from solid to liquid

Melting Point

By defn: Melting point is the definite temperature of a pure substance to melt

Freezing

By defn: *Freezing is the change of state from liquid to solid*

Sublimation

By defn: *Sublimation is the change of state from solid to gas*

Deposition

By defn: Deposition *is the change of state from gas to solid*

Freezing point

By defn: Freezing point is the Temperature at which a liquid changes into a solid without a change in temperature

Boiling

By defn: Boiling state at which all liquid change into gas

Boiling Point

By defn: Boiling point is the temperature at which all liquid change into gas

Boiling Point of Some Pure Substance

Substance	Boiling point (°C)
Helium	-269
Hydrogen	-253
Oxygen	-183
Ethyl alcohol	78.4
Benzene	80.2
Water	100
Mercury	357
Aluminium	2 467
Copper	2 567
Iron	2 750

Evaporation

By defn: Evaporation is the change of state from liquid to gas (vapour)

Different Between Boiling and Evaporation

Boiling	Evaporation
Occurs at a definite temperature which is boiling point	Occurs at any temperature
Occurs within a liquid with formation of bubbles	Occurs at the surface of the liquid
Has no cooling effect	Has cooling effect
Takes place rapidly	Takes place slowly

Importance of Changes of States of Matter

Changes of states of matter it has a wide important. Consider the follows important

i. Water cycle
ii. Refrigeration/ Air Condition
iii. Refinery
iv. Metallurgy
v. Steam engines
vi. Drying of materials

Water cycle

Water change to vapour appear as clouds and finally rain

Refrigeration/ Air Condition

Water change to vapour absorb energy (heat) from the surround and final cause cooling effect

Refinery

Refinery of petroleum and other liquids refinery due to boiling point, if the mixture of high and low liquid, the liquid with **higher boiling point** start first to evaporate which collected as vapour/gas and the one with **lower boiling** point remain at the mixture. The **simple distillation** and **fractional distillation** is employed in petroleum refineries

Metallurgy

Metallurgy Involves in the following

i. Purification of metals from their ores
ii. Manufacture of alloys

Purification of metals from their ores

Purification of metals from their ores made due to its boiling point of combined substance contains in the ores, if the ore contain substance of high and low liquid, the required metal of **higher boiling point** start first to evaporate which collected as vapour/gas cool to obtain solid metal and the one (impurity) of **lower boiling** point remain as residue

Manufacture of alloys

By defn: Alloy a metal made by combining two or more metallic elements to give greater strength or resistance to corrosion

How alloys made?

The vapour/gas of two or more metals cooled to make an alloy

Steam engines

The liquid (fuel) of low pressure evaporate to make vapour/gas/steam of high pressure used to push **piston**. The downward movement of the piston pushes a rod that turns a **crankshaft**

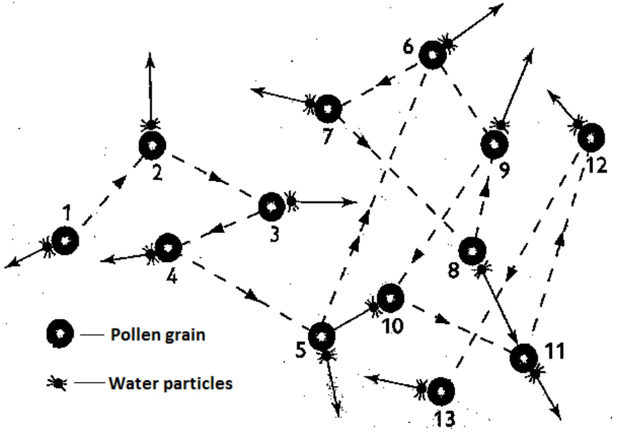
Drying of materials

Material dry when contaminated liquid evaporates, Example when wet clothes exposed in a sun dry because water contaminated change to vapour/gas

The Particulate Nature of Matter

Scientist called **Robert brown** used a microscope and observed that pollen grains suspended in water moved short distance in an irregular zigzag manner. After that observation Robert brown concluded by the law called **Brownian motion**

Diagram:



Brownian motion

Brownian motion state that ***"Matter is made up of tiny particle that are in a state of continuous random motion"***

Kinetic Theory of Matter

It describes the physical properties of matter in terms of the behaviour of its component atom or molecules. It state that

"All matter is made up of very small particles that are in constant motion"

Nb:

Motion of solid particles is in vibration

Motion of liquid and gas particles are in random

Properties of Gases, Liquids and Solids

properties	Gas	Liquid	Solid
Shaped	no definite shape	Takes shape of container	Fixed shape
Movement of particle	Move past one another	Move/slide past one another	Rigid (locked into place)
Compressibility	Compressible	Not easily Compressible	Not easily Compressible
Space	Large space	Moderate space	No space
Flow	Flow easily	Flow easily	Do not flow
Volume	Takes volume of container	Has a Fixed volume	Has a Fixed volume

Physical changes

By Defn: *Physical changes are the changes which do not change the identity of matter/substance*. It physical properties must vary which may be size, state etc. For example tearing, crushing, melting, dissolving, freezing, evaporation, condensation and sublimation

Changes undergoes Physical changes

i. Aluminium foil cuts into half
ii. Clay is moulded into a new shape
iii. Butter melts on warm toast
iv. Water evaporates from the surface of ocean
v. The juice in a bottle freezes
vi. Drying of wet clothes
vii. Grinding a piece of chalk
viii. Burning of a candle
ix. Dissolving sugar in water
x. Crushing stone into fine powder
xi. Melting of ice
xii. Water vapour condenses on the outside of your eyeglasses

Chemical changes

By Defn: *Chemical changes are the changes which change the identity of matter/substance*. It chemical properties vary which may be smell, colour etc. For example **rusting**, **burning**, **decaying**, **rotting**, **fermentation of fruit** and **souring of milk**

Changes undergoes chemical changes

i. Milk turns sour
ii. Jewellery tarnishes (changes colour)
iii. Toasting bread
iv. Nails or iron sheets rust
v. Wood is burnt
vi. Food scraps are turned into compost in a compost pit
vii. A match is lit
viii. An antacid settles your stomach upset
ix. Your body digests food
x. An egg is fried
xi. Food is cooked

Different between Physical Changes and Chemical Changes

Physical Changes	**Chemical Changes**
Change physical	Change chemically
No new substance formed	new substance formed
No product given off	product given off
Changes is reversible	Changes is irreversible
Does not affect component of substance	affect component of substance

Elements, compound and mixtures

Element

By Defn: Element is a pure chemical substance which cannot be split into simple substance by a simple chemical process. For example **iron**, **silver**, **gold**, **copper**, **oxygen**, **hydrogen** etc

Names and chemical symbol of elements

All known element have name, usually the names represents by letter (abbreviation or short representation of the name) called **chemical symbol**

Nb:

i. Most Chemical symbol often derived from Latin or Greek name of the element. For example of some elements

Element	Latin name	Symbol
Sodium	Natrium	Na
Gold	Aurum	Au
Potassium	Kalium	K
Copper	Cuprum	Cu
Iron	Ferrum	Fe
Mercury	Hydrargyrum	Hg
Silver	Argentum	Ah
Tin	Stannum	Sn
Lead	Plumbum	Pb

ii. Other Chemical symbol often derived from English name of the element. For example of some elements

Element	English name	Symbol
Carbon	Carbon	C
Iodine	Iodine	I
Fluorine	Fluorine	F
Hydrogen	Hydrogen	H
Calcium	Calcium	Ca
Aluminium	Aluminium	Al
Argon	Argon	Ar

Criteria used to generate chemical symbol

i. Elements can be represented by a symbol delivered from the first letter

Element	Symbol
Carbon	C
Iodine	I
Fluorine	F

ii. Elements can be represented by a symbol delivered from the first and second letter

Element	Symbol
Calcium	Ca
Aluminium	Al
Chlorine	Cl
Cobalt	Co
Magnesium	Mg
Manganese	Mn
Argon	Ar

iii. Elements can be represented by a symbol delivered from their Latin names

Element	Symbol
Sodium	Na
Gold	Au
Potassium	K
Copper	Cu
Iron	Fe

Common elements

There are twenty common elements which we were using most in our o'level chemistry course. Consider the table below

Element name	Element symbol
Hydrogen	H
Helium	He
Lithium	Li
Beryllium	Be
Boron	B
Carbon	C
Nitrogen	N
Oxygen	O
Fluorine	F
Neon	Ne
Sodium	Na
Magnesium	Mg
Aluminium	Al
Silicon	Si
Phosphorus	P
Sulphur	S
Chlorine	Cl
Argon	Ar
Potassium	K
Calcium	Ca

How to remember common 20 elements

You should sing a Swahili simple song In order to remember common elements as

Element	Word to sing	Stand for
Hydrogen	**H**allo	H
Helium	**He**medi	He
Lithium	**Li**le	Li

Beryllium	**Be**beru	Be
Boron	**B**ora	B
Carbon	**C**hinja	C
Nitrogen	**N**a	N
Oxygen	**O**ndoa	O
Fluorine	**F**igo	F
Neon	**Ne**ne	Ne
Sodium	**Na**	Na
Magnesium	**Mg**eni	Mg
Aluminium	**Al**iye	Al
Silicon	**Si**mama	Si
Phosphorus	**P**ale	P
Sulphur	**S**erengeti	S
Chlorine	**Cl**ub	Cl
Argon	**Ar**udishwe	Ar
Potassium	**K**wao	K
Calcium	**Ca**nada	Ca

Significance of chemical symbol

i. Help to understand quickly element instead of memorize full names
ii. Possible to write chemical equation instead to write in full name
iii. show clear quantity of element

Compound

By defn: *compound is a pure substance that is made up of more than one element in a chemical combination*. Example **sugar**, **salt**, **water** etc

Nb:

i. Combination is always in fixed ratio. For example
   a. **carbon dioxide (CO_2)** is made up of **two parts of oxygen** for every **one part of carbon**
   b. **water (H_2O)** is made up of **two parts of hydrogen** for every **one part of oxygen**
ii. they are separated chemically

Properties of compound

i. Compound cannot be seen separated
ii. Constituent elements can be separated by chemical means
iii. Constituent elements Have definite ratio
iv. When formed involve chemical change
v. Its properties differ from its Constituent elements

Mixture

By defn: *Mixture is a physical combination of two or more substances in any ratio*. Example **muddy water**, **mixture of sand and salt, mixture of oil and water**, **mixture of maize and sand** etc

Nb:
They separated physically

Types of mixture

They are two types include
i. Homogenous mixture
ii. Heterogeneous mixture

Homogenous mixture

By defn: *Homogenous mixture is the kind of mixture in which has uniform composition, appearance and properties*. Example
i. Mixture of salt and water
ii. Mixture of sugar and water

Heterogeneous mixture

By defn: *Heterogeneous mixture is the kind of mixture in which has difference composition, appearance and properties*. Example
i. Mixture of water and sand
ii. Mixture of ice and water

Properties of mixture

i. mixture can be seen separated
ii. Constituent elements can be separated by physical means
iii. Constituent elements Have no definite ratio
iv. When formed involve physical change
v. Its properties same from its Constituent elements

Different between compound and mixture

Compound	**Mixture**
Compound cannot be seen separated	mixture can be seen separated
Constituent elements can be separated by chemical means	Constituent elements can be separated by physical means
Constituent elements Have definite ratio	Constituent elements Have no definite ratio
When formed involve chemical change	When formed involve physical change
Its properties differ	Its properties same

from its Constituent elements	from its Constituent elements

Solution

By defn: solution is a homogenous mixture of two or more substances (solvent and solute)

Where

i. **By defn**: solvent is a substance dissolves the other substance (solute)
ii. **By defn** solute is a substance dissolved by other substance (solvent)

Example of solute and solvent

i. Mixture of sugar and water to form a solution
    a. Sugar is a solute
    b. Water is a solvent
ii. Mixture of salt and water to form a solution
    a. Salt is a solute
    b. Water is a solvent

Types of solution

Their three types of solution, includes

i. Unsaturated solution
ii. Saturated solution
iii. Supersaturated solution

Unsaturated Solution

By defn: *Unsaturated solution is the solution that can dissolve more solute at a given temperature*

Saturated Solution

By defn: *Saturated solution is the solution that cannot dissolve more solute at a given temperature*

Supersaturated Solution

By defn: *Supersaturated solution is the solution that temporarily holds more solute than the saturated solution at a given temperature*

Application of saturation

It uses when

i. Separating certain mixtures in the laboratory
ii. Extracting some minerals such as **common salt (NaCL)**

Classification of solution into state of matter

Solution can be solid, liquid or gas. Even solute and solvent can exist in three state of matter. Consider the table follows

		Solutes		
		Solid	**Liquid**	**Gas**
solvent	gas	Naphthalene slowly sublimes in air to form a solution	water vapour in air	oxygen and other gases in air
	liquid	sucrose (sugar) in water and salt in water	ethanol (alcohol) in water and various hydrocarbons in each other (petroleum)	carbon dioxide in water(carbonated water
	solid	steel and other metal alloys	mercury in gold and hexane in paraffin wax	hydrogen in metals

Uses of solvents

i. **Varnish removal**: solvent used to removal varnish
ii. **Degrease**: solvent used to remove excess grease or fat from. For example when we wash our hand if contaminated with oil
iii. **Thinning paint**: a volatile solvent used to make paint or other solutions less viscous
iv. **Bleaching agent**: it make white or much lighter by a chemical process or by exposure to sunlight
v. **Stain removal**: solvent used mark or discolour with something that is not easily removed
vi. **Cleaning**: solvent (soap) removal dirt (solute) by form solution

Properties of solution

i. Homogenous mixture
ii. transparent/clear
iii. Particles completely dissolved
iv. Components separate by **Evaporation**

Suspension

By defn: *Suspension is heterogeneous mixture of liquid and fine particles of a solid*

Nb:

i. Suspended particles are slight visible

ii. Particles Settle at bottom if undisturbed
iii. Suspension formed either by liquid droplets or fine particle float in a gas is called **Aerosols**
iv. The blood in our body also is suspension
v. Suspension used at homes as **insecticides**, **body spray** and **medicine(syrup)** always labelled ''***Shake well before use***"

Properties of suspension

i. Heterogeneous mixture
ii. Opaque (not clear)
iii. Particles separate without dissolving
iv. Components separate by filtration

Different between solution and suspension

Solution	**Suspension**
Homogenous mixture	Heterogeneous mixture
transparent/clear	Opaque (not clear)
Particles completely dissolved	Particles separate without dissolving
Components separate by Evaporation	Components separate by filtration

Emulsion

By defn: *emulsion is a mixture of liquids that do not completely mix*. Example of emulsion

i. **Milk**, which is drops of butterfat in water
ii. **Emulsion paint**, which is drops of coloured oils in water

Nb:

i. Liquids do not mix at is called **immiscible**
ii. Liquids mix is called **miscible**
iii. Usually formed from two liquids (oil and water)
iv. When emulsion shakes form droplets (oil and water)
v. When emulsion harder shakes become **homogenous solution**

Methods of separating mixture

Mixture can be separated according to properties of substance (mixture). The follows methods used to separate are follows

i. Decantation
ii. Evaporation
iii. Distillation
iv. Sublimation
v. Filtration
vi. Chromatography
vii. Solvent extraction
viii. Layer separation
ix. Magnetization

Decantation

By defn: *Decantation is the process of separating a heterogeneous mixture of a liquid and solid by pouring out of the liquid only and leaving the solid at the bottom of the container*

Nb:

i. The process of some components of mixture settling at the bottom is called **Sedimentation**

Decantation can be used to separate

i. Water from muddy water
ii. **Blood test**: Clearer part of blood from mixture of clear blood and its solid components

Separation Application of Decantation

i. Water treatment systems
ii. Separate of components of blood

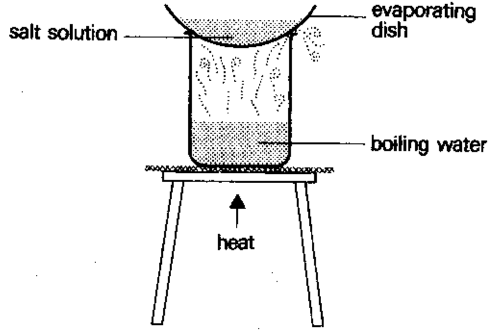
Magnetization

This process involve the separation of iron (magnetic material) from a mixture where by magnetic material is attracted to magnet and leaves behind other components of mixture

Evaporation

By defn: *Evaporation is the method in which solvent converted from liquid to gas and solute remains as residue*. Example Mixture of water (solvent) and salt (solute), when heated water evaporates and salt remains

Diagram:



Separation Application of Evaporation

i. In extraction of common salt

Distillation

By defn: *Distillation is the method of separating mixture due to components boiling point and finally obtains the wanted substance*. The wanted substance (low boiling point) is cooled until back to liquid. The cooled vapour is called **Distillate**

Types of Distillation

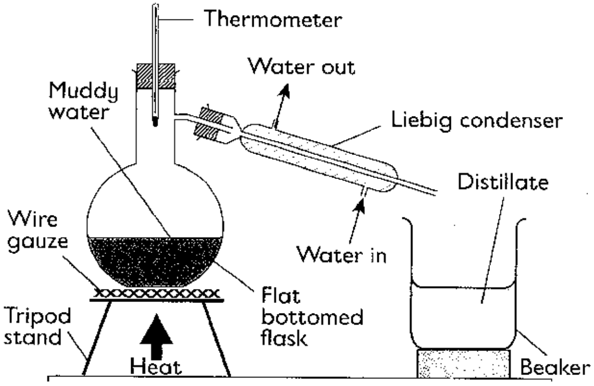
There are two types include

i. Simple Distillation
ii. Fraction Distillation

Simple Distillation

By defn: Simple Distillation *is the method of separating mixture of liquid contains dissolved substance*

Diagram:



Simple Distillation can be used to separate

i. Distilling water from muddy water
ii. Distilling water from salt water

Nb:

If Liebig condenser absent, the distillate can collect in a test tube that dipped in beaker contain very cold water or ice

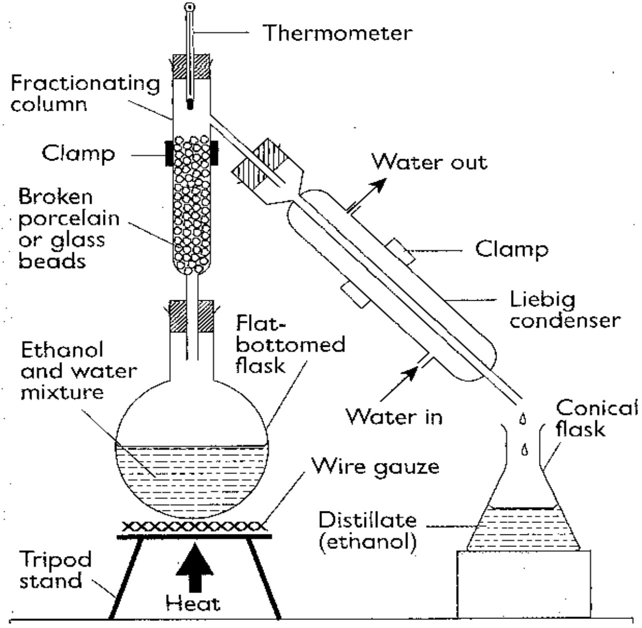
Separation Application of distillation

i. Purification of water
ii. Manufacture of alcohol

Fraction Distillation

By defn: Fraction Distillation *is the method of separating mixture (homogeneous solution) of two or more liquids due to its boiling point by means of fraction columns*

Diagram:



Fraction Distillation can be used to separate

i. Distilling ethanol from mixture of ethanol and water
ii. Distilling petrol from crude oil (petroleum)

Nb:

i. Fraction distillation can collect more than one component at the same time at the **fraction distillation columns**
ii. The liquids with lower boiling point first collected as **distillate**
iii. Each components collected is called **fraction**

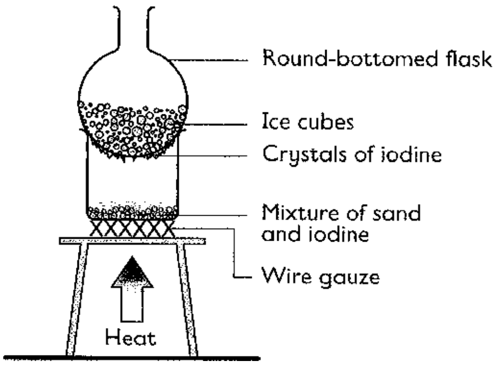
Separation Application of Distillation

i. Purification of water
ii. Manufacture of alcohol

Sublimation

By defn: *Sublimation is the is the method of separate mixture whereby a solid (wanted substance) changes state directly to gas final form Solid that forms after the gas cools*

Diagram:



Nb:

i. Solid that forms after the vapour cools is called **sublimate**
ii. This method Used to separate mixture where one component sublimes
iii. **Iodine** and **ammonium chloride** are few compounds can sublimes
iv. The reverse process of change from vapour to solid on cooling is called **Deposition**

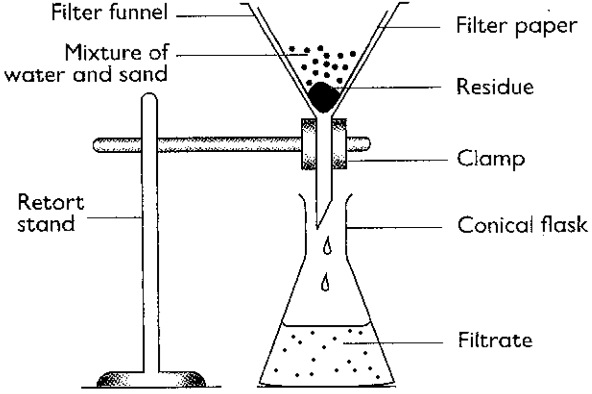
Sublimation Can Be Used To Separate
i. Separate iodine from mixture of sand and iodine
ii. Separate ammonium chloride from mixture of salt and ammonium chloride

Separation Application of Sublimation
i. Purification of substance

Filtration

By defn: *Filtration is the method of separate heterogeneous mixture of a solid and liquid by using porous filter*

Diagram:



Nb:
i. Solid remain is called **residue**
ii. Liquid pass through filter is called **filtrate**

Fraction Distillation can be used to separate
i. Water from muddy water

Separation Application of Filtration
i. Purification of water
ii. Extraction of juice from fruit
iii. Extraction of cream from milk

Chromatography

By defn: *Chromatography is the method of separate mixture using moving solvent on material absorbs the solvent*

Nb:
i. Moved solvent is called **mobile phase**
ii. Absorbed solvent is called **stationary phase**
iii. Substance separated is called **Analyte**

Uses of chromatography

Used in many different ways
i. Medicine
ii. Security
iii. Chemistry
iv. Health

Medicine

Used as follows
i. Used to analyses blood and urine sample
ii. Study blood cells in blood
iii. Detect types of drugs in blood

Security

Used as follows
i. Used to analyses blood and urine sample
ii. Detect different fibres

Chemistry

Used as follows
i. Test purity of organic substance
ii. Separates mixture

Health

Used as follows
i. Causes of pollution
ii. Test for blood contamination

Separation Application of Chromatography
i. In medical diagnosis and studies
ii. In security for crime detection
iii. In chemical analysis and tests

Solvent extraction

By defn: *Solvent extraction is the method of separate mixture essential oil from plant materials*. This process referred as **solid-solid extraction**

From the diagram above can be used to separate
i. Oil seeds from seed

Mechanism how separated

Extract oil seed by using water to get mixture of oil and water then mixture separated by distillation to get oil

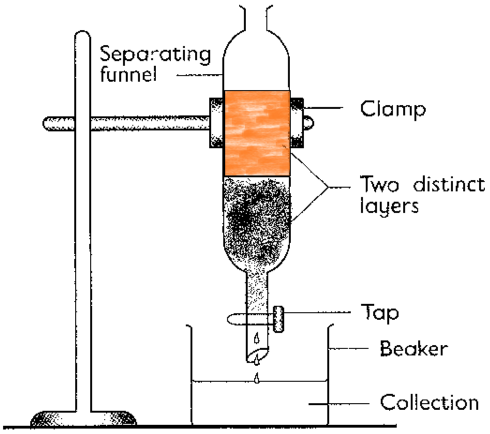
Separation Application of Solvent extraction

1. Extraction of certain edible oils from seeds
2. Extraction of some metals from sludge mixture

Layer separation

By defn: *Layer separation is the method of separating immiscible mixture by using separating funnel if its components allowed settling form distinct layers.*

Diagram:



Nb:

1. Denser component(higher density) settles at bottom
2. Less Denser component(low density) stay at top

Separation Application of Layer separation

1. Recovery of liquids from contaminations

Air, combustion, firefighting and rusting

Air

By defn: *Air is colourless, homogenous mixture of gases in the atmosphere*

Composition of air

Mixture of gases include the following

1. Nitrogen
2. Oxygen
3. Carbon dioxide
4. Noble gases (helium, krypton, argon, neon and xenon)
5. Water vapour

Nb:

The components of air in atmosphere have definite proportions by volume which can be approximate to percentage. Consider the table below

Gas	**Percentage**
Nitrogen	78%
Oxygen	21%
Carbon dioxide	0.03%
Noble gas	0.94%
Water vapour	0% – 4%

Test for gases in air

Consider the table below which show how gases tested

Gas	**Tester reagent (colour)**	**Product (colour)**
Oxygen	Copper (**brown**)	Copper oxide (**black**)
Carbon dioxide	Lime water (**colourless**)	Calcium carbonate (**milky**)
Water vapour	Anhydrous copper (II) sulphate (**White**)	Anhydrous copper (II) sulphate (**blue**)

Combustion

By defn: *combustion is the chemical reaction involves the burning of a substance in the presence of oxygen to releases energy (heat and light)*

Nb:

1. Material which catch fire and burn easily is called **combustible**
2. enclosed space (closed system) in which combustion takes place, especially in an engine or furnace is called **combustion chamber**
3. different material are combustible but some burn up faster than others

Application of combustion

It's applied in many areas, includes

Industries

1. Engine or furnace
2. In large boilers
3. Incinerators for burning wasters
4. welding and smelting (extract metal)

Domestic

5. Cooking
6. Heating homes
7. Burning wastes

Laboratory

8. Sterilization
9. During experiments

Fire Fighting

By defn: *Fire Fighting is the process extinguishing harmful fires*

Fire

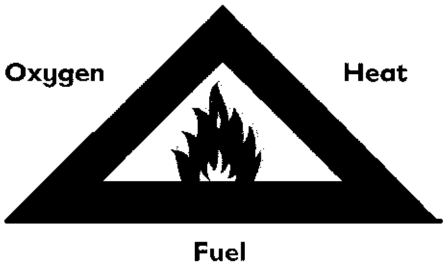
By defn: *fire is the state/process of combustion result **light**, **heat**, **smokes** and* **flame**

Diagram:

Fire Triangle

By defn: *fire triangle is the components needed to start a fire*

Diagram:



Component of fir triangle

This include

1. Fuel
2. Oxygen
3. Heat

Caused Of Laboratory Fire

1. Electrical faults
2. Smoking materials
3. Carelessness
4. Ignorance
5. negligence

Basic Principles of Fire Prevention

1. No light of open fires near buildings
2. No smoking in prohibited areas
3. No interference with electrical installations
4. all electrical appliances must off after use
5. all sources of heat should not kept near the bench edge where they can easily be knocked down
6. all flammable substances should be locked up in drawers or cabinets

Fire Extinguisher

Fire extinguisher is the one in which used to fight/stop fire to continue

Types of Fire Extinguisher

The follows is types of extinguisher include

1. water/APW extinguisher
2. Sand extinguisher
3. Fire Blanket extinguisher
4. (DC) Dry chemical extinguisher
5. Carbon dioxide extinguisher
6. Halons extinguisher
7. Foam extinguisher
8. Wet chemical extinguisher
9. ABC extinguisher

Water/APW Extinguisher

Component: Air pressurize water
Suitable for: class A
Unsuitable for: class B, C and D
Reason for Unsuitable: the flame will spread

Sand extinguisher

It used to extinguishes small fire
Component: sand collected on basket
Suitable for: class B and A

Blanket extinguisher

It used to extinguishes small fire
Component: sand collected on basket
Suitable for: class B and A

(DC) Dry chemical extinguisher

Component: Fine sodium bicarbonate powder pressurize by nitrogen
Suitable for: class A, B, C and E
Unsuitable for: class D, Aircraft and electronics
Reason for Unsuitable: it is corrosive

Carbon dioxide extinguisher

Component: carbon dioxide gas under extreme pressure
Suitable for: class B, C and E
Unsuitable for: class A (material can reignite)

Halons extinguisher

Component: Bromochloro-Difluoro-Methane
Suitable for: class A and E
Unsuitable for: class B and C (least suitable)

Foam extinguisher

Component: protein and fluoro-protein
Suitable for: class A and B
Unsuitable for: class E

Wet chemical extinguisher

Component: potassium acetate
Suitable for: class F
Unsuitable for: class E

ABC extinguisher

Component: mono-ammonium phosphate with a nitrogen carrier
Suitable for: class A, B and C
Unsuitable for: electronic equipment

Mechanism of Fighting For Fire

Fire extinguisher stop fire by prevent one among of the fire components/fire triangle

Class of Fire

Fire classified according to materials burnt; therefore we have six class of five namely

1. Class A
2. Class B
3. Class C
4. Class D
5. Class E
6. Class F

Class A

The burning materials is organic/ordinary solid combustible materials such as **paper**, **wood**, **plastic**, **wool**, **clothing** etc

Suitable Fire Extinguisher
Use any type of Fire extinguisher except carbon dioxide. But water is suitable

Question: Why carbon dioxide not suitable?
Answer: when molecules of carbon dioxide reach fire gain heat and result lowered its density then escape away for fire and the fire continue

Class B
The burning materials is flammable liquids such as **petrol**, **paraffin**, **alcohol**, **kerosene** etc

Suitable Fire Extinguisher
1. Use fire blanket or sand extinguisher if fire is a small
2. Use dry powder, foam or carbon dioxide extinguisher if fire is large

NB: water extinguisher is not suitable

Question: Why water not suitable?
Answer: water is denser than flammable liquid so flammable liquids will float over water results the fire continues

Class C
The burning materials is flammable gas such as methane, butane, propane etc

Suitable Fire Extinguisher
Use **dry powder** and **carbon dioxide** extinguisher

Class D
The burning combustible metals such as magnesium, sodium, lithium etc

Suitable Fire Extinguisher
Use dry powder, foam or foam extinguisher

Class E
The burning electrical equipment such as damaged electrical cables, switchboards etc

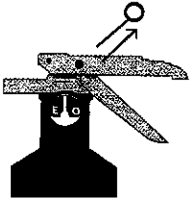
Suitable Fire Extinguisher
Use carbon dioxide extinguisher
NB: first switch off power from the mains switch

Class F
The burning cooking appliances with oils and fats at high temperature

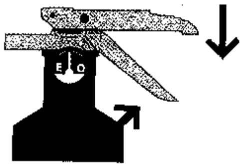
Suitable Fire Extinguisher
Use wet chemical extinguishers

Steps to use portable fire extinguisher
There are four procedure in easy to remember just remember acronym '**PASS**' which stand for **Pull**, **Aim**, **Squeeze** and **Sweep** as follows

i procedure: **Pull**: Pull the pin to make the extinguisher ready for use

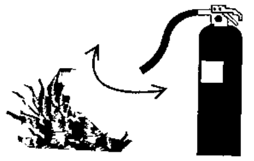


ii procedure: **Squeeze:** Squeeze the top lever to release extinguishing agent



iii procedure: **Aim**: Aim at the base not at the fire, otherwise the fire only spreads

iv procedure: **Sweep:** Sweep from side to side until the fire is out



Precaution when using fire extinguisher
The following precaution should take when using fire extinguisher
1. Keep reasonable distance (such as 3 metres) from the fire as it may suddenly change direction
2. Never use a portable extinguisher on people instead us a fire blanket

iii. Do not test a portable extinguisher to see if works
   Why: it may leak and afterwards fail to work during and emergence/accident
iv. Do not retain a used portable extinguisher to the wall
v. When a fire gets out of control, abandon it and notify the nearest fire fighting squared (fire brigade)

Rusting

By defn: *Rusting is the reddish brown occurs in iron/steel in presence of air and water*. The reddish brown coat occurs in metals (iron or steel) is called **Rust**

Condition for rusting

There are two condition includes

i. Air (oxygen)
ii. water

Methods used to prevents rusting

To prevent rusting should prevent contamination of water and air in iron and steel and to avoid using material made from iron or steel. The follows is the methods which we can use

i. Painting
ii. Oiling
iii. Galvanization
iv. Anodizing
v. Tin plating
vi. Use of silica gel
vii. Use of plastic

Painting

Paint when introduce on iron/steel prevent iron/steel to contact with water and oil

Oiling

Oil when introduce on iron/steel prevent iron/steel to contact with water and oil

Galvanization

By defn: *Galvanization is the process of mix iron/steel with metal that does not rusting*. When iron/steel mix with metal that does not rusting tend to prevent an iron/steel from rusting. Example

i. Iron sheets are galvanized with zinc

Anodizing

Iron is joined to reactive metals (e.g. Magnesium) by wire. Examples

i. Bridges are anodized to protect it from rusting
ii. pipelines are anodized to protect it from rusting

Tin plating

By defn: *plating is the coating of iron/steel with tin (metal) that does not rusting*. When iron/steel mix with metal that does not rusting tend to prevent an iron/steel from rusting. Example

i. Iron/steel Can is coated inside to prevent rusting so as suitable for canning a foods

Use of silica gel

By defn: *silica gel is a substance in the form of grains and absorbs moisture*. Silica gel prevent presents of water so that prevent iron/steel from rusting. Example

i. silica gel bags put inside cameral parts which made from iron/steel to prevent rusting

Use of plastic

Uses of plastics tend to avoid cost of damage parts or instruments and household made from rusting

FORM TWO NOTES

Oxygen

By defn: *Oxygen is a gas that forms about 21% by volume of the air*. Also present as compound like **water**, **carbon dioxide** etc

Term used

i. **Decomposition**: *Decomposition is the breakdown of a chemical compound into elements or smaller compound*

ii. **Catalyst**: *Catalyst is the substance speed up the rate of chemical but remain unchanged at the end of chemical reaction*

iii. **Reduction:** *Reduction is the* ***remove of oxygen*** *from substance*
Or
By defn: *Reduction is the* ***addition of hydrogen*** *to a substance*

iv. **Reducing agent :** *Reducing agent is the substance which removes* ***of oxygen*** *from that substance*
Or
By defn: *Reducing agent is the substance which* ***transfers of hydrogen*** *to another substance*

v. **Oxidation:** *Oxidation is the* ***addition of oxygen*** *from substance*
Or
By defn: *Oxidation is the* ***remove of hydrogen*** *to a substance*

vi. **Oxidizing agent:** *Oxidizing agent is the substance which removes* ***of hydrogen*** *from that substance*
Or
By defn: *Oxidizing agent is the substance which* ***transfers of oxygen*** *to another substance*

Laboratory preparation of oxygen

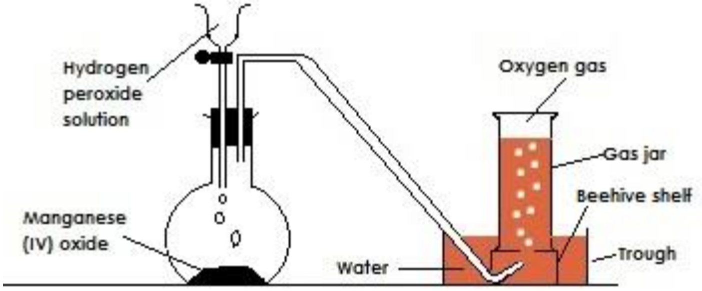
Common method Oxygen separated is;

i. Decomposition of hydrogen peroxide
ii. Decomposition of potassium chlorate in the presence of catalyst (**manganese (IV) oxide**)
iii. Heating compound rich in oxygen
iv. Electrolysis of water

Decomposition of hydrogen peroxide

Hydrogen peroxide decompose on heat to give oxygen gas and water in the presence of catalyst (**manganese (IV) oxide**

Diagram:



Equation:

Hydrogen peroxide $\xrightarrow{MnO_2}$ *water + oxygen*

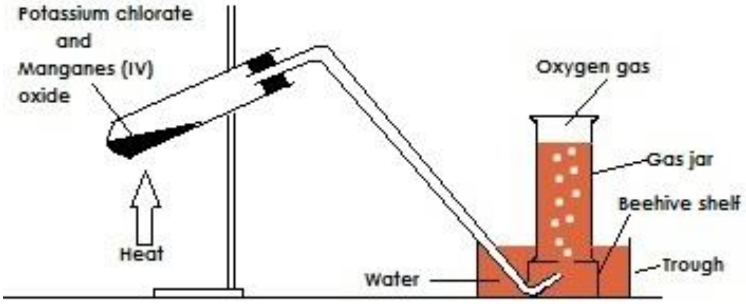
$H_2O_{2\,(aq)} \xrightarrow{MnO_2} H_2O_{(l)} + O_{2(g)}$

Question: Why oxygen gas collected downward displacement of water
Answer: oxygen is less dense than air

Decomposition of potassium chlorate

Potassium chlorate decomposed on heating by using manganese (IV) oxide to produce potassium chloride and oxygen gas

Diagram



Reaction

Decomposed on heating by using manganese (IV) oxide to produce potassium chloride and oxygen gas

Potassium chlorate $\xrightarrow{MnO_2}$ *potassium chloride + oxygen*

$KClO_{3\,(s)} \xrightarrow{MnO_2} KCl_{(s)} + O_{2(g)}$

Test for oxygen gas

Oxygen on gas jar tested by introduce a **glowing wooden splint** if oxygen present lights up

Physical properties of oxygen

i. It is colourless, tasteless and odourless
ii. It is slightly soluble in water
iii. Its 1.1 denser than air
iv. It Boil at -183℃

v. It Freezes at ℃

Chemical properties of oxygen

i. It support combustion
ii. It is a very strong oxidizing agent
iii. React with metal to form basic oxides
iv. React with non-metal to form acidic oxides

Reaction of some metals and oxygen

Oxygen reacts with metal to produce basic oxide

a) Potassium melts easily and burns with a **lilac flame** to produce potassium oxide

Potassium $\xrightarrow{\Delta}$ potassium oxide
(**Silvery-white**) (**White powder**)

b) sodium burns vigorous with a **yellow flame** to produce sodium oxide

Sodium $\xrightarrow{\Delta}$ sodium oxide
(**Yellow**) (**Pale yellow solid**)

c) calcium doesn't melts, burns with **brick red flame** to produce calcium oxide

Calcium $\xrightarrow{\Delta}$ calcium oxide
(**Silver**) (**White solid**)

d) Magnesium melts before it burns with **bright white flame** to produce Magnesium oxide

Magnesium $\xrightarrow{\Delta}$ Magnesium oxide
(**Grey**) (**White powder)**

e) zinc burns slowly with a **dull red flame** to produce zinc oxide

Zinc $\xrightarrow{\Delta}$ zinc oxide
(**Bluish white**) (**Yellow/green flakes)**
(**White flakes if cool)**

f) iron **glows red** to produce iron three oxide

Iron $\xrightarrow{\Delta}$ iron (III) oxide
(**Greyish silver**) (**Black solid)**

g) copper turn orange then the surface of the product (copper two oxide) turns black solid

Copper $\xrightarrow{\Delta}$ copper (II) oxide
(**Bronze**) (**Black solid)**

Nb

This compound they said basic because when react with water form base solution

Reaction of some non-metals and oxygen

Oxygen reacts with non-metal to produce basic oxide

a) carbon burns slowly with a **yellow-white flame** to produce carbon dioxide

Carbon $\xrightarrow{\Delta}$ carbon dioxide
(**Black solid**) (**Colourless gas)**

b) phosphorus burns brightly to produce clouds of white smokes of phosphorus (v) oxide

Phosphorus $\xrightarrow{\Delta}$ phosphorus (v) oxide
(**Yellow solid**) (**White solid)**

c) sulphur melts and burns slowly with a **blue flame** to produce sulphur dioxide

Sulphur $\xrightarrow{\Delta}$ sulphur dioxide
(**Yellow solid**) (**Misty (white gas))**

Nb

This compound they said acidic because when react with water form acidic solution

Industrial manufacture of oxygen

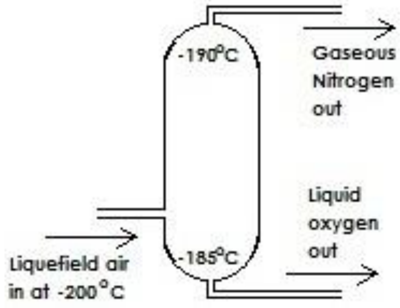
In industry oxygen produced in large scale by using **Fractional Distillation of Liquefied Air**

Fractional Distillation of Liquefied Air

Consider the follows steps which used to obtain the oxygen

i. **filter** air to remove dust
ii. Air is liquefied (air changed to liquid) by lower temperature to -200℃
   a) Water vapour condensed and removed by using special filters
   b) Carbon dioxide freezes at -79℃ and removed
   c) Oxygen liquefied at -183 ℃
   d) nitrogen liquefied at -196 ℃
iii. The remains mixture (nitrogen and water) is separated by using fractional distillation. Consider the diagram below

Diagram:



Nb:

i. Nitrogen collected at the top and piped off and stored
ii. Oxygen collected at the bottom and piped off and stored

Uses of oxygen

i. Oxygen for living organisms

Transport

ii. Oxidizer for rocket fuel
iii. Respiration in spacecraft and submarine

Medical/hospitals

iv. Aids in breathing
v. Anaesthesia
vi. Incubator for premature babies

Manufacturing

vii. Steel from iron
viii. Metal cutting
ix. Welding
x. Glass making
xi. Pulp and Paper making

Environment

xii. Treatment of sewage plants

Chemical process

xiii. Manufacturing of chemicals e.g. acid and oxides
xiv. Combustion/incineration
xv. Oxidation to remove impurities
xvi. To speed up rate of reaction
xvii. Manufacture of synthesis fuels

Hydrogen

By defn: *hydrogen is the lightest and most abundant element in the universe*

Laboratory preparation of Hydrogen

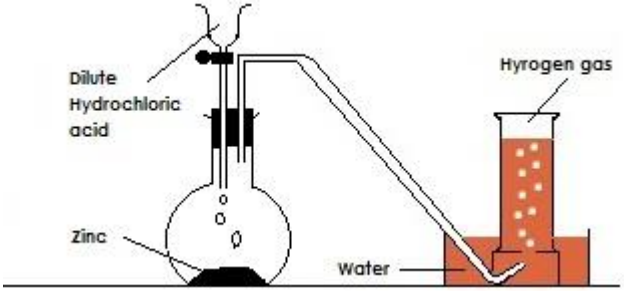
Common method hydrogen prepared is;

1. Reaction of dilute acid with some metals
2. Reaction of water with certain metals
3. Reaction of water with hot carbon
4. Electrolysis of water

Reaction of dilute acid with some metals

Hydrochloric acid reacts with zinc metal to produce zinc chloride and hydrogen gas

Diagram:



Equation:

Zinc + Hydrochloric acid → zinc chloride + Hydrogen

$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$

Question: Why hydrogen gas collected downward displacement of water

Answer: hydrogen is less denser that air

Test for hydrogen

Hydrogen on gas jar tested by introduce a **glowing wooden splint** if hydrogen present it **explode with a pop sound**

Properties of Hydrogen

Consider the physical and chemical properties of hydrogen as follows

Physical properties of Hydrogen

1. It is tasteless, colourless and odourless
2. It is lighter(less denser) than air
3. It is only slight soluble in water
4. Does not support combustion
5. It neutral to litmus

Chemical properties of Hydrogen

1. Combine easily with other chemical substance at high temperature
2. Usual does not react with other element at room temperature
3. High flammable and burns with blue flame
4. Mixture of hydrogen and oxygen explodes when lit
5. It React with oxides of metal to produce metal
6. It React with chlorides of metal to produce metal
7. React slowly with oxygen to produce water

React of hydrogen with oxides

When hydrogen react with oxide of metal produce metal and water

a. Cooper (II) oxide reacts with hydrogen to form copper and water

Cooper (II) oxide + hydrogen → copper + Water

b. lead (II) oxide reacts with hydrogen to form lead and water

Lead (II) oxide + hydrogen → lead + Water

c. iron (II) oxide reacts with hydrogen to form iron and water

Iron (II) oxide + hydrogen → iron + water

d. calcium oxide reacts with hydrogen to form calcium and water

Calcium oxide + hydrogen → calcium + Water

React of hydrogen with chlorides

When hydrogen react with chloride of metal produce metal and hydrogen chloride

a. Cooper (II) oxide reacts with hydrogen to form copper and hydrogen chloride

Cooper (II) oxide + hydrogen → copper + hydrogen chloride

b. lead (II) oxide reacts with hydrogen to form lead and hydrogen chloride

Lead (II) oxide + hydrogen → lead + hydrogen chloride

c. iron (II) oxide reacts with hydrogen to form iron and hydrogen chloride

Iron (II) oxide + hydrogen → iron + hydrogen chloride

d. calcium oxide reacts with hydrogen to form calcium and hydrogen chloride

Calcium oxide + hydrogen → calcium + hydrogen chloride

Industrial manufacture of Hydrogen

Hydrogen in industrially manufactured by

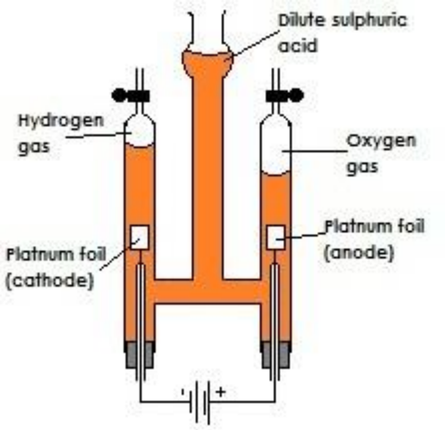
1. Electrolysis of water

ii. Steam reforming of natural gas

Electrolysis of water

By defn: *Electrolysis is the process whereby water decomposes into hydrogen and hydrogen due to electricity***.** Consider the diagram below

Diagram:



Mechanism

When electricity switch on water decomposes and hydrogen collected at cathode (negative terminal) and oxygen collected at anode (positive terminal)

Steam reforming of natural gas

This method is used to produce or manufacture hydrogen. Also called **stream methane reforming (SMR)**

Mechanism

When stream at (700 – 1100)℃ reacts with methane (natural gas) produce carbon monoxide and hydrogen

Stream + methane → carbon monoxide + hydrogen

Nb:

This reaction takes in the presence of **metal-base catalyst**

Uses of Hydrogen

The following are main uses of hydrogen

i. Manufacture of ammonia
ii. Manufacture of margarine
iii. Manufacture of Oxy-hydrogen flame
iv. Manufacture of hydrochloric acid
v. Prepare water gas (Fuel)
vi. Filling Weather balloons

Manufacture of ammonia

Hydrogen reacts with nitrogen under **iron catalyst** to yield ammonia on a large scale called **Haber process**

Uses of ammonia

i. Production of nitric acid
ii. Production of Fertilizers
iii. Synthetic fabrics such as polyester fabrics and polyamide fabrics

Manufacture of margarine

Hydrogen is bubbled through liquid oil with **nickel catalyst** to harden the liquid oil, which then is processed to form margarine. This process is called **Hydrogenation**

Hydrogenation

By defn: *Hydrogenation is the process whereby hydrogen reacts with other chemical substance*

Manufacture of Oxy-hydrogen flame

Hydrogen is manufacture oxy-hydrogen flame which is very hot up to 3000℃

Uses of Oxy-hydrogen flame

i. Used for welding
ii. Used for cutting metals

Manufacture of hydrochloric acid

Hydrogen reacts with chlorine to yield hydrogen chloride gas, which dissolved in water to form hydrochloric acid

Prepare water gas (Fuel)

Water gas prepared by using hydrogen used as fuel which used by rocket

Filling Weather balloons

Since hydrogen is less dense than air it used to fill balloons

Relation uses of hydrogen and its properties

Use	**Property**
Manufacture of **ammonia**	Readily combines with elements e.g. nitrogen
Manufacture of **margarine**	Reducing agent
Manufacture of **Oxy-hydrogen flame**	Highly flammable
Manufacture of **hydrochloric acid**	Readily reacts with other chemical substance
Prepare water gas **(Fuel)**	Highly flammable

Filling **Weather balloons**	Less dense than air

Water

By defn: *Water is the compound formed between hydrogen gas and water*

Term used

i. **Evaporation**: Evaporation is the process whereby water changes to vapour/gas or steam
ii. **Transpiration**: Transpiration is the process whereby plant loses water by evaporation
iii. **Condensation**: Condensation is the process whereby water vapour change back to liquid to form clouds
iv. **Precipitation**: Precipitation is the situation whereby rain, snow and sleet (rain with ice) that falls to ground
v. **Collection**: Collection is the situation whereby rain accumulated at earth ground
vi. **Water body**: water body is the natural place where can be a source of water. E.g. wells, rivers, lakes, stream, sea, ponds, springs etc
vii. **environmental conservation:** environmental conservation is the process of preservation or restoration of the natural environment and wildlife
viii. **fog**: fog is a thick cloud of tiny water droplets suspended in the atmosphere at or near the earth's surface which make visibility difficult
ix. **Universal Solvent**: universal solvent is a solvent dissolves more substance than any solid
x. **Specific Heat Index**: specific heat index is ability of a substance to absorbs heat before being hot
xi. **Surface Tension**: surface tension is properties of liquid to behave like an elastic skin
xii. **Solubility:** Solubility is the process of dissolving a solute in solvent
xiii. **Water treatment:** Water treatment is the process of making water usable
xiv. **Water purification:** Water purification is the process of removal contaminants from treated water

Occurrence of water

The water on the earth occurs in three main states includes

i. Solid state e.g. snow, hail
ii. Liquid state e.g. dew, rain
iii. Vapour state e.g. mist, steam, clouds

Distribution of earth's water

There two kind of water include

i. **Salt water** – 97% of earth's water
ii. **Fresh water** - 3% of earth's water

Distribution of Fresh's water

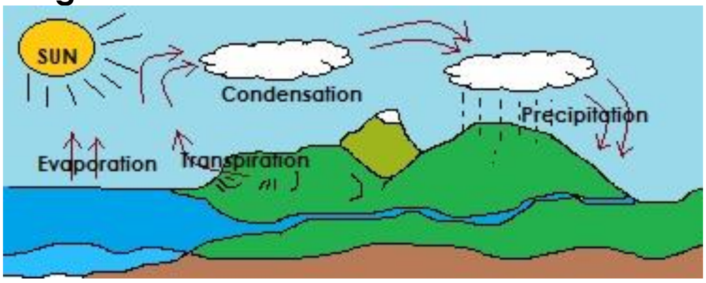
Fresh water distributed as follows

i. **Ice caps and glaciers** – 68.7% of fresh's water
ii. **Ground water**– 30.1% of fresh's water
iii. **Surface water**– 0.3% of fresh's water
iv. **Other water**– 0.9% of fresh's water

Water Cycle

By defn: water cycle is the system whereby water being recycled. Also is called **Hydrological Cycle**

Diagram:



Water Cycle Parts

Water cycle is made up to four main parts, includes

i. Evaporation (include transpiration)
ii. Condensation
iii. Precipitation
iv. Collection

Evaporation (include transpiration)

Water from rivers, lakes, stream, sea, ponds etc **evaporate** to air. Plants lose water by **transpiration** while animal and human being lose water through **perspiration** and **sweating**

Condensation

Water vapour obtained by evaporation, transpiration, perspiration and sweating in the air gets cold and changes back into liquid to form **clouds**

Precipitation

Rain start when air fails to hold condensed water and final results rain

Collection

Takes place when rain water back to the ground which may run over the soil and collected in the rivers, lakes, stream, sea, ponds where cycle stars all over again

Water cycle and environmental conservation

In order to preservation or restoration of water to be clean, the following should be done in various aspect includes

1. Water bodies
2. Water vapour
3. Acidic rain

Water bodies

Water bodies should not pollute in order to preservation or restoration of water to be clean

How water body polluted

1. Environment degradation destroy the quality of water in water bodies
2. People damp waste materials into water bodies

Water vapour

Gases (sulphur dioxide, nitrogen dioxide and carbon dioxide) form industrial combine with water vapour to form **fog**

Acidic rain

Acidic gases when combine with water vapour to form acidic rain

Effect of acidic rain

1. Acidic rain kills plants
2. Acidic rain kills life in water bodies
3. Acidic rain accelerates the decay of building materials like iron sheet and paints

Properties of water

Consider the physical and chemical properties of water as follows

Physical properties of water

1. It is colourless, odourless and tasteless
2. Occurs natural in all state of mater
3. It is universal solvent
4. Freezing point is 0 ℃
5. Its boiling point is 100 ℃
6. It has high surface tension
7. It has high specific heat index
8. It expand when freeze thus why ice float over water
9. It's miscible with many liquids

Chemical properties of water

1. Pure water is neutral (neither acidic nor basic)
2. Cold water react with some metals to form hydroxide and liberate hydrogen gas
3. Some metals react with steam to give respective metal oxide and hydrogen gas

Uses of water

Used of water based in different activities includes

Domestic use (daily use)

In domestic activities water used for

1. Drinking
2. Cooking food
3. Cleaning our surrounding
4. Washing our bodies
5. Washing our clothes

Transportation use

In transport activities water used for

1. Boats and ships used to transport people
2. Boats and ships used to transport goods

Recreation use

In recreation activities water used for

1. Used for swimming
2. Used Sporting fishing
3. Ocean water used for scuba-diving

Economic use

In economic activities water used in

1. Manufacture
2. Agriculture
3. Mining
4. Energy
5. Construction
6. Fishing

Manufacture

1. Manufacture of chemicals
2. Manufacture of Food
3. Manufacture of Beverages

Agriculture

1. Used in Irrigation

ii. Used in Animal dips
iii. Used in Watering animal

Mining

i. Used to carry away impurities
ii. Used as solvent to extract mineral

Energy

i. Moving water used to generate electricity (HEP)

Construction

i. Contraction of buildings used to mix sand and cement
ii. Contraction of road it used to compress the sand

Fishing

i. It used for fishing
ii. Used for artificial fish pond

Solubility of different substances in water

i. Water as universe solvent dissolves many substance (solute) like **common salts**, **liquid soap**, **Sodium carbonate** etc
ii. All substance which does not dissolve in water they dissolve in organic substance. Example
   a. Propane used to dissolve cooking oil
   b. Ethanol used to dissolve glue and printing ink

Water treatment and purification

Water should be treated and purified before it can be clean and safe for use

Domestic water purification

The follows methods used to treat water as

i. Boiling
ii. Use of purifiers
iii. Use of commercial filters

Boiling

Untreated water boiled for 5 minutes to kill bacteria and the filtered by using clean cloth

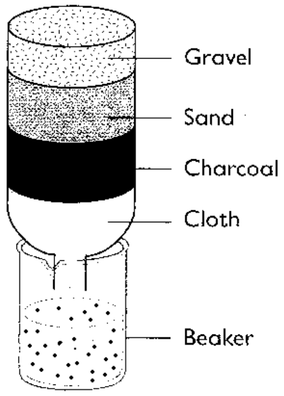
Use of purifiers

Recommended amount of Chemical purifiers (AQUAGUARD and WATERGUARD) in liquid or tablet form putted in a specific amount of water then shaken or stirred well and left to settle for twenty minutes before it can be safe for drinking

Use of commercial filters

Commercial filter is a filter system which Contains two or more filter element/media through which the water passes to be cleaned

Diagram:



Unban water treatment

Tap water used in urban is usual obtained from sources such as rivers, stream and lakes which are not treated. Processes for treat urban water are follows

i. Screening
ii. Reservoirs
iii. Primary filtration
iv. Secondary filtration
v. Disinfection/chlorination
vi. Storage

Screening

This process involves the removing of floats substance

Reservoirs

This process involves the storing of water at high up so it flows through gravitation (atmospheric pressure)

Primary filtration

This process involves

i. Filtered water comes from reservoir through coarse sand (filter medium) to remove particles
ii. Addition of **aluminium sulphate** to water comes from reservoir to remove smaller particles which was not filtered at coarse sand

Secondary filtration

This process involves Filtered water comes from primary filtration through finer sand (filter medium) to remove smallest particles

Disinfection/chlorination

This process involves put Disinfection to water comes from secondary filtration to kill harmful bacteria

Storage

This process involves to store soft water (comes from Disinfection/chlorination) ready for use

Importance of water treatment

i. To kill harmful micro-organism such as bacterial, algae, fungi
ii. To get accurate results from experiment and effect treatment In laboratories and medical facilities
iii. To ensure the manufacture products are safe for consumption in factories
iv. To use small of certain substance to make solution with water
v. To remove human made chemical pollutant
vi. To make water safe and clean etc
vii. To removal mineral such as iron, sulphur etc
viii. To remove the particles such as dust, sand, leaves etc

Nb:

Disease like **amoebic dysentery**, **cholera**, **typhoid** and **other diarrhoea related** diseases are caused by using contaminated water

Fuels and energy

In this topic will deals with fuels and energy, let us start with fuel

Fuel

By defn: *Fuel is combustible substance burning in air to produce energy (heat)* .Since combustion is chemical process so fuel is also called **chemical fuel**

Categories of fuels

Fuel classifies according to;

i. Occurrence (preparation)
ii. Physical state

Occurrence (preparation)

According to occurrence fuel classified into two fuels includes

i. Natural/primary fuel
ii. Artificial/secondary fuel

Natural fuel

By defn: Natural fuel is the fuel occurs natural. Example **wood**, **coal**, **peat**, **petroleum** and **natural gas**

Artificial fuel

By defn: *Artificial fuel is the fuel manufacture in industries or fining from natural fuel*. Example coke, kerosene, petrol, coal gas and producer gas

Physical state

According to physical state fuel classified into three fuels include

i. Solid fuel
ii. Liquid fuel
iii. Gaseous fuel

Table show classification of fuels

Physical state	Natural fuel	Artificial fuel
Solid	Wood, coal	Charcoal, coke
Liquid	Crude petroleum	Petrol, diesel, kerosene, biodiesel
Gaseous	Natural gas	Liquefied petroleum gas (LPG), coal gas, water gas, hydrogen

Characteristics of a good fuel

A good fuel should have the following characteristics

i. High energy value
ii. High rate of combustion
iii. Have Average ignition point
iv. Low Non-combustible material content
v. Not produce poisonous gas
vi. Highest pyrometric burning effect
vii. Readily available
viii. Affordable
ix. Ease to transport and store
x. Have no effect on environment

High energy value

A good fuel should have a high energy value. Energy value is determined by the amount of energy produced per unit mass of the fuel. This is called **heat value**

High rate of combustion

A good fuel should have high rate of burns and moderate rate for a continuous supply of heat

Have Average ignition point

By defn: *ignition point is the temperature needed to burn fuel*. A good fuel should have average ignition point

Nb:

i. Low ignition is risk due to fire hazard
ii. High ignition point makes difficult to start a fire
iii. Fuel with high ignition point is safe to transport and store

Low Non-combustible material content

A good fuel should have low or no contents of non-combustible material. For example ashes

Nb:

i. Non-combustible materials lower the heat value of the fuel
ii. Non-combustible materials left in form of ash

Not produce poisonous gas

A good fuel should **not give off poisonous gases** and also it should **give off very little or no smoke**

Highest pyrometric burning effect

By defn: *Pyrometric burning effect is the highest temperature reached by burning fuel*. A good fuel should have highest Pyrometric burning effect

Nb:

1. Gaseous fuels have Pyrometric burning effect

Readily available

A good fuel should be readily available in large quantities

Affordable

A good fuel should be affordable to most people

Ease to transport and store

A good fuel should be easy and safe to transport and store

Have no effect on environment

A good fuel should not have harmful effect on the environment. Example *Fossil fuels which produce carbon monoxide* on burning are major contributor to **global warming**

Destruction distillation

By defn: *Destruction distillation is the process whereby organic fuel decomposed by heating in the absence of air (oxygen) to obtain useful product*

Nb:

i. Organic fuel is wood, coal and oil shale
ii. Useful product is coke, charcoal, oil and gases

Solid fuels

This is the kind of fuel which exist as solid, solid fuels include

i. Coal
ii. Charcoal

Coal

By defn: *Coal is the fossil energy formed by anaerobic (without oxygen) decay of plants that lived millions of years ago*

Nb:

i. **By defn** *Fossil energy is the energy formed by anaerobic (without oxygen) decay of plants that lived millions of years ago*
ii. Energy remain in the coal is Solar energy stored in plants

Composition of coal

Coal is composed by four components includes

i. Moisture
ii. Volatile matter
iii. Ash
iv. Coke

Nb:

i. When coal heated at 950℃ **volatile matter** is driven off in absence of air
ii. Volatile matter consists **gases** and **low boiling point organic compound** that condense into **oil** when cooled and **tar**
iii. **Ash** is the non-combustible residue material left coal burnt
iv. **Coke** is the material left after the volatile matter driven off

Types of coal

There are different types of coal vary in composition and properties. The most important types of coal are

i. Peat coal
ii. Lignite coal
iii. Bituminous (soft) coal
iv. Anthracite (hard) coal

Destruction distillation of coal

By defn: *Destruction distillation of coal is the process whereby coal decomposed by heating in the absence of air (oxygen) to obtain coke, gases and volatile matter*

Nb:

i. Coal contains a large amount of volatile matter burns with **smoky flame** and has low **energy value**
ii. Coke is most used most coal product
iii. Some gases produced can be refined to form **ammonia**, **coal tar** and **light oil**
iv. Destruction distillation of coal takes place in **kilns**

Coal Kilns

By defn: Coal *Kiln is a furnace or oven for burning coal in absence of air*

Types of coal kilns

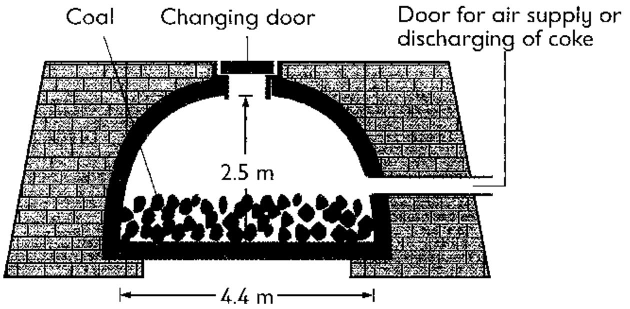
There two types, include

i. Otto Hoffman kiln
ii. Beehive kiln

Beehive kiln

It is a dome-shaped structure made up of bricks. This is earliest and cheapest process of distilling coal

Diagram:



How coke distilled

The following process used to distilling coal

1st. Coal is spread over the base through charging door
2nd. Air is supplied through the side door to ignite coal
3rd. Volatile matter escapes and burns inside the side door
4th. Distillation take (3 – 4)days to complete
5th. Hot coke is cooled with water and taken out through the side door

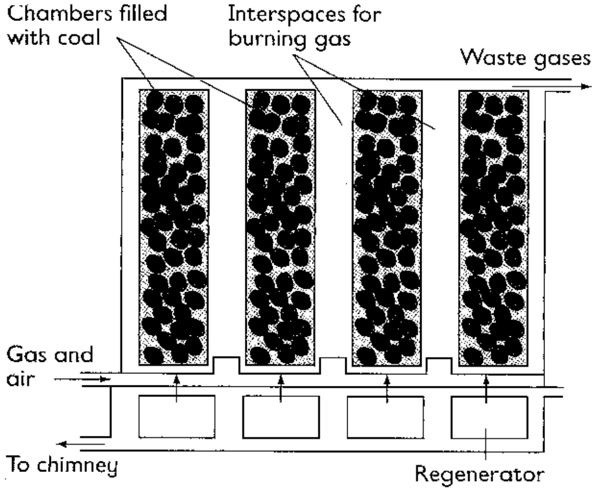
Nb:

i. This process yield about 60% coke by mass
ii. Beehive kiln cannot producing **ammonia**, **coal gas**, **benzol oil** and **tar**

Otto Hoffman kiln

It advanced one which can produce extra materials like ammonia, coal gas, benzol oil and tar

Diagram:



Structure of Otto Hoffman kiln

i. It consists of a number of narrow silica chambers separated by spaces for burning gas
ii. Each chamber has charging hole at the top
iii. A gas outlet and doors at each end for discharging coke

How coke distilled

1st. Coal added into chambers then chamber closed
2nd. Coal heated to drive out liquid or gaseous components. this is called **dry distillation**

Nb:

Heating done externally by a part of **coal gas** produced during the process or by **producer gas** or by **blast furnace gas**

3rd. Heating continues until evolution of volatile matter stop, this evolution takes 24 hours
4th. Coke obtained pushed out and (quenched) cooled

Nb:

a. When quenched by water spray. This is called **wet quenched**
b. When red hot coke is quenched an inert gas like nitrogen. This is called **dry quenched**
c. Dry quenched produce strong, denser, clean and non-reactive coke

Nb:

i. This process yield about 75% coke by mass
ii. It can producing **ammonia**, **coal gas**, **benzol oil** and **tar**

Charcoal

Charcoal is made from dry distillation of wood at 94000 – 4500)℃ in an earth-pit kiln or earth-mound kiln. Charcoal burns with non luminous flame and is easily ignited

Earth-pit kiln

Consider the process takes in earth-pit kiln

1st. The wood is heaped in hemispherical pile in a central pit
2nd. Then it covered by with earth and sod, leaving small air holes near the bottom
3rd. Wood is lit at the center and allowed to burn until the whole pile is on fire

Nb:
a. Smouldering combustion takes place, utilizing oxygen and hydrogen components of the wood fibre
b. The product of Smouldering combustion is water, carbon dioxide and volatile organic compound

4th. Small hole closed until the fire goes off and charcoal cool

Nb: This process yield about 20% charcoal by weight and 75% by volume

Earth-mound kiln

It works as earth-pit kiln but earth-mound kiln has not a pit but the wood is heaped in a pile above the ground surface

Nb:

i. Earth-mound kiln is Preferred if the soil occupied by rocky (stones)
ii. Earth-mound kiln is Preferred if the soil water table is close to the surface

Characteristics of good charcoal

i. Should be porous
ii. Should be Brittle
iii. Should be Retains in the form of the wood

Gaseous fuels

This is the kind of fuel which exists as gas, include the follows

i. Producer gas
ii. Water gas

Producer gas

Producer gas is a mixture of flammable gases and non-flammable gases made by the combustion of carbonaceous substances in an atmosphere of air and steam

Nb:

i. **By defn**: a carbonaceous substance is the fuel contains a high proportion of carbon
ii. Example of carbonaceous substance is coal
iii. **Flammable gases** includes carbon monoxide and hydrogen
iv. **non-flammable gases** includes nitrogen and carbon dioxide

Composition of producer gas

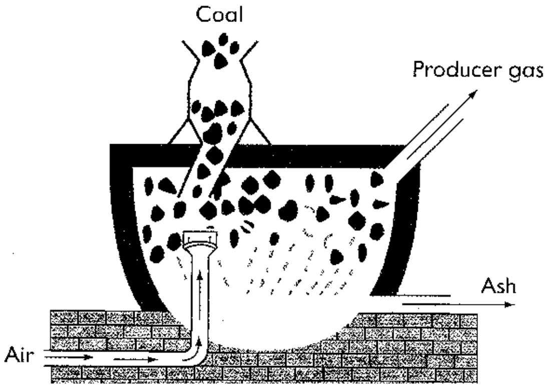
Producer gas composed with the follows

Gas	Percentage composition
Nitrogen	(52 – 55) %
Carbon monoxide	(22 – 30) %
Hydrogen	(8 – 12) %
Carbon dioxide	3 %
Methane	Trace amounts

Production of Producer gas

It produced in producer furnace

Diagram:



Mechanism

i. When air mixed with stream, is passed through the inlet, the carbon (coal) combines with oxygen (air) to form carbon dioxide at lower part
ii. Carbon dioxide formed is rise up to hot coal and reduced to carbon monoxide
Nb: Nitrogen from air not affected at all process
iii. The mixture of carbon monoxide and nitrogen, with traces of carbon dioxide and some organic compound collected at outlet as producer gas

Properties of producer gas

i. It is poisonous gas

ii. Insoluble in water
iii. Denser than air

Uses of producer gas

i. Used as fuel to heating open-hearth furnace in steel and glass manufacturing
ii. Used as fuel to heating muffle furnace and retorts in production of coke and coal gas
iii. Used to reducing atmosphere in certain metal extraction operations

Water gas

Water gas is a mixture of carbon monoxide and hydrogen gas with a small amount of carbon dioxide. It buns with a non-luminous blue flame therefore is called **blue water gas**

Composition of water gas

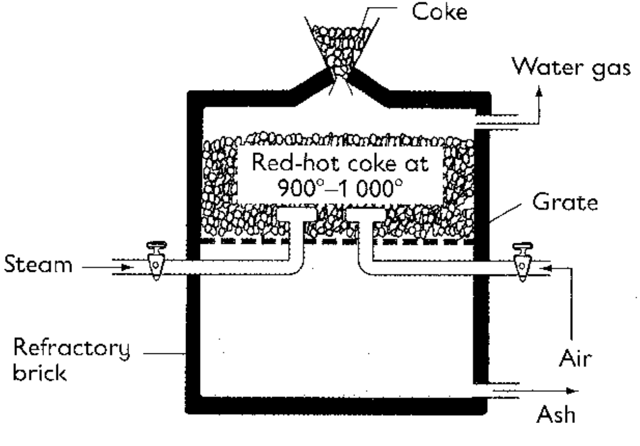
Water gas composed with the follows

Gas	Percentage
hydrogen	48 %
Carbon monoxide	44 %
Carbon dioxide	4.2 %
nitrogen	3 %
Methane	0.8 %

Production of water gas

It produced in a water gas generator

Diagram:



Mechanism

i. When steam at 1000 ℃ react with red hot coke produce water gas (carbon monoxide and hydrogen gas)
  Nb:
  a. Reaction above is endothermic (absorb) heat from red hot coke which cause red hot coke to cool
  b. Cold coke react with stream to form carbon dioxide and hydrogen gas instead of water gas
  c. Steam (hot blow) is passed for (1 – 2) minutes
  d. Air (cold blow) is passed for 4 minutes to make coke to be red hot again at 1000 ℃
  e. Carbon dioxide, carbon monoxide and nitrogen produced during air blow are escapes into atmosphere
ii. When coke become red hot again at 1000 ℃, the steam is allowed to react with red hot coke in order to produce water gas
iii. The water gas collected at water gas outlet

Properties of water gas

i. It buns with a non-luminous blue flame
ii. It has energy value about 13628kJ/m^3
iii. It burns with high temperature about 1200℃

Uses of blue water gas

i. Used as an industrial fuel especially in making steel
ii. Used in preparation of hydrogen

Energy value of a fuel

By defn: *Energy value of a fuel is the total amount of heat liberated by the complete combustion of unit mass of the fuel in oxygen*. SI unit of energy value is J/g or KJ/Kg

Mathematically:

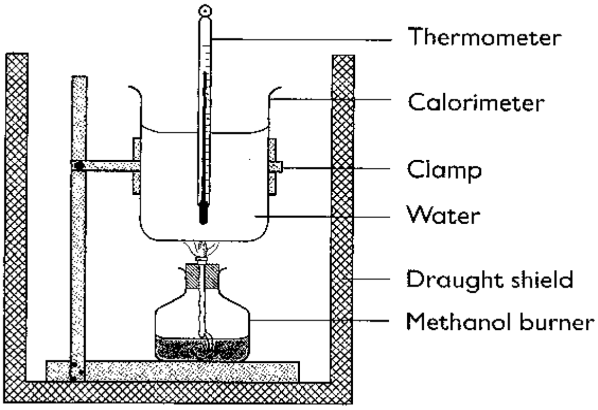
$$E = \frac{H}{m} \text{ - - - - - - - - - - } 1$$

Where

E = energy value of a fuel
H = heat energy liberated
M = mass of the fuel used

Consider the diagram below

Diagram:



When water heated by methanol, it means water deliver heat from methanol so

From: conservation of energy

Then: $H = He = Hw = mc\Delta\theta$

Finally: $H = mc\Delta\theta$ - - - - - - 2

Where:

H = Heat energy liberated

He = Heat energy liberated by ethanol

Hw = Heat energy absorbed by water

$\Delta\theta = (\theta 2 - \theta 1)$ = change in temperature

$\theta 1$=Initial temperature of water

$\theta 2$ = Final temperature of water

m = mass of water

c = specific heat of water

Insert eqn 2 into eqn 1

Therefore: $E = \frac{mc\Delta\theta}{M}$

$$E = \frac{mc\Delta\theta}{M}$$

Nb:

i. Calorimeter is used to control the loss of heat energy when determining energy value of fuel
ii. In calculation you should convert temperature to Kelvin unit (K)

Example

The following results were obtained n an experiment to measure the heat value of biodiesel

Initial temperature of water, $\theta 1 = 24.7℃$

Final temperature of water, $\theta 2 = 68.5$ ℃

Mass of biodiesel burnt, M = 56g

Volume of water used, v = 12 litres

Determine heat value of the biodiesel. (Specific heat capacity of water = 4.18 KJ $Kg^{-1}K^{-1}$, density of water = 1000 kg m^{-3})

Data given

$\theta 1$ = 24.7℃ = 24.7 + 273 = 297.7 k

$\theta 2$ = 68.5 ℃ = 68.5 + 273 =341.5 k

M = 56g 0.056 kg

v = 12 litres = 0.12 m^3

m = density x volume = 1000 x 0.12 = 120 kg

Heat value of biodiesel, E = ?

Solution

From: $E = \frac{mc(\theta 2 - \theta 1)}{M}$

$E = \frac{120 \times 4.18 \times (341.5 - 297.7)}{0.056} = 392.32$

E = 392.32 kJ / Kg

Uses of fuel

Fuel used according to its efficiency

i. Wood, coal and charcoal used for cooking, boiling and ironing
ii. Petrol, diesel and liquefied petroleum gases used for running industrial plants, cars, planes, ship etc
iii. Kerosene used for cooking and a source of light
iv. Coal is used to generate electricity in power plant
v. Coal is used to in industry to make dye, insecticides and fertilizers

Environmental effects on using charcoal and firewood

Uses of charcoal and firewood cause

i. Deforestation (cutting down tree)
ii. Drought
iii. Floods
iv. Disease

Deforestation

Cutting down tree cause land unprotected from soil erosion

Drought

Deforestation result disturb water cycle which can cause drought and final famine

Floods

Increase in carbon dioxide tend to increase global warming which results high temperature than normal which can cause rains or melts ice in ice lands and final floods

Disease

Flood always water may contaminate and when people uses can affected and final cause disease

Energy

By defn: *Energy is the capacity or ability of a body to do work*. SI Unit of energy is **Joule** (**J**)

Forms of Energy

Energy they can be in motion or in position. So we have about two main forms

i. Kinetic energy
ii. Potential energy

Kinetic Energy

By defn: *kinetic energy is the energy due to motion possessed by a body*. The motion may be of waves, electrons, atoms, molecules or object itself. For example of kinetic energy is

i. Electric energy
ii. Radiant energy
iii. Thermal energy
iv. Sound energy
v. Wind energy
vi. Water moving
vii. Ocean Waves
viii. Ocean Tides
ix. Moving machines
x. Falling bodies

Potential Energy

By Defn: *potential energy is the energy due to position possessed by a body*. For example of potential energy

i. (Chemical energy) Energy stored in food
ii. Gravitational energy etc
iii. Elastic energy
iv. Nuclear energy

Nb:

By defn: *Mechanical energy is the sum of kinetic energy and potential energy*

Principle of Conservation of Energy

The law of conversation of energy states that

"***Energy can neither be created nor destroyed but can be transferred from one form to another***"

Transformation of Energy

Energy can be changes from one form to another consider the follows examples

i. Battery convert chemical energy to electrical energy
ii. Generator convert mechanical energy to electrical energy
iii. A motor convert electrical energy to mechanical energy
iv. A microphone convert electrical energy to sound energy
v. Solar panel convert solar energy to electrical energy
vi. Solar cooker convert solar energy to heat energy
vii. Heater convert electrical energy to heat energy

Alternative sources of energy

Source of energy can be divided into two types

Types of Sources of Energy

There are two types of sources of energy namely:

i. Non- renewable sources
ii. Renewable sources

Non- Renewable Sources

These are the energy sources, which cannot be turned into use again. For Examples: **oil**, **natural gas** and **charcoal**

Renewable Sources

These are the energy sources, which can be turned into use again after being used. Example **sun**, **water**, **wind**, **fossils** etc, consider the follows

i. Solar energy
ii. Biomass
iii. Biogas
iv. Wind energy
v. Water power

Solar energy

By Defn: *Solar energy is the radiant energy emitted by the sun*

Ways used to tap/harvest solar energy

i. Generating electricity using photovoltaic or photoelectric solar cells
ii. Generating electricity using concentrated solar power
iii. Heating and cooking using parabolic mirror that focus the suns to a central position
iv. Heating and cooling using solar chimney

NB:

The energy from the sun is the sources of all energy on the earth

Biomass

Organic matter used as a fuel, especially in the generation of electricity. Biomass is used to produce **liquid biofuel**

Advantage of biomass

i. A way to Disposing a waste material
ii. Minimize agent of global warming

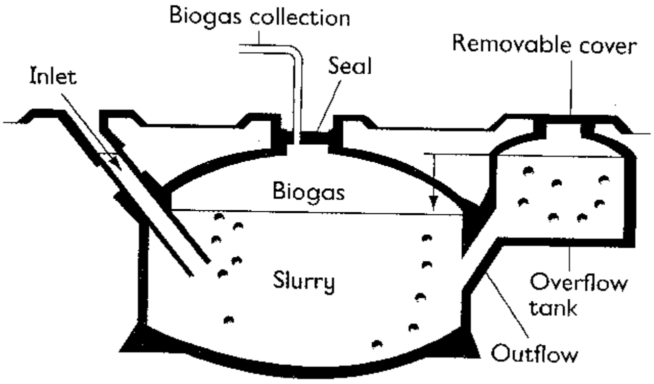
Biogas

By defn: Biogas is gaseous fuel, especially methane, produced by the fermentation of organic matter

Production of Biogas

Consider the diagram below

Diagram:

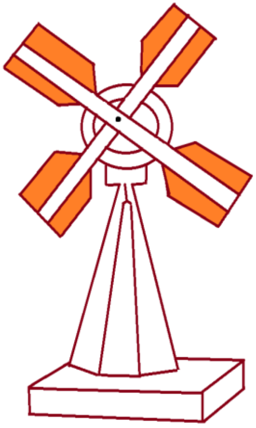


The waste matter is put together and allowed to ferment naturally and finally we get biogas

Nb:
The remains matter used as fertilizer

Wind energy

Wind energy can be converted into electricity by building a tall tower with a large propeller on top called **windmill.**



Country like Denmark, Spain and German use wind energy to produce electricity

Characteristics of Wind Energy

i. is not reliable
ii. is harnessed using noisy turbines
iii. Requires large wind sites to put up the turbines.

Advantage of Using Wind Energy

i. Wind energy is used in moving ships, boats, pumping water and grinding corn.
ii. It can also be used to drive generators to produce electricity
iii. It is used to cool land
iv. It used to cool sea
v. It is used by mechanical to remove dust in car parties

Water power

Water power includes the follows

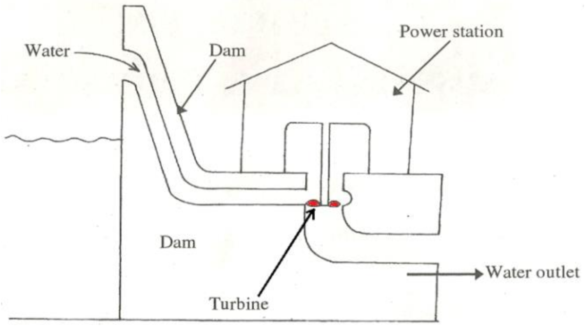
i. Hydroelectric energy
ii. Sea wave energy
iii. Ocean Geothermal energy
iv. Tidal stream energy

Hydroelectric energy

Hydroelectric energy is the generation of electricity using flowing water to drive a turbine which powers a generator. Also is called **water energy**

How Generated Water Energy

Consider the diagram below;



When the water comes from dam which constructed to hold water at a higher ground used to drive the turbine in order to generate electricity

Characteristics of Water Energy

i. reliable
ii. readily available in many places
iii. environmental friendly
iv. Can be constantly generated

Advantage of Using Water Energy

i. A industrial work

ii. lighting
iii. heating and cooking
iv. Running hospital equipment

Sea Wave Energy

Sea water is the form of energy in which caused by disturbing water particles resulting progress propagation from one to another point

Causes of Sea Wave Energy

Sea wave energy is as a result of wind blowing across the sea

Harvest of Sea Wave Energy

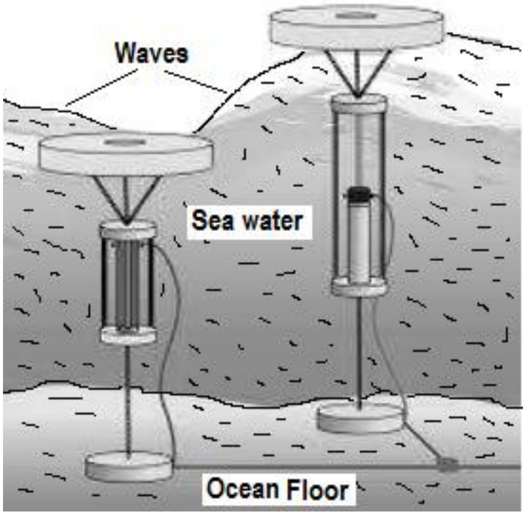
It can harvested by the following methods, includes

i. Point absorber buoys
ii. Surface attenuators
iii. Overtopping devices

Point Absorber Buoys

Point absorber buoys is the device which floats on sea water

Diagram:



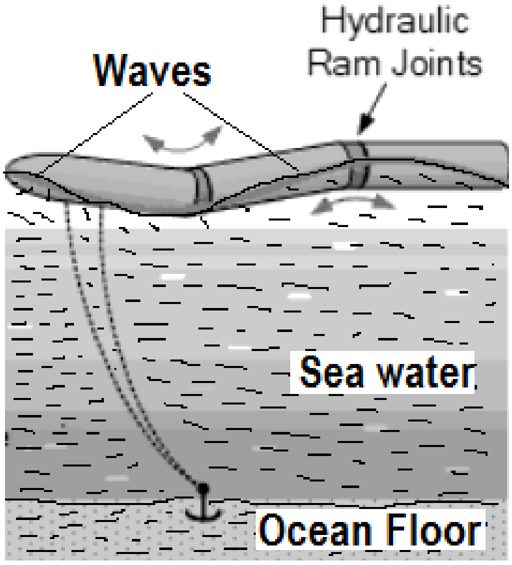
Mechanism

A buoy is a device that floats on the surface of water. Buoys use the rise and fall of swells (waves) to drive hydraulic pumps and generate electricity

Surface Attenuators

Surface attenuators is the device which floats on sea water

Diagram:



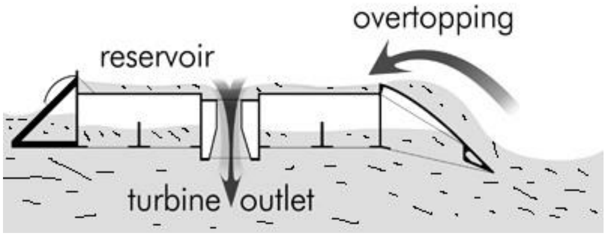
Mechanism

This consists of multiple floating segments connected to one another and is oriented perpendicular to incoming waves. A flexing motion is created by swells that drive hydraulic pumps to generate electricity

Overtopping Devices

Overtopping devices is the device which floats on sea water

Diagram:



Mechanism

During waves the sea water overtopping on reservoir which drop down through turbine outlet results rotation of turbine which generates electricity

Challenge of Harvesting Sea Wave Energy

i. It is very expensive
ii. Device can wear due to rusting
iii. Device can damage due to storm created by waves or tides

Tides

By Defn: Tides energy is the rising and falling of the ocean level

Causes of Tides

It causes by the gravitational pull of the moon and to some extent the sun

Tides Energy

By Defn: Tides energy is the energy results from the rising and falling of the ocean level. The change of water levels that the tides produce can be used as an energy source.

Harvest of Tides Energy

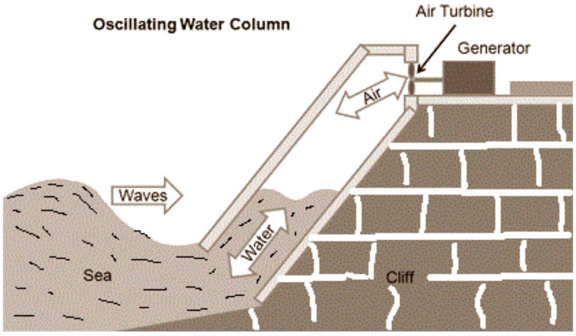
It can harvested by the following methods, includes

1. Oscillating water columns
2. Bay dam (tidal stream energy)

Oscillating Water Columns

The tidal power plants are constructed along a costal where rise and fall of water can enter and leave a column

Diagram:



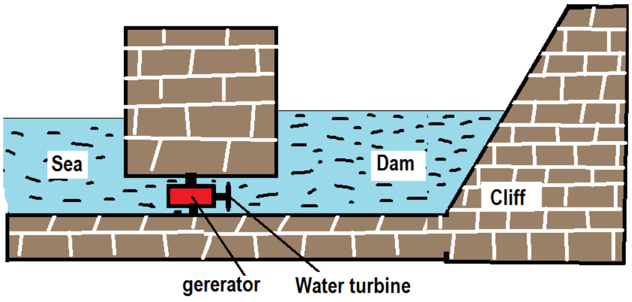
Mechanism

1. During high tides water compress/push air molecules in the column which creates high pressure than atmosphere pressure results air particles blowing away from the column therefore rotates generator in which generates electricity
2. During low tides water pull air molecules in the column which creates low pressure than atmosphere pressure results air particles blowing inside the column therefore rotates generator in which generates electricity

Bay Dam

The tidal power plants are constructed near the narrow bays, where the water level rises up and then falls down appreciably during the tides

Diagram:



Mechanism

1. During the high tide, the sea water is allowed to pass through the dam walls by opening the gates, therefore the sea water moves from the sea to the dam through turbine which rotates the turbine in which generates electricity
2. When the level of water tends to fall during low tide by opening the gates, therefore the sea water moves from the dam to the sea through turbine which rotates the turbine in which generates electricity

Challenge of Harvesting Tides Energy

1. It is very expensive
2. Device can wear due to rusting
3. Device can damage due to storm created by tides

Ocean Geothermal energy

Geothermal comes from two words

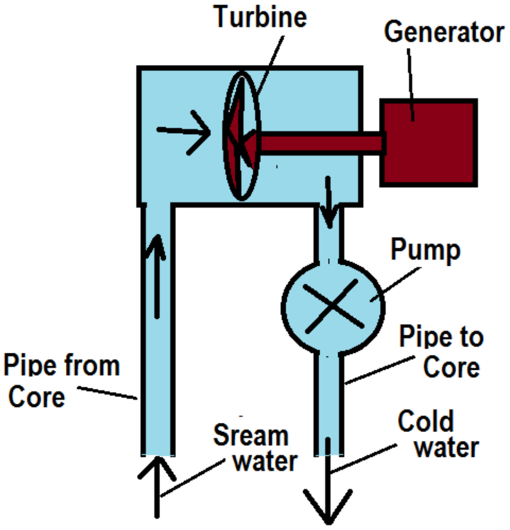
1. Geo means earth
2. Thermal means Heat

By Defn: geothermal energy is the energy generated by the flow of heat from the earth core

Harvest of Geothermal Energy

The heat energy from the earth can be converted to electrical. Consider the diagram that follows

Diagram:



Mechanism

By pumping water to the hotter rocks, steam drawn back to generate electricity by rotates a turbine which rotates a turbine which rotates a generator to produce electricity

NB:

The turbine and propeller where are inform of mechanical energy rotate dynamo or generator which produce electricity

Structure of the atom

Atom

By defn: *Atom is the smallest particle of an element that has all the chemical properties of that element*. For example helium (**H**), hydrogen (**He**), iron (**Fe**) etc

Molecules

By defn: *molecule a group of atoms bonded together, representing the smallest fundamental unit of a compound that can take part in a chemical reaction*. For Example water molecule (H_2O), hydrogen molecules (H_2)

Dalton's Atomic theory

John Dalton developed his theory about the atom with five main points as follows

i. Matter is made up of tiny particles called atom
ii. Atoms cannot be created or destroyed
iii. Atom of any one element are identical and have the same chemical properties and the same mass
iv. Atom of a given element are different from those of any other element
v. Atoms of one element can combine in simple ratio with the atom of another element to form a compound atoms or molecules

Modification from Dalton's Atomic theory

i. Atom is made by sub atomic particle such as electrons, protons and neutrons
ii. Atoms can be created or destroyed
iii. Atom of any one element can differ example isotopes
iv. Atoms of one element can combine in any ratio with the atom of another element

Sub atomic particles

We have three model which describe Sub atomic particles as follows

i. Thomson's 'Plum pudding' model of atom
ii. Rutherford's planetary model of atom
iii. Simplified model of atom

Thomson's 'Plum pudding' model of atom

Sir JJ Thomson carried experiment and describe atom as sphere of **positive change** with **negative particles** called **electrons**

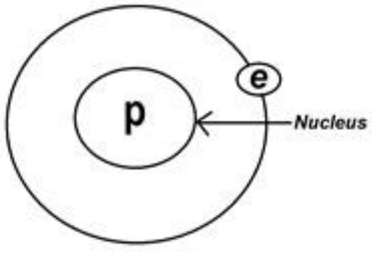
Diagram:

Rutherford's planetary model of atom

Ernest Rutherford, he carried experiment to prove if Thomson's model was correct, and final describe his finding

i. The positively charged particles of an atom located in the nucleus is called **protons**
ii. Most of the mass of the atom located in the nucleus
iii. Nucleus has a relative smaller volume compared to whole atom
iv. Negative charged particle moves around the nucleus in orbit is called **electrons**
v. Electrons have very small mass compared to the protons

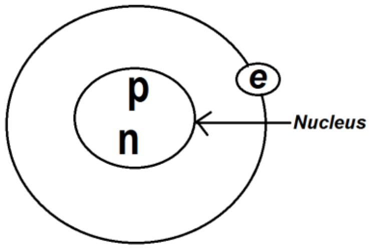
Diagram:



Simplified model of atom

Chadwick established that there was neutron in nucleus which had the same mass as protons but no charge

Diagram:



Where:
p = protons
n = neutrons
e = electrons

Therefore Atoms are made up by three sub atomic of particles namely

i. Protons
ii. Neutrons
iii. Electrons

Protons

By defn: *Protons is the positive charged particle located at nucleus*. It denoted by small letter **p**. its charge and his mass is +1.6 x 10^{-19}C and 1.6726 x 10^{-27}kg respectively

Neutrons

By defn: *Neutrons is the neutral charged particle located at nucleus*. It denoted by small letter **n**. its charge and his mass is 0C and 1.6749 x 10^{-27}kg respectively

Electrons

By defn: *Electrons is the negative charged particle revolves around the nucleus*. It denoted by small letter **e**. its charge and his mass is -1.6 x 10^{-19}C and 9.1094 x 10^{-31}kg respectively

Properties of Subatomic Particles

Particle	Symbol	Charge (C)	Mass (Kg)
Proton	p	+1.6 x 10^{-19}	1.6726 x 10^{-27}
Neutron	n	0	1.6749 x 10^{-27}
Electron	e	-1.6 x 10^{-19}	9.1094 x 10^{-31}

Electron arrangement

Electron is orbit the nucleus in a special regional called shells (energy levels) are fixed distance from nucleus. Each shell can hold a maximum number of electrons given by formula ($2n^2$)

$$Me = (2n^2)$$

Where:

Me = maximum number of electron

n = position of shell from nucleus

Nb:

i. Electron must occupy the lowest available shell (energy level) nearest to the nucleus
ii. Shell (energy level) can represent with letter as K, L, M, N, O ….. and 1,2,3,4,5 … respectively
iii. Table show total electron in shells

Shells	Letter	Formula	Total electrons
1	K	2 x 1^2	2
2	L	2 x 2^2	8
3	M	2 x 3^2	18
4	N	2 x 4^2	32

iv. Shell contains maximum number of electrons is called filled shell
v. Electron are arranged so that the lowest shell filled first

Electronic configuration

By defn: *Electronic configuration is the arrangement of electrons in different shells*

Electronic configuration of 20 elements

Element	symbol	Element number	Electronic configuration
Hydrogen	H	1	1
Helium	He	2	2
Lithium	Li	3	2:1
Beryllium	Be	4	2:2
Boron	B	5	2:3
Carbon	C	6	2:4
Nitrogen	N	7	2:5
Oxygen	O	8	2:6
Fluorine	F	9	2:7
Neon	Ne	10	2:8
Sodium	Na	11	2:8:1
Magnesium	Mg	12	2:8:2
Aluminium	Al	13	2:8:3
Silicon	Si	14	2:8:4
Phosphorus	P	15	2:8:5
Sulphur	S	16	2:8:6
Chlorine	Cl	17	2:8:7
Argon	Ar	18	2:8:8
Potassium	K	19	2:8:8:1
Calcium	Ca	20	2:8:8:2

Atomic Number

By defn: *Atomic number is the number of proton particle in nucleus of a particular element*. It denoted by capital letter Z

Mathematically: **$Z = p$**

Mass Number

By defn: *Mass number is the sum of protons and neutrons particles*. Also is called **atomic mass/weight**. It denoted by capital letter A

Mathematically: **$A = Z + n$**

Nb:

i. Magnitude of protons and electrons particles is equal
ii. Mass/weight of atom located at nucleus

Example:

Atom Q has a mass number of 49 and atomic number of 24

(a) What is its neutrons number

(b) what is the number of electrons

Data given

A = 49
Z = 24
n = ?
e = ?

Solution

(a) n = ?

From: A = Z + n
n = A – Z = 49 – 24 = 25
n = 25

(b) **since:** Z = p = e = 24
e = 24

Nuclide notation

Given atoms/elements (X) of a mass number (A) located as superscript while atomic number (Z) located as subscript. i.e. $^{A}_{Z}\mathrm{X}$

Example:

Hydrogen → $^{1}_{1}\mathrm{H}$
Boron → $^{11}_{5}\mathrm{B}$
Nitrogen → $^{14}_{7}\mathrm{N}$
Oxygen → $^{16}_{8}\mathrm{O}$

Example

The following information is about a potassium atom

Number of electrons →19
Mass number → 39

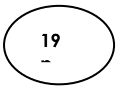
(a) work out atomic number and neutron number
(b) give the nuclide notation
(c) show the nucleus representation
(d) draw electronic configuration of atom

Solution

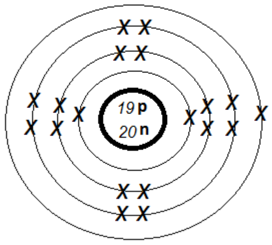
(a) atomic number = electron = 19
Neutrons = 39 – 19 = 20

(b) $^{39}_{19}\mathrm{K}$

(c)



(d)



Isotopes

By defn: *Isotopes is atoms with the same atomic number but differ in atomic mass*

Isotopy

By defn: *Isotopy is the existences of atoms with the same atomic number but differ in atomic mass*. Elements which can form Isotopy is called **isotopic elements**

Isotopic Elements and Their Isotopes

Elements	Z	Isotopes	A
Hydrogen	1	Hydrogen - 1 deuterium tritium	1 2 3
Carbon	6	Carbon - 12 Carbon - 13 Carbon - 14	12 13 14
Oxygen	8	Oxygen - 16 Oxygen - 17 Oxygen - 18	16 17 18
Chlorine	17	Chlorine - 35 Chlorine - 37	35 37
Uranium	92	Uranium - 234 Uranium - 235 Uranium - 238	234 235 238
lead	82	lead - 202 lead - 206 lead - 207 lead - 208	202 206 207 208

Nb:

i. The different isotopes always differ by one neutron $(1\,^{1}_{0}\mathrm{n})$

Isotopes of particular element/atom; the largest the mass number (A) the heaviest of element and vice versa

Example

State the following number of protons, neutrons and electrons in the following isotopes

i. $^{12}_{6}\mathrm{C}$
ii. $^{14}_{6}\mathrm{C}$
iii. $^{3}_{1}\mathrm{H}$
iv. $^{87}_{38}\mathrm{Sr}$
v. $^{238}_{92}\mathrm{U}$

Solution

i. Mass number = 12
Protons = atomic number = 6
Electrons = Protons = 6
Neutrons = 12 – 6 = 6

ii. Mass number = 14
Protons = atomic number = 6

Electrons = Protons = 6
Neutrons = 14 – 6 = 8

iii. Mass number = 3
Protons = atomic number = 1
Electrons = Protons = 1
Neutrons = 3 – 1 = 2

iv. Mass number = 87
Protons = atomic number = 38
Electrons = Protons = 38
Neutrons = 87 – 38 = 49

v. Mass number = 238
Protons = atomic number = 92
Electrons = Protons = 92
Neutrons = 238 – 92 = 146

Example

An isotope of carbon has a mass number of 13 and an atomic number of 6

i. Write its nuclide notation
ii. How many neutrons does it have
iii. How many electrons does it have

Solution

i. ${}^{13}_{6}\mathrm{C}$
ii. Neutrons = 13 – 6 = 7
iii. Electrons = Protons = atomic number = 6

Relative Atomic Mass

By defn: *Relative atomic mass of the element is the average mass of the element relative to $\frac{1}{12}$th the mass of one carbon-12 atom*

Mathematically

$$\mathbf{RAM} = \frac{\textbf{average mass of the element}}{\frac{1}{12}\textbf{th the mass ofcarbon}-\mathbf{12}}$$

Nb:

i. Average because other elements have isotope
ii. Relative atomic mass is the mass of atom by compare by carbon-12 (arbitrarily chosen as 12 units which is not actual value)
iii. Carbon was chosen as standard atom/reference

Atomic numbers and relative atomic masses of first 20 elements of the periodic table

Element	**Atomic number**	**RAM**
Hydrogen	1	1
Helium	2	4
Lithium	3	6.9
Beryllium	4	9
Boron	5	10
Carbon	6	12
Nitrogen	7	14
Oxygen	8	16
Fluorine	9	19
Neon	10	20.2
Sodium	11	23
Magnesium	12	24.3
Aluminium	13	27
Silicon	14	28.1
Phosphorus	15	31
Sulphur	16	32
Chlorine	17	35.5
Argon	18	39.9
Potassium	19	39.1
Calcium	20	40.1

Example

Calculate relative atomic mass of chlorine which two isotopes ${}^{35}_{17}\mathrm{Cl}$ (75%) and ${}^{37}_{17}\mathrm{Cl}$ (25%)

Solution

RAM = $\frac{(35x75)+(37x25)}{100}$

RAM = $\frac{3550}{100}$ = 35.5

RAM = 35.5

Example

Calculate relative atomic mass of neon which three isotopes ${}^{20}_{10}\mathrm{Ne}$ (90.5%), ${}^{21}_{10}\mathrm{Ne}$ (0.3%) and ${}^{22}_{10}\mathrm{Ne}$ (9.2%)

Solution

RAM = $\frac{(20x90.5)+(21x0.3)+(22x9.2)}{100}$

RAM = $\frac{1810+6.3+202.4}{100}$

RAM = $\frac{2018.7}{100}$ = 20.187

RAM = 20.187

Periodic classifiCation

Periodic Table

By Defn: Periodic table is the method of display chemical elements in a table format

ModifiCation of Periodic table

It was developed after several modifiCations, consider the follows

i. Contribution of John Newlands
ii. Contribution of Dimitri Mendeleev

Contribution of John Newlands

In 1866, a British chemist John Newlands he arrange elements in order of their increasing atomic masses in columns according to **Octaves Law**. He notice that an element tended to display characteristics similar to the 8th in front of it

H	Li	Be	B	C	N	O
F	Na	Mg	Al	Si	P	S
Cl	K	Ca	Cr	Ti	Mn	Fe

Nb:

i. During this time noble gas had not been discovered
ii. He grouped certain elements of different characteristics example oxygen and iron
iii. Grouping certain elements of different characteristics cause his ideas to rejected

Contribution of Dimitri Mendeleev

In 1869, a Russian chemist Dimitri Mendeleev he arrange elements in order of their increasing atomic masses and same properties in columns according to **Periodic Law**

Group / period	1	2	3	4	5	6	7	8
1	H							
2	Li	Be	B	C	N	O	F	
3	Na	Mg	Al	Si	P	S	Cl	
4	K	Ca	-	-	-	-	-	Ti, V, Cr,M, Fe,Co,Ni
5	Cu	Zn	-	-	As	Se	Br	

Periodic Law

It states that

> "***The properties of elements are a periodic function of their relative atomic masses***"

Nb:

i. Vertical column is called **Group**
ii. horizontal column is called **Period**
iii. He not include noble gas had not been discovered
iv. He was left gaps in his table predicting that there were existing element yet to been discovered at the time

Modern periodic table

Be defn: *Modern periodic table Is a table of elements arranged systematically according to their increasing atomic number*

Groups		**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
Periods	1	$^{1}_{1}H$							$^{4}_{2}He$
	2	$^{7}_{3}Li$	$^{9}_{4}Be$	$^{11}_{5}B$	$^{12}_{6}C$	$^{14}_{7}N$	$^{16}_{8}O$	$^{19}_{9}F$	$^{20}_{10}Ne$
	3	$^{23}_{11}Na$	$^{24}_{12}Mg$	$^{27}_{13}Al$	$^{28}_{14}Si$	$^{31}_{15}P$	$^{32}_{16}S$	$^{35.5}_{17}Cl$	$^{36}_{18}Ar$
	4	$^{39}_{19}K$	$^{40}_{20}Ca$						

Modern periodic law

It law states that

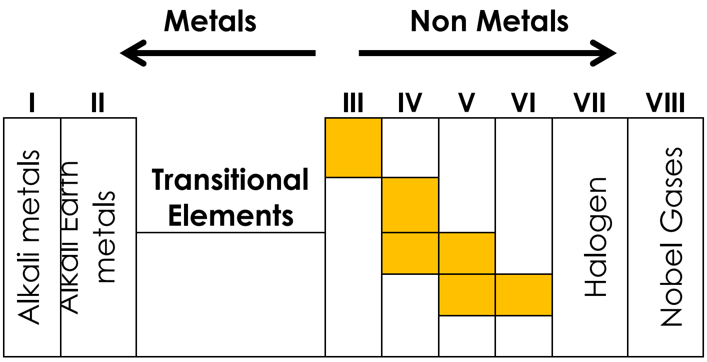
> "***The properties of elements are a periodic function of their atomic numbers***"

Nb:

The periodic recurrence of similar properties when elements are arranged according to their atomic numbers is called **periodicity**

Groups

By defn: *Group is the Vertical column with the same outer most shell*



Where:

🟨 = metalloids

Alkali metals

By defn: Alkali metal is the group one metals react with water to form alkaline (base) solution

Nb:

Hydrogen is placed in group one but is a not a alkali metal

Alkali earth metals

By defn: *Alkali earth metal is the group one metals but is less reactive and most found at the earth*

Transition metals

By defn: *Transition metals is metals between group two and three with high density and melting point, often act as catalyst and most of them form coloured compound*

Metalloids

By defn: *Metalloids is the elements with characteristics of metal and non-metal*

Nb:

i. Metals are more ductile (drawn out into a thin wire and deformed without losing toughness) than non-metals
ii. Non-metals are more brittle (hard but liable to break easily) than metals

Halogens

By defn: *Halogens is the group seven elements which react with water to form salts*

Nobel gases

By defn: *Nobel gas is the group eight elements whereby all their shells are completely filled up*. Also called **inert gases** because they do not react to form compound

Periods

By defn: *Periods is the horizontal column with the same number of shells*. Periods are numbered from I to VII

General Periodic Trends

Trends observation include variation in

i. **Melting Point**: *Melting Point is temperature at which solid melts to form liquid*
ii. **Boiling Point**: *Boiling Point is temperature at which liquid boil to form gas*
iii. **Density**: *Density is the degree of compactness(mass per unit volume) of a substance*
iv. **Electronegativity**: *Electronegativity is the ability of an atom to attract an electron*
v. **Ionization Energy**: *Ionization Energy is the energy required to remove electrons from an atom or ion*
vi. **Atomic Radius**: *Atomic Radius distance between the nucleus of an atom and the outermost stable shell*
vii. **Reactivity**: *Reactivity is refers to how an atom of a given elements reacts with other substance*. Reaction can be **likely** or **vigorously**

Trends across periods from left to right

i. Atomic radii of elements is decrease from left to right
ii. Elements of Left side of periodic table show metallic properties while right show non-metallic properties
iii. Electronegativity increases from left to right
iv. Number electrons and protons increase from left to right
v. Boiling point decrease from left to right

General group trends down the group

i. Atomic radii increase *(**Reason**: increase number of shell)*
ii. Metallic properties decrease
iii. Density increase
iv. Melting point decrease *(**Reason**: Metallic properties decrease)*
v. Electronegativity decrease
vi. ionization energy decrease *(**Reason**: atomic radii increase*

Specific trends in the group I

Alkali metal consist five metals, namely lithium (Li), sodium (Na), potassium (K), rubidium (Rb) and caesium (Cs)

Group I: Alkali Metal

Name	**Atomic Radius**	**Ionization Energy**	**Melting Point**	**Density (G/Cm³)**	**Electronegativity**
Lithium	152	526	180	0.54	1.0
Sodium	186	504	98	0.97	0.9
Potassium	231	425	64	0.86	0.8
Rubidium	244	410	39	1.5	0.8
Caesium	262	380	29	1.9	0.7

Nb:

i. Francium (Fr) is also alkali metal but not usual included in group

ii. Lithium (Li), sodium (Na) and potassium (K) all react very readily with water or air always Stored under water

Why placed in group I

Because these elements have one electron each in their outer most shell

Properties of Lithium, sodium and potassium

Consider the physical and chemical properties

Physical Properties of group I

i. They are good conductors of heat and electricity
ii. They are soft metals
iii. They have low density
iv. They have shiny surface when fresh cut

Chemical Properties of group I

i. They burn in oxygen or air to form white solid oxides
   Metal + oxygen → metal oxide
   These oxides dissolve in water to form alkaline solution of the metal hydroxide
   Metal oxide + water → metal hydroxide

ii. they react vigorously with water to give the alkaline solution and hydrogen gas
   Metal + water → metal hydroxide + hydrogen

Specific trends in the group II

Alkali earth metal consist six metals, namely Beryllium (Be), Magnesium (Mg), Calcium (Ca), Strontium (Sr), Barium (Ba) and Radium ((Ra)

Group II: Alkali Earth Metal

symbol	Atomic Radius	Ionization Energy	Melting Point	Density (G/Cm^3)	Electroneg ativity
Be	112	899	14,849	1280	1.5
Mg	160	738	7730	651	1.2
Ca	197	590	4741	851	1.0
Sr	215	549	4207	800	1.0
Ba	217	503	3420	850	0.9
Ra					

Nb:

Magnesium and calcium are usually available in school laboratories

Why placed in group II

Because these elements have two electrons each in their outer most shell

Physical Properties of Alkali Earth Metal

i. They are good conductors of heat and electricity
ii. They are harder metals than those in Group I
iii. They are silvery grey in colour when pure and clean
iv. They are tarnish in colour when left in air due the formation of respective metal oxide

Chemical Properties of Alkali Earth Metal

i. They burn in oxygen or air to form white solid oxides
   Metal + oxygen → metal oxide
ii. They react less vigorously with water to give the alkaline solution and hydrogen gas
   Metal + water → metal hydroxide + hydrogen
iii. The alkali earth metals become more reactive down the group

Bonding, formula and nomenclature

Chemical Bonding (Bonding)

By defn: *Bonding is a method whereby atoms become more stable by donating, gaining or sharing electrons*

Or

By defn: *Bonding is a force of attraction that holds atoms together*

Nb:

i. Atom become stable either by loose electrons, gain electrons or by sharing electrons
ii. Atom which loose electrons called **Cation**
iii. Cation is denoted by **positive charge**
iv. Atom which gain electrons called **anion**
v. Anion is denoted by **negative charge**
vi. Metal always form Cation
vii. Non Metal always form anion
viii. Any charged atom (Cation and anion) is called **Ion**
ix. **Ion** *stable atom either by loose electrons, gain electrons or by sharing electrons*

Types of bonding

i. Ionic or electrovalent bond
ii. Covalent bond

Ionic or electrovalent bond

By defn: *Ionic or electrovalent bond is the body formed by transfer of electrons from one atom to another*

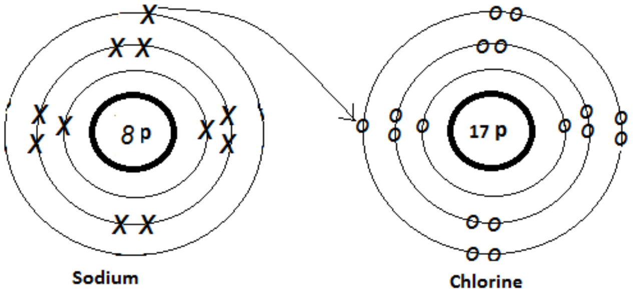
Or

By defn: *Ionic or electrovalent bond is chemical bond between Cation and anion*

Formation of sodium chloride (NaCL) crystal

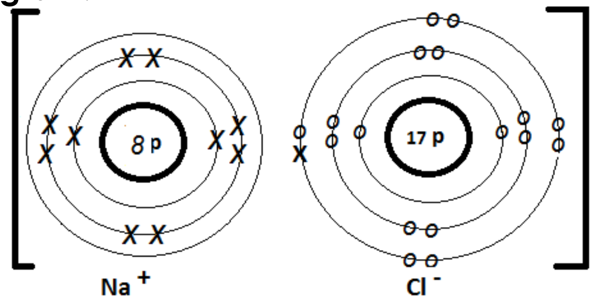
On forming sodium chloride, sodium lose electrons to form Cation (sodium ion) and chlorine gain electron to form anion (chlorine ion)

Diagram:



Sodium ion and chlorine ion form sodium chloride crystal

Diagram:



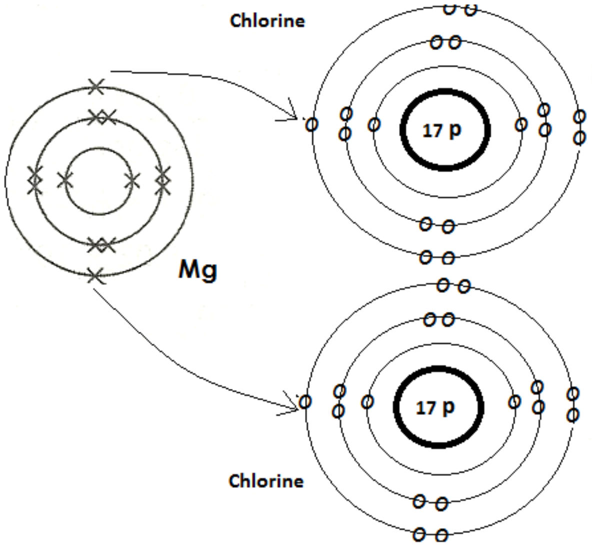
Nb:

Molecules of electrovalent compounds are **Not Discrete** (electrons are not localized/attached to particular ions Cation). Group of Cation surround an anion and Group of anion surround an Cation this cause ions to move free around each other when in molten or solution thus why ionic conduct electricity

Formation of magnesium chloride ($MgCl_2$)

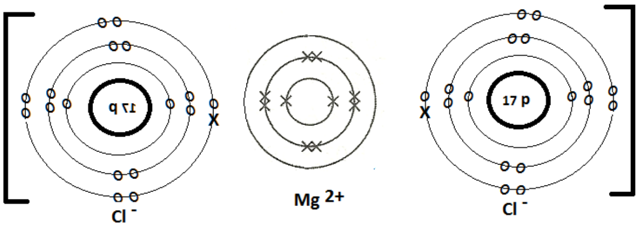
On forming magnesium chloride, magnesium lose two electrons to form Cation (magnesium ion) and chlorine gain one electron each electron to form two anion (chlorine ion)

Diagram:



Magnesium ion and chlorine ion form magnesium chloride crystal

Diagram:



Properties of electrovalent bond

i. Soluble in water
ii. Conduct electricity when in solution or molten
iii. Usually crystalline solid at room temperature
iv. Have high boiling point
v. Insoluble in organic (non-polar) solvent like ethanol, either, benzene, kerosene etc

Covalent bond

By defn: *Covalent bond is a bond formed by sharing electrons between atoms*

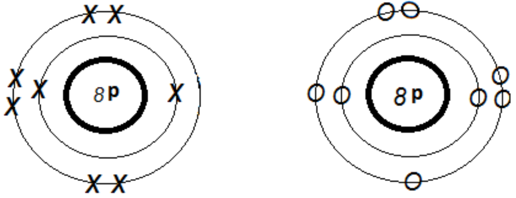
Example of covalent bond compound

i. Formation of oxygen gas from oxygen atoms (O_2)
ii. Hydrogen and chlorine to form hydrogen chloride molecule (HCl)
iii. Hydrogen and hydrogen to form hydrogen gas (H_2)
iv. Formation of chlorine gas (Cl_2)
v. Formation of methane (CH_4)
vi. Formation of Ammonia (NH_3)
vii. Formation of Carbon dioxide (CO_2)

Formation of oxygen gas (O_2)

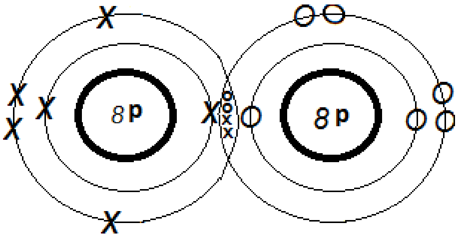
Consider the two Oxygen atoms, each need two electron to be stable

Diagram:



They share to form molecule of oxygen gas

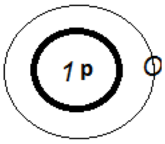
Diagram:



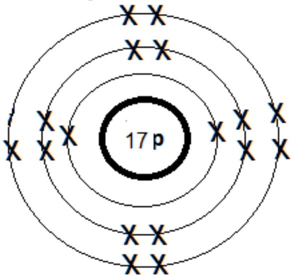
Hydrogen and chlorine to form hydrogen chloride molecule (HCl)

Consider the hydrogen and chloride atoms, each need two electron to be stable

Diagram:



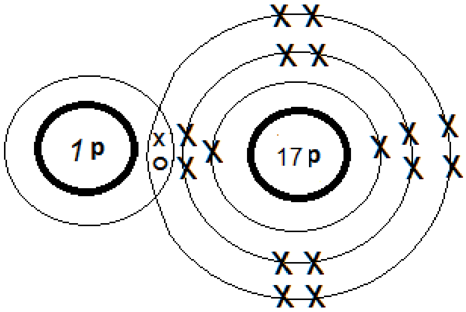
Hydrogen Atom



Chloride atom

They share to form molecule of hydrogen chloride gas

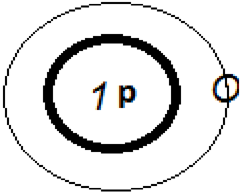
Diagram:



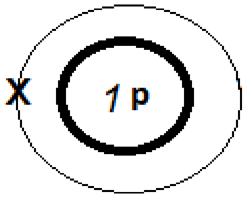
Hydrogen and hydrogen to form hydrogen gas (H_2)

Consider the two Hydrogen atoms, each need one electron to be stable

Diagram:



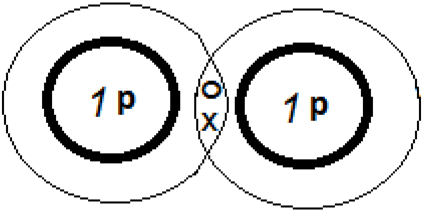
Hydrogen Atom



Hydrogen Atom

They share to form molecule of Hydrogen gas

Diagram:

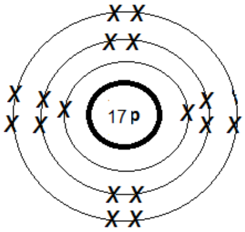


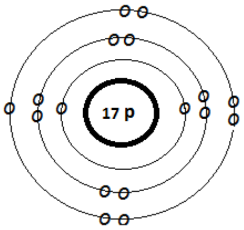
Hydrogen gas

Formation of chlorine gas (Cl_2)

Consider the two chlorine atoms, each need one electron to be stable

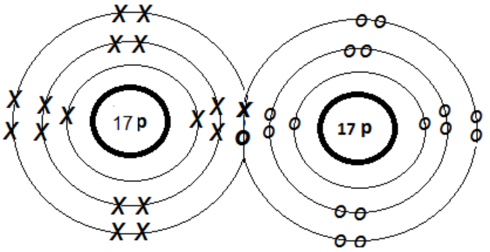
Diagram:





They share to form molecule of chlorine gas

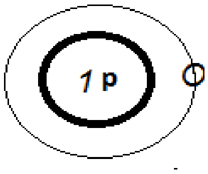
Diagram:



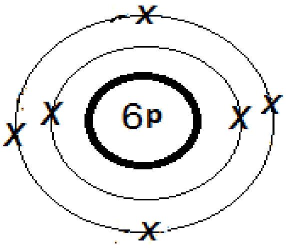
Formation of methane (CH_4)

Consider the carbon and hydrogen atoms, each need one electron to be stable

Diagram:



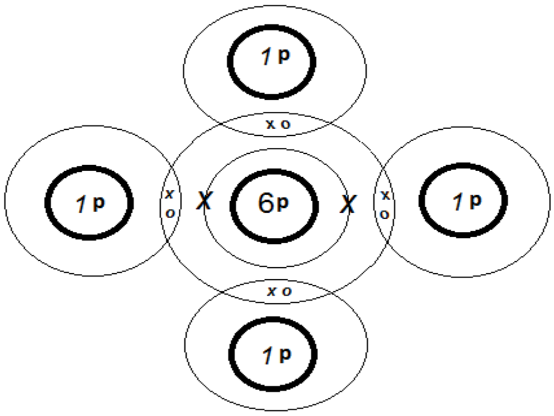
Hydrogen Atom



Carbon atom

They share to form molecule of methane gas

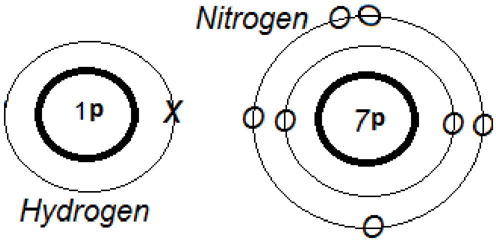
Diagram:



Formation of Ammonia (NH_3)

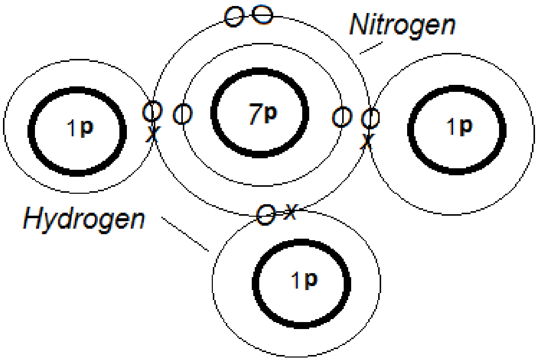
The hydrogen atom need 0ne electron to be stable and nitrogen atom three electrons to be stable

Diagram:



They share to form molecule of ammonia

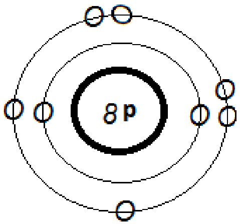
Diagram:



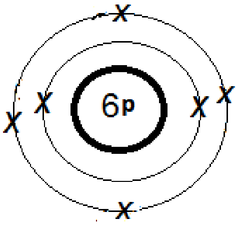
Formation of Carbon dioxide (CO_2)

Consider the carbon and oxygen atoms, each need one electron to be stable

Diagram:



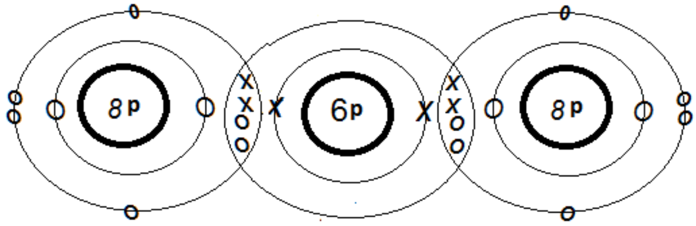
Oxygen atom



Carbon atom

They share to form molecule of carbon dioxide gas

Diagram:



Nb:

i. Covalent bond usually formed between non metals

ii. Molecules of covalent compound are discrete or distinct (their electrons remain bound together in molecules and their electron are not free to form bond with other atoms)

Properties of covalent bond

i. Its melting point and boiling point are low

ii. Usually exist as liquid or gas at room temperature

iii. Do not conduct electricity

iv. Soluble in organic solvent

v. Insoluble in water

Valency

By defn: *Valency is the electron number of atom which donates, share or receive in formation of chemical bond*

Or

By defn: *Valency is the combining capacity of an element*

Table shows Valency of atoms

Atoms	Z	Oxidation state	Valency
Hydrogen	1	+1	1
Helium	2	0	0
Lithium	3	+1	1
Beryllium	4	+2	2
Boron	5	+3	3
Carbon	6	4	4
Nitrogen	7	-1	1
Oxygen	8	-2	2
Fluorine	9	-1	1
Neon	10	0	0
Sodium	11	+1	1
Magnesium	12	+2	2
Aluminium	13	+3	3
Silicon	14	+4	4
Phosphorus	15	-3	3
Sulphur	16	-2	2
Chlorine	17	-1	1
Argon	18	0	0
Potassium	19	+1	1
Calcium	20	+2	2

Nb:

i. Atoms with positive valency is **metals**
ii. Atoms with negative valency is **metals**
iii. Atoms with 0 valency is **noble gas**
iv. Atom with neutral valency is **metalloid**
v. Outmost shell is called valency shell
vi. Some element have more than one valency example iron have +2 and +3 valency, lead have +2 and +3 valency, copper have +1 and +2 valency etc

Oxidation state

By defn: *Oxidation state is the number of electrons a particular element has lost shared or gained on forming compound*

Rules to assign oxidation number

i. Free element has zero oxidation number. Example

Element	Symbol	Oxidation number
Nitrogen	N_2	0
Hydrogen	H_2	0
Sodium	Na	0
Oxygen	O_2	0
Potassium	K	0

ii. Oxidation number Ions consist of only one atom is equal to the charge of ions. Example

Ions	Symbol	Oxidation number
Sodium	Na^+	+1
Aluminum	Al^{3+}	+3
Iron (II)	Fe^{2+}	+2
Iron (III)	Fe^{3+}	+3
Oxide	O^{2-}	-2

iii. Hydrogen has oxidation number of +1 in most compound but in compound of most reactive metal is -1
iv. Oxidation number of oxygen is -2 in most compound except
  a. In peroxide e.g. H_2O_2, its oxidation number is -1
  b. If bonded with fluorine form F_2O, its oxidation number is +2 and fluorine is -1
v. Oxidation number should be consistent with the conservation of charge

Sum of left side charge **=** ***sum of right-side charge***

Example

Find oxidation number of chlorine in the compound $KClO_3$

Data

Oxidation number of $KClO_3$ = 0
Oxidation number of K = +1
Oxidation number of 0 = -2
Oxidation number of Cl = n

Solution

Charge of K + n + (3 x O) = Charge of KCO_3
1 + n + (3 x -2) = 0
1 + n + -6 = 0
n + 1+ -6 = 0
n - 5 = 0
n = +5

Radicals

By defn: *Radical is a group of atoms with unpaired electrons*

Or

By defn: *Radical is a group of elements which act like a single atom in forming compound*

Table shows radical and its valency

Radical	Symbol	valency	Oxidation state

Nitrate	NO_3-	1	-1
Nitrite	NO_2-	1	-1
Sulphate	SO_4^{2-}	2	-2
Hydrogen-Sulphate	HSO_4^{1-}	1	-1
Carbonate	CO_3^{2-}	2	-2
Hydrogen Carbonate	HCO_3^{-1}	1	-1
Hydroxide	OH^{1-}	1	-1
Phosphate	PO_4^{3-}	3	-3
Thiosulphate	$S_2O_3^{2-}$	2	-2
Cyanide	CN^-	1	-1
Permanganate	MnO^{4-}	4	-4
Dichromate	$Cr_2O_7^{2-}$	2	-2
Ammium	NH_4^+	1	+1

Chemical formulae

By defn: *Chemical formula is presentation of proportion of the elements present in a chemical compound by symbol*

Nb:

1. Cation should written before anions
2. Radical must be treated as a unit
3. Radical is in brackets
4. Valency 1 does not written in the formula
5. If valency are equal there no need for the exchange and therefore not written

Steps To Write Chemical Formulae

There are three main steps, includes

Step 1: Write the symbols of the elements and radicals

W X

Step 2: Write down the ions used with their valences as superscripts

W^m X^n

Step 3: Interchange the valences of W and X and write them as subscripts

$$\begin{tikzcd} W^m \arrow[dr] & X^n \arrow[dl] \\ W_n & X_m \end{tikzcd}$$

The formula is W_nX_m

Example

Give the formula of calcium chloride

Step 1: Write the symbols of the elements and radicals

Ca Cl

Step 2: Write down the ions used with their valences as superscripts

Ca^{2+} Cl^{1-}

Step 3: Interchange the valencies of W and X and write them as subscripts

$$\begin{tikzcd} Ca^{2+} \arrow[dr] & Cl^{1-} \arrow[dl] \\ Ca_1 & Cl_2 \end{tikzcd}$$

The formula of calcium chloride is $CaCl_2$

Example

Give the formula for aluminium sulphate

Step 1: Al SO_4

Step 2: Al^3 SO_4^2

Step 3:

$$\begin{tikzcd} Al^3 \arrow[dr] & SO_4^2 \arrow[dl] \\ 2 & 3 \end{tikzcd}$$

$Al_2(SO_4)_3$

The chemical formula is $Al_2(SO_4)_3$

Types of chemical formulae

There are three types includes

1. Empirical Formula
2. Molecular Formula
3. Structural Formula

Empirical Formula

By den: *Empirical Formula Is the formula which represents the simplest ratio of the atoms or ions in a compound*

Or

By den: *Empirical Formula Is the simplest formula which expresses its composition by mass*

For Example

1. CH_2 is contains two atom of hydrogen and one atom of carbon
2. H_2O is contains two atom of hydrogen and one atom of oxygen

Calculations involves Empirical Formula

From composition by mass empirical formula can be calculated as follows steps

Step 1: Write symbol of each element

Step 2: Obtain the mass/percentage

Step 3: Divide the mass/percentage by its RAM

Step 4: Divide each of the values obtained in step 3 by lowest value among them to get smallest value

Step 5: the values obtained in step 4

Nb:

1. Total Percentage composition of atoms in a molecule of the compound should be 100%

ii. Total mass composition of atoms in a molecule (relative Molecular mass (RMM)) should be equal to sum of RAM of all atoms in a molecule of the compound
iii. Hydrocarbon is the compound formed by carbons and hydrogen

Example
Hydrocarbon contains 20% by mass of hydrogen and has a molar mass of 30g. Calculate the empirical formula of the compound

Data
RAM of H = 1
RAM of C = 12
Percentage of H = 20%
Percentage of C = 100% - 20% = 80%
RMM of hydrocarbon = 30g

Solution

Steps			
1	Element	C	H
2	Percentage	20	80
3	Divide percentage by RAM	$\frac{20}{12}$ 6.7	$\frac{80}{1}$ 20
4	Divide by smallest value	$\frac{6.7}{6.7}$ 1	$\frac{20}{6.7}$ 3.125
5	Approximate to whole number	1	3

Empirical Formula Is CH_3

Example
What is the empirical formula for a compound of mass 8.1g if contains 4.9g of magnesium and 3.2g of oxygen

Data
RAM of Mg = 24
RAM of O = 16
Mass of Mg = 4.9g
Mass of O = 3.2g
Mass of compound = 8.1g

Solution

Steps			
1	Element	Mg	O
2	Percentage	4.9	3.2
3	Divide percentage by RAM	$\frac{4.9}{24}$ 0.2	$\frac{3.2}{16}$ 0.2
4	Divide by smallest value	$\frac{0.2}{0.2}$ 1	$\frac{0.2}{0.2}$ 1
5	Approximate to whole number	1	1

Empirical Formula Is MgO

Molecular Formula

By defn: *Molecular Formula Is the formula which shows actual number of each different atom in a molecule*

Or

By defn: *Molecular Formula Is the multiple of Empirical Formula*

Mathematically

Molecular formula = multiple of Empirical Formula

Molecular formula = n(Empirical Formula)

Nb:
i. n is whole number
ii. if n = 1, molecular formula is equal to empirical formula
For Example
$CH_2 = 1(CH_2)$ = empirical formula
$C_2H_4 = 2(CH_2)$ = molecular formula
$C_3H_6 = 3(CH_2)$ = molecular formula
iii. RMM = n(sum of RAM of all atoms)

Example
Hydrocarbon contains 20% by mass of hydrogen and has a molar mass of 30g. Calculate the empirical formula of the compound

Data
RAM of H = 1
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Percentage of H = 20%
Percentage of C = 100% - 20% = 80%
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Solution

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1	Element	C	H
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4	Divide by smallest value	$\frac{6.7}{6.7}$ 1	$\frac{20}{6.7}$ 3.125
5	Approximate to	1	3

	whole number		

Empirical Formula Is CH_3

From: RMM = n(sum of RAM of all atoms)
$30 = n(C + 3H)$
$30 = n(12 + 3x1)$
$30 = n(12 + 3)$
$30 = 15n$
n = 2

Then:
Molecular formula = n(Empirical Formula)
Molecular formula = $2(CH_3)$
Molecular formula = C_2H_6

Structural Formula
By defn: *Structural Formula Is the formula which show arrangement of atoms in molecule*

Nomenclature
By defn: *Nomenclature is the systematic way of assign names to item*

Binary Inorganic Compounds
By defn: *Binary Inorganic Compound is the compound formed by two ions*

Types of Binary Inorganic Compounds
There are two types include
i. Binary ionic Compounds
ii. Binary covalent Compounds

Binary ionic Compounds
By defn: *Binary* ionic Compounds *is the compound formed by metal and non-metal*

Binary Ionic Compound Nomenclature
By defn: *Binary Inorganic Compound Nomenclature is the systematic way of assign names to Binary Ionic Compound*

Steps For Naming Binary ionic Compounds
Steps used to name include
i. Name first the Cation
ii. Second Name the anion
iii. Anion should end with "**Ide**"
iv. Multivalent which form more than one valency should distinguished by starting ions in the compound

Example
What is the name of the compound with formula NaCl?

Solution
Cation is Sodium
Anion is Chlorine and become chlor-ide
Its name is **Sodium Chloride**

Example
What is the name of the compound with formula $FeCl_3$?

Solution
Cation is Iron
Anion is Chlorine and become chlor-ide
But: find oxidation state of Iron (multivalent)
$FeCl_3 = 0$
$Fe + 3 x -1 = 0$
$Fe - 3 = 0$
$Fe = +3$
Then: Iron named as Iron (III)
Its name is **Iron (Iii) Chloride**

Table shows Binary ionic Compounds

Symbol	Name
CuS	Copper (II) Sulphide
MgO	Magnesium oxide
$AlCl_3$	Aluminium Chloride
MnO_2	Manganese (IV) oxide

Binary covalent Compounds
By defn: Binary covalent Compounds *is the compound formed by two non-metal*

Steps for Naming Binary Covalent Compounds
Steps used to name include
i. Name first the element
ii. Name second element ending with "**Ide**"
iii. If more than one elements use prefixes to indicate the number of atoms of each element

Prefixes to indicate the number of atoms

Number of atom	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-
8	octa-
9	nona-
10	deca-

Example

What is the name of the compound with formula PCl_3?

Solution

First element has one Phosphorus atom
Second element has three chlorine atoms
Chlorine become chlor-ide
Its name is **Phosphororus Trichloride**

Example

What is the name of the compound with formula N_2O_4?

Solution

First element has two Nitrogen atoms
Second element has four oxygen atoms
Oxygen become ox-ide
Its name is **Dinitrogen Tetraoxide**

Some Binary Covalent Compounds

Formula	**Names**
CO_2	Carbon dioxide
SF_6	Sulphur hexafluoride
N_2O_5	Dinitrogen pentaoxide
NO	Nitrogen monoxide
CO	Carbon monoxide
HCl	Hydrogen chloride

Chemical names of common substance

Chemical names of common substance Is the name of substance we encounter daily to give accurate description of the composition of a substance. Include

Common name	**Chemical name**	**Chemical symbol**
Water	Water	H_2O
Common salt	Sodium chloride	NaCl
Sugar	Sucrose	$C_{12}H_{22}O_{11}$
Soda ash	Sodium carbonate	$NaCO_3$
Aspirin	Acetyl/salicyclic acid	$C_9H_8O_4$
Baking soda	Sodium hydrogencarbonate	$NaHCO_3$
Vitamin C	Ascorbic acid	$C_6H_8O_6$
Chalk	Calcium carbonate	$CaCO_3$
Asbestos	Magnesium silicate	$MgSiO_3$
Plaster of paris (POP)	Calcium sulphate	$CaSO_4$
Marble	Calcium carbonate	$CaCO_3$
Fluorspar (fluorite)	Calcium fluoride	CaF_2
Lime water	Calcium hydroxide	CaOH

Nb:

Common name can vary from one place to another

FORM THREE NOTES

Chemical Equations

First we study chemical equation let study chemical reaction first

Chemical reaction

By defn: *Chemical reaction is event or process in which chemical substances change into different substance*

Or

By defn: *Chemical reaction is event or process in which atoms and molecules rearrange themselves to form new compound*

Nb:

i. Chemical substance (atoms and molecules) reacting is called **reactants**
ii. New compound (substance) formed is called **products**
iii. Characteristics of Product formed are different from the original reactants

Characteristics of chemical reactions

i. One or more new chemical reactions are formed
ii. Energy is taken in or given out during reactions
iii. Reaction may be reversible or irreversible reaction

Irreversible reaction

By defn: Irreversible reaction *is the reaction proceeds only in one (forward) direction*. It goes forward direction to form product. It denoted by single allow (→)

Reversible reaction

By defn: *Reversible reaction is the reaction whereby proceed both direction forward and backward direction*. It goes either forward direction to form product then backward direction to form original reactants. It denoted by double allow (⇌)

Chemical Equation

By defn: *chemical equation is a short way of describe chemical reaction, when reactant changes to product*

$$\mathbf{A + B \rightarrow C + D}$$

Nb:

i. Reactants (A and B) are placed on the left-hand side of the equation
ii. Products (C and D) are placed on the right-hand side of the equation
iii. Reactants and Product separated by an **arrow** either single (→) or double (⇌) which means **Produce**, **Yield** and **form**
iv. Each side of chemical reaction Reactant and products separated by plus (+) sign
v. Number of reactants and products do not necessary to be the same
vi. Chemical equation written first in word equation and second in formula equation
vii. State symbol must be included in chemical equation inside parentheses () which is
    (a) Solid (s) – substance is solid state
    (b) Liquid (l) - substance is liquid state
    (c) Gas (g) - substance is gas state
    (d) Aqueous (aq) – substance dissolved in water

Types of chemical equation

There are three types of chemical equation include

i. Word equation
ii. Molecular(formula) equation
iii. Ionic equation

Writing and balancing equation

Chemical equation must written according to law of conservation of matter which state that

"***In a chemical reaction, the total mass of products equal to the total mass of the reactants***"

Steps to write simple chemical equation

The follows includes the steps used to write and balance simple chemical equation

i. Write equation in word
ii. Write equation by using symbol
iii. Balance the equation
    Make sure the total atoms of products equal to the total atoms of the reactants
iv. Include the state symbol

Example

Solid calcium burns in chlorine to form solid calcium chloride. Write an equation for the reaction

Solution

i. Write equation in word
    Calcium + chlorine →calcium chloride

ii. Write equation by using symbol
$Ca + Cl_2 \rightarrow CaCl_2$
iii. Balance the equation
$Ca + Cl_2 \rightarrow CaCl_2$ (Balanced)
iv. Include the state symbol
$Ca_{(s)} + Cl_{2(g)} \rightarrow CaCl_{2(s)}$

Example

Hydrogen chloride is formed when hydrogen burns in chlorine. Write an equation for the reactions

Solution

i. Write equation in word
Hydrogen + chlorine → hydrogen chloride
ii. Write equation by using symbol
$H_2 + Cl_2 \rightarrow HCl$
iii. Balance the equation
$H_2 + Cl_2 \rightarrow 2HCl$ (Balanced)
iv. Include the state symbol
$H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$

Example

Zinc dissolved in dilute hydrochloric acid to form zinc chloride and hydrogen gas. Write balanced chemical reaction

Solution

i. Write equation in word
Zinc n + dilute hydrochloric acid → zinc chloride + hydrogen gas
ii. Write equation by using symbol
$Zn + HCl \rightarrow ZnCl_2 + H_2$
iii. Balance the equation
$Zn + 2HCl \rightarrow ZnCl_2 + H_{2\,(g)}$ (Balanced)
iv. Include the state symbol
$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$

Example

Balance the following chemical equation and show the reactants and reactants

i. $CaCO_{3(s)} + 2HCL_{(aq)} \rightarrow CaCL_{2(s)} + H_2O_{(l)} + CO_{2(g)}$
ii. $H_2O_{(l)} + O_{2(g)} \rightarrow H_2O_2$

Types of chemical reaction

The follows are types of chemical reactions, includes

i. Combination or synthesis reaction
ii. Decomposition reaction
iii. Displacement reaction
iv. Precipitation (double displacement) reaction
v. Redox (reduction-oxidation) reaction

Combination or synthesis reaction

By defn: *Combination reaction is reaction whereby two or more substances combine to form a single more complex compound*

Example:

A + B → AB

Example

Ammonia gas may be made from nitrogen and hydrogen in an industrial process

Chemical equation

Nitrogen + hydrogen → Ammonia gas
$N_{2(g)} + H_{2(g)} \rightarrow NH_{3(g)}$

Example

If lead (IV) oxide is slight heated and then lowered into a gas jar of sulphur dioxide, the two compound combine to form one new compound Lead (II) sulphate

Chemical equation

Lead (IV) oxide + sulphur dioxide → Lead (II) sulphate
$PbO_{2\,(s)} + SO_{2\,(g)} \rightarrow PbSO_{4(s)}$

Decomposition reaction

By defn: *Decomposition reaction is reaction whereby single compound splitting to form its components parts or simpler substance often on heating*

Example:

AB → A + B

Types of decomposition reaction

There are three types include

i. Catalytic decomposition reaction
ii. Electrolytic decomposition reaction
iii. Thermal decomposition reaction

Catalytic decomposition reaction

Catalyst is introduce to alter the rate of a chemical reaction

Electrolytic decomposition reaction

Aqueous solution or molten compound exposed in electrical current to decomposition compound

Thermal decomposition reaction

Heat used to decompose compound

Example

Potassium chlorate will readily decompose when heated with manganese (IV) oxide as a catalyst to produce oxygen and potassium chloride

Chemical equation

Potassium chlorate $\xrightarrow[MnO_2]{Heat}$ oxygen + potassium chloride

$2KClO_{3\,(s)} \xrightarrow[MnO_2]{Heat} 3O_{2\,(g)} + 2KCl_{(s)}$

Example

When lead (II) nitrate crystals are heated, they decompose with a cracking sound to give off nitrogen (IV) oxide gas which is brown in colour and oxygen gas. The solid left behind is lead oxide which is yellow in colour

Chemical equation

Lead nitrate $\xrightarrow{Heat}$ lead oxide + nitrogen (IV) oxide + oxygen

$2Pb(NO_3)_{2\,(s)} \xrightarrow{Heat} 2PbO_{(s)} + 4NO_{2\,(g)} + O_{2\,(g)}$

Example

White silver chloride breaks down in the presence of light to give tiny black crystals of silver and chlorine gas

Chemical equation

Silver chloride $\xrightarrow{Light}$ silver + chlorine

$2AgCl_{(s)} \xrightarrow{Light} 2Ag_{(s)} + Cl_{2\,(g)}$

Displacement reaction

By defn: *Displacement reaction is a reaction whereby a more active substance takes place of a less active substance in a compound*

Example:

AB + C → AC + B

Example

When zinc combines with hydrochloric acid, the zinc takes place of hydrogen

Chemical equation

Zinc + hydrochloric acid → zinc chloride + hydrogen

$Zn_{(s)} + HCL_{(aq)} \rightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$

Example

When iron reacts with copper (II) sulphate, copper is replaced from the copper sulphate

Chemical equation

Iron + copper (II) sulphate → iron (II) sulphate + copper

$Fe_{(s)} + CuSO_{4\,(aq)} \rightarrow FeSO_{4\,(aq)} + Cu_{(s)}$

Precipitation (double displacement) reaction

By defn: *Precipitation reaction is the reaction whereby two soluble compound combine to give a soluble compound and precipitate (insoluble compound)*

Example:

$AB_{(aq)} + CD_{(aq)} \rightarrow AC_{(s)} + BD_{(aq)}$

Example

White aqueous silver nitrate added to aqueous solution of sodium chloride, a white precipitate of silver chloride is formed

Chemical equation

Silver nitrate + sodium chloride → silver chloride + sodium nitrate

$AgNO_{3\,(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3\,(aq)}$

Example

White aqueous solution of sodium sulphate is mixed with an aqueous solution of barium chloride; a solid barium sulphate is formed

Chemical equation

Sodium sulphate + barium chloride→ barium sulphate + sodium chloride

$Na_2SO_{4\,(aq)} + BaCl_{2\,(aq)} \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$

Redox (reduction-oxidation) reaction

By defn: *Redox reaction is a reaction where one substance oxidized and one is reduced*

Term used

i. **Reduction:** *Reduction is reaction where the **oxygen removed** from substance*
   Or
   Reduction: *Reduction is reaction where the **hydrogen added** to a substance*
   Or
   Reduction: *Reduction is reaction where **electrons gained***
   Or
   Reduction: *Reduction is reaction where oxidation number (state) **lost***

ii. **Reducing agent :** *Reducing agent is the substance which removes **of oxygen** from that substance*
   Or
   Reducing agent: *Reducing agent is the substance which **transfers of hydrogen** to another substance*

iii. **Oxidation:** *Oxidation is reaction where the **addition of oxygen** from substance*
   Or

Oxidation: *Oxidation is reaction where the* ***remove of hydrogen*** *to a substance*
Or
Oxidation: *Oxidation is reaction where* ***electrons lost***
Or
Oxidation: *Oxidation is reaction where oxidation state (number)* ***gained***

iv. **Oxidizing agent:** *Oxidizing agent is the substance which removes* ***of hydrogen*** *from that substance*
Or
Oxidizing agent: *Oxidizing agent is the substance which* ***transfers of oxygen*** *to another substance*

Example

When copper (II) oxide is heated in hydrogen it is reduced to copper metal while the hydrogen gas is oxidized to water

Chemical equation

Copper (II) oxide + hydrogen $\xrightarrow{Heat}$ copper + water

$CuO_{(s)} + H_{2\,(g)} \xrightarrow{Heat} Cu_{(s)} + H_2O_{\,(l)}$

Oxidation: copper (II) oxide loses oxygen to form copper metal
Oxidizing agent: hydrogen (takes away oxygen)
Reduction: hydrogen gains oxygen to form water
Reducing agent: copper (II) oxide loses oxygen

Example

When iron metal is heated in a stream of chlorine, it is oxidized while chlorine is reduced. The product is Iron (III) chloride

Chemical equation

Iron + chlorine $\xrightarrow{Heat}$ Iron (III) chloride

$fe_{(s)} + 3Cl_{2\,(g)} \xrightarrow{Heat} FeCL_{3(aq)}$

Since is not involve oxygen and hydrogen, let us looking electrons and charge

$fe_{(s)} + 3Cl_{2\,(g)} \xrightarrow{Heat} Fe^{3+}{}_{(aq)} + CL^{-}{}_{(aq)}$

$fe_{(s)} - 6e \rightarrow Fe^{3+}{}_{(aq)}$

$3Cl_{2\,(g)} + 6e \rightarrow CL^{-}{}_{(aq)}$

Oxidation: iron metal loses electron
Oxidizing agent: chlorine cause iron metal to loose electrons
Reduction: chlorine gain electrons
Reducing agent: iron metal cause chlorine to gain electrons

Ionic equation

By defn: *Ionic equation is the equation whereby compound in aqueous solution or ionic compound in molten state is written as dissociated ions spectator ions are removed*
Or
By defn: *Ionic equation is the equation whereby spectator ions are omitted*

Spectator Ions

By defn: *spectator ions are ions do not change their valency in the reaction*
Or
By defn: *spectator ions are ions their Valency remain unchanged in a chemical reaction*

Steps to write ionic equation

The follows includes the steps used to write ionic equation

i. Write equation in word
ii. Write equation by using symbol
iii. Balance the equation
iv. Split all soluble ions compound into individual ions
Nb: insoluble ionic compound should not be split into ions
v. insert state symbol
vi. cancel out spectator ions and write the net ionic equation

Example

Consider the reaction of silver nitrate with an aqueous solution of calcium chloride

Ionic equation

Silver nitrate + calcium chloride → silver chloride + calcium nitrate

$AgNO_{3(aq)} + CaCl_{2(aq)} \rightarrow AgCl_{(s)} + Ca(NO_3)_{2(aq)}$

$Ag^{+}{}_{(aq)} + NO_3^{-}{}_{(aq)} + Ca^{2+}{}_{(aq)} + Cl^{-}{}_{(aq)} \rightarrow AgCl_{(s)} + Ca^{2+}{}_{(aq)} + NO_3^{-}{}_{(aq)}$

$Ag^{+}{}_{(aq)} + \cancel{NO_3^{-}{}_{(aq)}} + \cancel{Ca^{2+}{}_{(aq)}} + Cl^{-}{}_{(aq)} \rightarrow AgCl_{(s)} + \cancel{Ca^{2+}{}_{(aq)}} + \cancel{NO_3^{-}{}_{(aq)}}$

$Ag^{+}{}_{(aq)} + Cl^{-}{}_{(aq)} \rightarrow AgCl_{(s)}$

Example

Write the net ionic equation for the reaction of barium chloride with sodium sulphate

Ionic equation

Barium chloride + sodium sulphate → barium sulphate + sodium chloride

$BaCl_{2\,(aq)} + Na_2SO_{4\,(aq)} \rightarrow BaSO_{4(s)} + NaCl_{(aq)}$

$Ba^{2+}_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)} + Na^+_{(aq)} + Cl^-_{(aq)}$

$Ba^{2+}_{(aq)} + \cancel{Cl^-_{(aq)}} + \cancel{Na^+_{(aq)}} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)} + \cancel{Na^+_{(aq)}} + \cancel{Cl^-_{(aq)}}$

$Ba^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow BaSO_{4(s)}$

Example

Write the net ionic equation for the reaction between dilute hydrochloric acid and aqueous sodium hydroxide

Ionic equation

Hydrochloric acid + sodium hydroxide → sodium chloride + water

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

$H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$

$H^+_{(aq)} + \cancel{Cl^-_{(aq)}} + \cancel{Na^+}_{(aq)} + OH^-_{(aq)} \rightarrow \cancel{Na^+_{(aq)}} + \cancel{Cl^-_{(aq)}} + H_2O_{(l)}$

$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$

Hardness of Water

By defn: *Hardness of water is the water contaminated with calcium and magnesium compounds*

Causes of water hardness

It caused by chemical compound includes

- i. Calcium sulphate
- ii. Calcium hydrogen carbonate
- iii. Magnesium sulphate
- iv. Magnesium hydrogen carbonate

Types of water hardness

It classified into two types include

- i. Temporary hard water
- ii. Permanent hard water

Temporary hard water

By defn: *temporary hard water is the hard water contaminated with hydrogen carbonates of calcium and magnesium*

How to soft temporary hard water

Permanent hard water soften by the follows methods, includes

- i. Boiling
- ii. Distillation
- iii. Adding sodium carbonate (washing soda)
- iv. Use of ion exchangers

Boiling

Temporary hard water softens by boiling to promote formation of carbonate from hydrogen carbonate. Precipitate (substance to be deposited in solid form from a solution) of carbonate filtered and leaves water soft

$Ca(HCO_3)_{2(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)} + CaCO_{3(s)}$

Distillation

Temporary hard water by separate water and it's contaminated by using their boiling points. It also give soft water even if is more expensive

Adding sodium carbonate

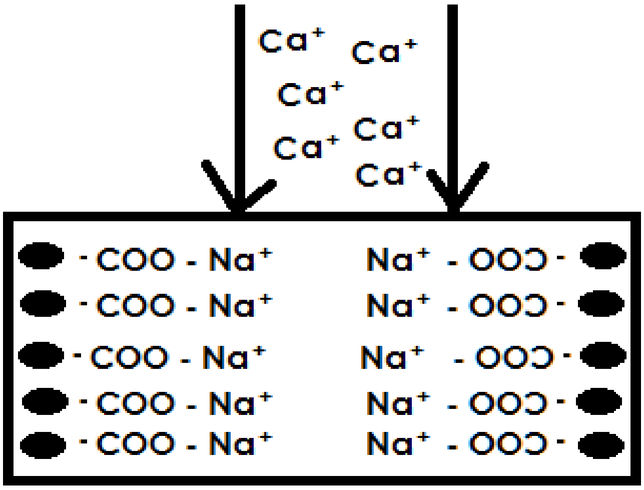
Sodium carbonate is added to precipitate calcium carbonate

$Ca(HCO_3)_{2(aq)} + Na_2CO_{3(aq)} \rightarrow CaCO_{3(s)} + NaHCO_{3(aq)}$

Use of ion exchangers

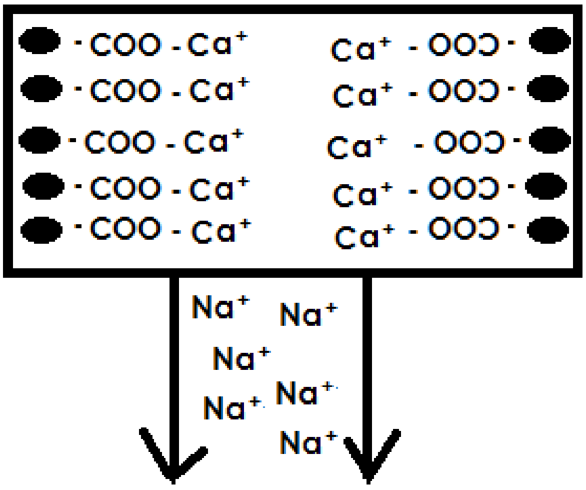
Ion exchanger is containers full of small beads which consists special plastic called **ion exchange resign**

Diagram



When tap water (temporary hard water) with calcium ions flow into ion exchanger, the calcium from temporary hard water replace sodium ions in the ion exchanger to be used in the household as soft water

Diagram



Nb:

When all sodium ions replaced, ion exchanger cannot remove hardness any more. This is resolved by regeneration of the resign by pouring a concentrated solution of sodium chloride into exchanger

Permanent hard water

By defn: *permanent hard water is the hard water contaminated with calcium and magnesium sulphate or chloride*. This mineral become more soluble as the temperature rises

How to soft permanent hard water

Permanent hard water soften by the follows methods, includes

i. Distillation
ii. Adding sodium carbonate (washing soda)
iii. Use of ion exchangers

Distillation

Permanent hard water by separate water and it's contaminated by using their boiling points. It also give soft water even if is more expensive

Adding sodium carbonate

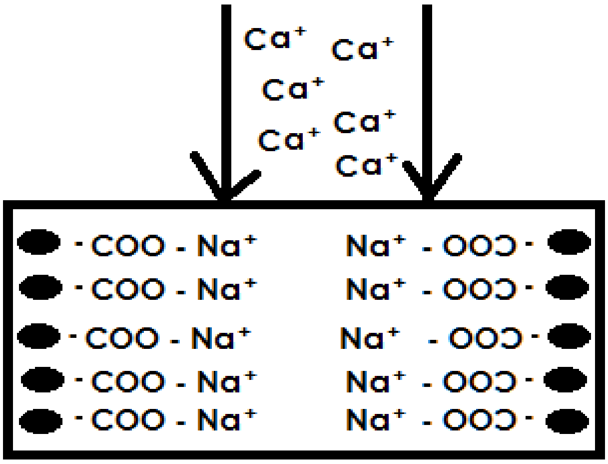
Sodium carbonate is added to precipitate calcium carbonate

$CaSO_{4(aq)} + Na_2CO_{3(aq)} \rightarrow CaCO_{3(s)} + Na_2SO_{4(aq)}$

Use of ion exchangers

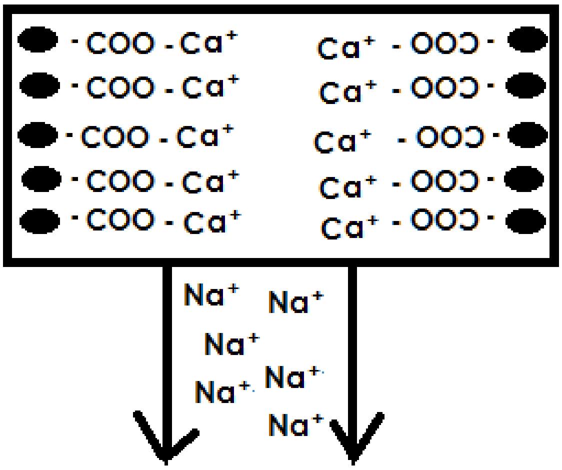
Ion exchanger is a container full of small beads which consists special plastic called **ion exchange resign**

Diagram



When tap water (permanent hard water) with calcium ions flow into ion exchanger, the calcium from permanent hard water replace sodium ions in the ion exchanger to be used in the household as soft water

Diagram



Nb:

When sodium ions replaced and ion exchanger cannot remove hardness any more. This is resolved by regeneration of the resign by pouring a concentrated solution of sodium chloride into exchanger

Advantage of hard water

i. It tastes better due to dissolved compound
ii. It provide useful calcium for growth of bones and teeth
iii. Formation of limescale (form insulator) which prevent pipe(tap) from rust
iv. Formation of limescale(form insulator) which prevent poisonous metal salt in the water from water tap
v. Help in the formation of strong shells in some aquatic animals

Disadvantage of hard water

i. Temporary hard water causes limescale in water boiler, hot water pipes, kettles and other appliances
ii. It need more soap than soft water
iii. It leaves scummy deposition on clothing and in baths
iv. Destroy the quality some special finishes on clothes

Acids, Bases and Salts

Acid

By defn: *Acid is a chemical substance (compound) when dissolved in water produce hydrogen ions [$H^+_{(aq)}$] as only positive charged ions*

$HCL_{(aq)} \longrightarrow H^+_{(aq)} + CL^-_{(aq)}$

$H_2SO_{4(aq)} \longrightarrow H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

$HNO_{3(aq)} \longrightarrow H^+_{(aq)} + NO_3^-{}_{(aq)}$

$CH_3COOH_{(aq)} \rightleftharpoons H^+_{(aq)} + CH_3COO^-{}_{(aq)}$

Nature of acid

Word acid comes from the Latin word **acidus** means **sour**

Natural sources of acids

Nature acid can be found in all substance with sharp taste due to the citric acid are acid (Citrus fruits like oranges, lemon and sour milk)

Sources of common natural acids

Acid	Source
Carbonic acid	Soft drink
Oxalic acid	Spinach
Acetic acid	Vinegar
Lactic acid	Sour milk
Citric acid	Citrus fruits

Laboratory acids

The acids found at laboratory includes

i. Hydrochloric acid (HCL)
ii. Sulphuric acid (H_2SO_4)
iii. Nitric acid (HNO_3)

Physical properties of acid

i. Acid have a sour taste
ii. Acid turn blue litmus paper red
iii. Acid is corrosive

Chemical properties of acid

i. Acid React with metal to liberate hydrogen gas

Acid + metal → metal salt + hydrogen gas

$HCL_{(aq)} + Zn_{(s)} \longrightarrow ZnCL_{2(aq)} + H_{2\,(g)}$

$H_2SO_{4(aq)} + Zn_{(s)} \longrightarrow ZnSO_{4(aq)} + H_{2\,(g)}$

$HNO_{3(aq)} + Zn_{(s)} \longrightarrow Zn(NO_3)_{2(aq)} + H_{2\,(g)}$

Nb:

Most reactive like sodium and potassium should not in such experiment, their reactions are extremely explosive

ii. Acid React with base to form salt and water

Acid + base → salt + water

$HCL_{(aq)} + NaOH_{(aq)} \longrightarrow NaCL_{(aq)} + H_2O_{\,(l)}$

$H_2SO_{4(aq)} + NaOH_{(aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{\,(l)}$

$HNO_{3(aq)} + NaOH_{(aq)} \longrightarrow NaNO_{3(aq)} + H_2O_{\,(l)}$

iii. Acid React with carbonates to form salt, carbon dioxide and water

Acid + carbonate → salt + carbon dioxide + water

$2HCL_{(aq)} + CaCO_{3(aq)} \longrightarrow CaCL_{2(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

$H_2SO_{4(aq)} + CaCO_{3(aq)} \longrightarrow CaSO_{4(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

$2HNO_{3(aq)} + CaCO_{3(aq)} \longrightarrow Ca(NO_3)_{2(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

iv. Acid React with hydrogen carbonates to form salt, carbon dioxide and water

Acid + hydrogen carbonates → salt + carbon dioxide + water

$HCL_{(aq)} + Ca(HCO_3)_{2(aq)} \longrightarrow CaCL_{2(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

$H_2SO_{4(aq)} + Ca(HCO_3)_{2(aq)} \longrightarrow CaSO_{4(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

$HNO_{3(aq)} + Ca(HCO_3)_{2(aq)} \longrightarrow Ca(NO_3)_{2(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

Nb:

Not all substance contain hydrogen are acid because other compound its hydrogen atom cannot ionize when dissolved in water. For example table sugar

Strength of acid

Due to degree of dissociation when dissolved in water, acid can be classified as

i. Strong Acid
ii. Weak Acid

Strong Acid

By defn: *Strong Acid is the acid whereby all atoms present in acid dissociate completely in water to give hydrogen ions and negative ions associated with acid*

$HCL_{(aq)} \longrightarrow H^+_{(aq)} + CL^-_{(aq)}$

$H_2SO_{4(aq)} \longrightarrow H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$

$HNO_{3(aq)} \longrightarrow H^+_{(aq)} + NO_3^-{}_{(aq)}$

Weak Acid

By defn: *Weak Acid is the acid whereby all atoms present in acid dissociate partial in* *water to give hydrogen ions and negative ions associated with acid*

$CH_3COOH_{(aq)} \rightleftharpoons H^+_{(aq)} + CH_3COO^-_{(aq)}$

Concentration of acid

Concentration of acid is the quantity of the acid (solute) in the water

Nb:

i. If acid contain very little or no water is called **concentrated acid**
ii. If acid contain more water is called **diluted acid**
iii. Weak or strong acid can be concentrated or diluted

Basicity of acid

By defn: *Basicity of acid is number of hydrogen atoms per molecules of acid that can be replaced by metal in a solution*

***Table shows* Basicity of acid**

Acid	Basicity
$HCL_{(aq)} \longrightarrow H^+_{(aq)} + CL^-_{(aq)}$	Monobasic
$HNO_{3(aq)} \longrightarrow H^+_{(aq)} + NO_3^-_{(aq)}$	Monobasic
$CH_3COOH_{(aq)} \rightleftharpoons H^+_{(aq)} + CH_3COO^-_{(aq)}$	Monobasic
$H_2SO_{4(aq)} \longrightarrow 2H^+_{(aq)} + SO_4^{2-}_{(aq)}$	Dibasic
$H_3PO_{4(aq)} \longrightarrow 3H^+_{(aq)} + PO_4^{3-}_{(aq)}$	Tribasic

Uses of acid

i. Sulphuric acid
   (a) Remove rust from metal (iron and steel)
   (b) Manufacture of synthetic textiles such as nylon
   (c) Making fertilizers
   (d) Production of sulphate
   (e) Production of hydrogen and oxygen by electrolysis
ii. Hydrochloric acid
   (a) Production of chlorides
   (b) In electroplating
   (c) Manufacture of fertilizer
   (d) Manufacture of rubber

iii. Nitric acid
   (a) Manufacture of fertilizer
   (b) Of explosives
   (c) Of nylon
   (d) Used as an oxidizing agent to clean metal

Bases

By defn: *Base is a chemical substance (compound) when dissolved in water produce hydroxyl ions [$OH^-_{(aq)}$] as only negative charged ions*

Or

By defn: *Base is a chemical substance (compound of oxide, carbonates and hydroxide) which neutralizes an acid to form salt and water*

$NaOH_{(aq)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$

$NH_4OH_{(aq)} \rightleftharpoons NH_4^+_{(aq)} + OH^-_{(aq)}$

Nb:

Soluble bases are called **Alkalis**

Natural sources of bases

i. Some bases are found in substance that we encounter in our environment like Banana peels, Baking powder, Tooth paste, Wood ash etc
ii. Also found in many bleaches, soaps and cleaning agent

Sources of common natural bases

Base	Source
Ammonia	Gills of fish
Methylamine	Decaying fish
Ethylamine	Decaying fish
Pyridine	Coal tar
Putrescine	Decaying meat
Cadaverine	Decaying flesh

Laboratory bases

The bases found at laboratory includes

i. Ammonia solution
ii. Metal oxides
iii. Metal hydroxides

Classification of bases

Base classified into two parts includes

i. Base oxides
ii. Base hydroxides

Base oxides

Base oxide is the base of oxide compound. For example Calcium oxide (CaO)

Classification of Base oxides

Classified into two part includes

i. Soluble oxides (Alkalis)
ii. Insoluble oxides (basic Oxides)

Base hydroxides

Base hydroxide is the base of hydroxide compound. For example Calcium hydroxide ($Ca(OH)_2$)

Classification of Base oxides

Classified into two part includes

i. Soluble hydroxide (Alkalis)
ii. Insoluble hydroxide (basic hydroxide)

Physical properties of base

i. Have a bitter taste
ii. Turn red litmus paper blue
iii. Have a soap or slippery feel
iv. Most insoluble in water

Chemical properties of base

i. Base react with acid to form salt and water

Acid + base → salt + water

$HCL_{(aq)} + NaOH_{(aq)} \longrightarrow NaCL_{(aq)} + H_2O_{(l)}$

$H_2SO_{4(aq)} + CaO_{(aq)} \longrightarrow CaSO_{4(aq)} + H_2O_{(l)}$

ii. Alkalis precipitate insoluble metal hydroxides from their salt solution

Alkalis + salt solution → insoluble hydroxides + salt

$3KOH_{(aq)} + FeCl_{(aq)} \rightarrow Fe(OH)_{3(s)} + 3KCl_{(aq)}$

iii. Alkalis react with ammonium salt to produce ammonia gas, water and salt

Alkalis + ammonium salt → ammonia gas + water + salt

$2NH_4Cl_{(s)} + Ca(OH)_{2(aq)} \rightarrow CaCl_{2(aq)} + 2H_2O_{(l)} + 2NH_{3(g)}$

Strength of base

Due to degree of dissociation when dissolved in water, acid can be classified as

i. Strong base
ii. Weak base

Strong base

By defn: *Strong base is the base whereby all atoms present in base dissociate completely in water to give hydroxyl ions and positive ions associated with base*

$NaOH_{(aq)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$

Weak base

By defn: *Weak base is the base whereby all atoms present in base dissociate partial in water to give hydroxyl ions and positive ions associated with base*

$NH_4OH_{(aq)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$

Concentration of base

Concentration of base is the quantity of the base (solute) in the water

Nb:

i. If base contain very little or no water is called **concentrated base**
ii. If base contain more water is called **diluted base**
iii. Weak or strong base can be concentrated or diluted

Uses of alkalis

i. In various neutralization process
ii. In the manufacture of cleaning agent
iii. In various industrial process like manufacture of paper

Indicator

By defn: *Indicator is a chemical compound that shows a definite colour change in acid or base*. It used to test whether a substance is acidic, neutral or base

Common indicator

The follows are common includes

i. Litmus paper (LT)
ii. Phenolphthalein (POP)
iii. Methyl orange (MO)
iv. Bromothymol blue (BB)

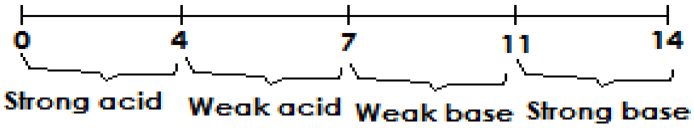
Colour change of common indicator

Indicator	**Acidic**	**basic**
LT	Red	Blue
POP	Colourless	Red
MO	Red	Yellow
BB	Yellow	blue

pH scale

By defn: *pH scale is the scale that indicates the degree of acidity and basicity of a solution*

Diagram



Relation between Ph scale and acidity

Ph scale is inversely proportion to the acid means increase in pH scale acidity decrease

Mathematically

$pH = \frac{1}{acidity}$

Relation between Ph scale and basicity

Ph scale is directly proportion to the basicity means increase in pH scale basicity increased

Mathematically

pH = basicity

Universal Indicator

Universal indicator is the mixture of indicators whereby indicate pH values more range about 3-14 value

Colour of Universal Indicator

it changes from bright pink in acid solution to purplish then to green in middy alkaline solutions and finally to yellow in very alkaline solution

Neutralization

By defn: Neutralization is the reaction between base and acid to form salt and water

Nb:

1. Volume of acid neutralize alkalis is called **Titre**
2. Method of neutralization is known as **volumetric titration** since its involved to find quantity of volume of titre

Application of neutralization

i. **Treating insect stings and bites**
   (a) Acidic liquids injected into the skin by insect stings (bees) is neutralized by rubbing with baking soda ($NaHCO_3$) in affected area
   (b) Ant bites and nettle sting contain methanoic acid which also neutralized by baking soda or other alkaline substance like cucumber, avocado etc
   (c) Wasp sting are alkaline and can be neutralized by vinegar (acetic acid)

ii. **Relieving indigestion**
   Stomach pain (indigestion) caused by presence of excess acid (HCl) in the stomach. It relieving (neutralized) by liquid/tables contain magnesium bicarbonates or sodium bicarbonates

iii. **Soil treatment**
   When soil is too acidic **lime materials** include quick lime (CaO), Slaked lime (CaOH) and Calcium carbonate ($CaCO_3$) added to neutralize soil

iv. **Treating factory wasters**
   Waste from factories often contains acid which can cause death to living organism either land or water bodies. To prevent these lime materials added to neutralize wastes from industries

v. **Manufacture of fertilizers**
   Ammonium fertilizer produced from neutralization between ammonia (NH3) with mineral acid
   $HNO_{3\,(aq)} + 2NH_{3\,(g)} \rightarrow NH_4NO_{3\,(aq)}$
   $H_2SO_{4\,(aq)} + 2NH_{3\,(g)} \rightarrow (NH_4)_2NO3_{\,(aq)}$

vi. **Neutralizing accidental spills chemicals**
   When acid accidental spill at a particular area since is corrosive is neutralized by base

vii. **Reducing acid rain occurrence**
   Acid rain (acid formed by carbon dioxide, sulphur dioxide and nitrogen dioxide) is reduced by fitted exhaust pipes and chimneys to neutralize acidic compound before reaching the atmosphere

Salts

By defn: *Salt is compound formed when hydrogen ions of an acid is replaced directly or indirectly by metal or an ammonium*

Term used

1. **Water of crystallization**: *Water of crystallization is the water bonded to compound which when removed , the compound reabsorb water again*
2. **Crystallization**: *Crystallization is the process formation of solid crystals from a homologous solution*
3. **Crystallization point:** *Crystallization point is the point where solid crystal formed when water evaporated*
4. **Solubility**: *Solubility is the number of moles of the solute required to saturate 1kg of solvent at a given temperature*. Its SI Unit is **Mol/kg**

Natural source of salt

Natural sources of salt are sea water and rocks which consists

1. Sodium chloride (common salt) - NaCl
2. Sodium sulphate – Na_2SO_4
3. Calcium sulphate - $CaSO_4$
4. Calcium carbonates – $CaCO_3$

Preparation of salts

Method used depend either salt is

1. soluble salt
2. insoluble salt

Preparation of soluble salt

They prepared by the following methods

(a) Reaction between acid and metal

Acid + metal → salts + hydrogen gas

$HCL_{(aq)} + Zn_{(s)} \longrightarrow ZnCL_{2(aq)} + H_{2\,(g)}$

$H_2SO_{4(aq)} + Zn_{(s)} \longrightarrow ZnSO_{4(aq)} + H_{2\,(g)}$

$HNO_{3(aq)} + Zn_{(s)} \longrightarrow Zn(NO_3)_{2(aq)} + H_{2\,(g)}$

Nb:

This reaction is not suitable for very reactive metals like potassium, sodium or calcium, the reaction would be too first so can cause explosion

(b) Reaction between acid and alkalis

Acid + alkalis → salt + water

$HCL_{(aq)} + NaOH_{(aq)} \longrightarrow NaCL_{(aq)} + H_2O_{\,(l)}$

$H_2SO_{4(aq)} + CaO_{(aq)} \longrightarrow CaSO_{4(aq)} + H_2O_{\,(l)}$

Nb:

Water removed by evaporation to get crystals

(c) Reaction between acid and insoluble base

Acid + insoluble base → salt + water

$2HCL_{(aq)} + CuO_{(s)} \longrightarrow CuCl_{2(aq)} + H_2O_{\,(l)}$

$H_2SO_{4(aq)} + ZnO_{(s)} \longrightarrow ZnSO_{4(aq)} + H_2O_{\,(l)}$

Nb:

Water removed by evaporation to get crystals

(d) Reaction between acids and metal carbonates

Acid + metal carbonate → salt + carbon dioxide + water

$2HCL_{(aq)} + CaCO_{3(aq)} \longrightarrow CaCL_{2(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

$H_2SO_{4(aq)} + CaCO_{3(aq)} \longrightarrow CaSO_{4(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

$2HNO_{3(aq)} + CaCO_{3(aq)} \longrightarrow Ca(NO_3)_{2(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

Nb:

Water removed by evaporation to get crystals

(e) Reaction between acids and metal hydrogen carbonates

Acid + hydrogen carbonate → salt + carbon dioxide + water

$HCL_{(aq)} + Ca(HCO_3)_{2(aq)} \longrightarrow CaCL_{2(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

$H_2SO_{4(aq)} + Ca(HCO_3)_{2(aq)} \longrightarrow CaSO_{4(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

$HNO_{3(aq)} + Ca(HCO_3)_{2(aq)} \longrightarrow Ca(NO_3)_{2(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$

Nb:

Water removed by evaporation to get crystals

(f) Direct combination

Salt (anhydrous salt) can be formed by direct combination or synthesis

$2Fe_{\,(s)} + 3Cl_{2\,(g)} \rightarrow FeCl_{3\,(s)}$

Preparation of insoluble salt

The only method used to prepare insoluble salt is double decomposition or ionic precipitation reaction, then filters, washed by distilled water and dried to get crystals

$Pb(NO_3)_{2\,(aq)} + 2KI_{\,(aq)} \rightarrow PbI_{2\,(s)} + 2KNO_{3\,(aq)}$

Other common insoluble salts which can be prepared using this method include

1. Calcium sulphate – $CaSO_4$
2. Magnesium carbonate – $MgCO_3$
3. Silver chloride - $AgCl$
4. Barium carbonate - $BaCO_3$
5. Barium sulphate - $BaSO_4$
6. Lead sulphate - $PbSO_4$

Types of salt

There are four types of salts include

1. Normal salt
2. Acidic salt
3. Basic salt
4. Double salt

Normal salt

Normal salt is the salt formed when all the replacement hydrogen ions of acid are replaced by metal. For example

Potassium carbonate – K_2CO_3
Sodium sulphate – Na_2SO_4
Ammonium sulphate – $(NH_4)_2SO_4$
Zinc chloride - $ZnCl$

Acidic salt

Acidic salt is the salt formed when only part of the replacement hydrogen ions of acid are replaced by metal. For example

First stage
$NaOH_{\,(aq)} + CO_2\,(g) \rightarrow Na_2CO_{3\,(aq)}$

Second stage
$Na_2CO_{3\,(aq)} + H_2O\,(l) + CO_{2\,(g)} \rightarrow NaHCO_{3\,(aq)}$

Other acidic salt

1. Sodium hydrogen sulphate – $NaHSO_4$
2. Potassium hydrogen carbonate - $KHCO_3$
3. Sodium hydrogen phosphate – $NaHPO_4$

Nb:

Monobasic acid cannot form acidic salts

Basic salt

Basic salt is the salt formed when amount of acid required to neutralize an alkali (base) is insufficient. For example

1. Basic zinc chloride – $[ZnCl_2 . Zn(OH)_2]$
2. Basic magnesium chloride – $[MgCl_2.Mg(OH)_2]$
3. Basic lead carbonates - $[PbCO_3.\,Pb(OH)_2]$

Double salt

Double salt is the salt formed when two solution of salt are mixed together and allowed to stand for some time, they react to form a single new salt which is different from the original salts. For example

$(NH_4)_2SO_{4(aq)} + Fe_2(SO_4)_{3(aq)} \rightarrow [FeNH_4(SO_4)_{(aq)}]$

Solubility of salt

By defn: *Solubility of salt is the amount moles of salt required to saturate 1 kg of solvent at a given temperature*

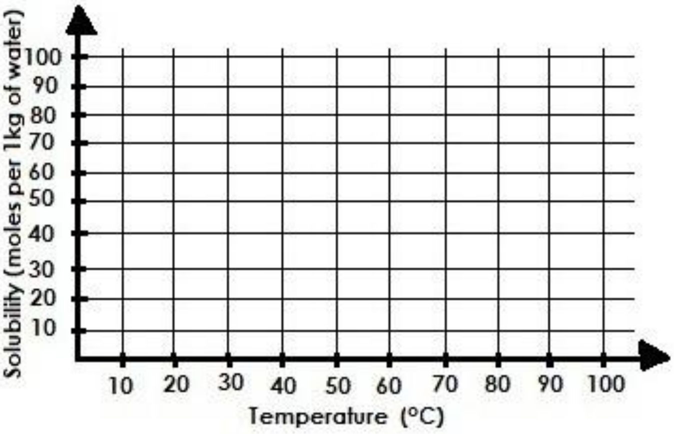
Nb:

1. Solubility varies with temperature
2. Solubility useful for predicting amount of solute can dissolved in a given mass of solvent at a particular temperature
3. All nitrates are soluble in water
4. All suphates are soluble in water, except
   - (a) Lead sulphate - $PbSO_4$
   - (b) Barium sulphate - $BaSO_4$
   - (c) Calcium sulphate - $CaSO_4$
   - (d) Mercury (II) sulphate - $HgSO_4$
5. All chlorides s are soluble in water, except
   - (a) Lead chloride - $PbCl_2$
   - (b) Silver chloride - $AgCl$
   - (c) Mercury (II) chloride – $HgCl_2$
6. All carbonates are soluble in water except
   - (a) Sodium carbonate - Na_2CO_3
   - (b) Potassium carbonate - K_2CO_3
   - (c) Ammonium carbonate – $(NH_4)_2CO_3$

Solubility curve

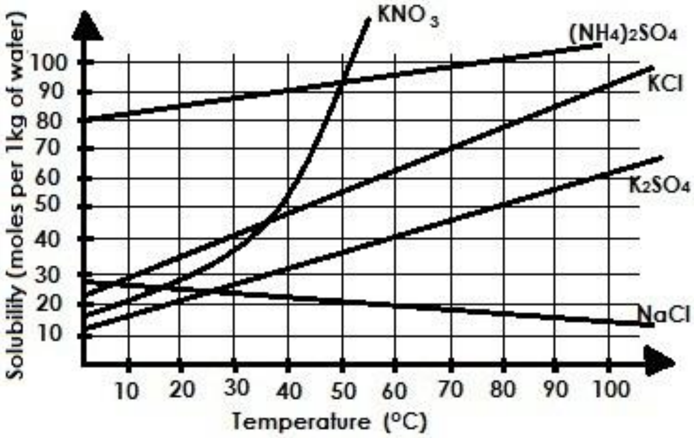
Solubility curve is the graph of solubility (y-axes) against temperature (x-axis) which used to predict how much solute (salt) will dissolved in a given mass of solvent (water) at a particular temperature

Diagram



Example

Consider the diagram below



at 50 ℃?, What solubility of

(a) KNO_3
(b) $(NH_4)_2SO_4$
(c) KCl
(d) K_2SO_4
(e) NaCl

Solution

The solubility at 50 ℃ is

(a) KNO_3 – 92 mol/kg
(b) $(NH_4)_2SO_4$ – 92 mol/kg
(c) KCl – 55 mol/kg
(d) K_2SO_4 – 35 mol/kg
(e) NaCl - 21 mol/kg

Action of heat on salts

When salt heated some salts decompose on slight heating, other salts decompose when heated strongly and other salts do not decompose on heating instead changes its state, consider the follows

i. Action of heat on carbonates
ii. Action of heat on nitrates
iii. Action of heat on sulphates

Action of heat on carbonates

Metal carbonates decompose on heating to form a metal oxide and carbon dioxide

Metal carbonates $\xrightarrow{Heat}$ *metal oxide + carbon dioxide*

Sodium and potassium carbonates does not decompose on heating because is the very reactive metal

$Na_2CO_3 \xrightarrow{Heat}$ *no reaction*

$K_2CO_3 \xrightarrow{Heat}$ *no reaction*

Magnesium and calcium carbonates decompose to gives oxide and carbon dioxide

$MgCO_{3\,(s)} \xrightarrow{Heat} MgO_{(s)} + CO_{2\,(g)}$

$CaCO_{3\,(s)} \xrightarrow{Heat} CaO_{(s)} + CO_{2\,(g)}$

Green copper (II) carbonate decompose easily to give black copper (II) oxide and carbon dioxide

$CuCO_{3\,(s)} \xrightarrow{Heat} CuO_{(s)} + CO_{2\,(g)}$

Zinc (II) carbonate decompose to form yellow zinc (II) oxide and carbon dioxide gas

$ZnCO_{3\,(s)} \xrightarrow{Heat} ZnO_{(s)} + CO_{2\,(g)}$

Nb: when yellow zinc (II) oxide cool become white

Lead (II) carbonate decompose to give reddish brown lead (II) oxide and carbon dioxide gas

$PbCO_{3\,(s)} \xrightarrow{Heat} PbO_{(s)} + CO_{2\,(g)}$

Nb: when reddish brown lead (II) oxide cool become yellow

Ammonium carbonate decompose to give ammonia gas, carbon dioxide and water

$(NH_4)_2CO_{3\,(s)} \xrightarrow{Heat} NH_{3\,(g)} + CO_{2\,(g)} + H_2O_{(g)}$

Nb: ammonia carbonate decompose slowly at room temperature to produce ammonia gas which has a **strong pungent smell**

Effect of heat on carbonates

Carbonate	Product
Potassium Sodium	Do not decompose
Calcium Magnesium Aluminium Zinc Iron Lead Copper	Metal oxide +carbon diode
Silver Mercury	Not exist
Ammonium	ammonia gas + carbon dioxide + water

Action of heat on nitrates

Nitrates are not stable so Most Metal nitrates decompose on heating to form a metal oxide, nitrogen dioxide (brown fumes) and oxygen gas

Metal nitrate $\xrightarrow{Heat}$ *metal oxide* + nitrogen dioxide + oxygen gas

Sodium and potassium nitrates melts and decompose slowly to give oxygen and metal nitrite

$2NaNO_{3\,(s)} \xrightarrow{Heat} 2NaNO_{2\,(s)} + O_{2\,(g)}$

$2KNO_{3\,(s)} \xrightarrow{Heat} 2KNO_{2\,(s)} + O_{2\,(g)}$

All remain metal nitrates decompose to give metal oxides, nitrogen dioxide and water

$CuNO_{3\,(s)} \xrightarrow{Heat} CuO_{(s)} + NO_{2\,(g)} + O_{2\,(g)}$

$CaNO_{3\,(s)} \xrightarrow{Heat} CaO_{(s)} + NO_{2\,(g)} + O_{2\,(g)}$

Silver and mercury decompose to give metal, nitrogen dioxide and oxygen gas

$2AgNO_{3\,(s)} \xrightarrow{Heat} 2Ag_{(s)} + 2NO_{2\,(g)} + O_{2\,(g)}$

$2HgNO_{3\,(s)} \xrightarrow{Heat} 2Hg_{(s)} + 2NO_{2\,(g)} + O_{2\,(g)}$

Ammonium nitrates decompose to give Dinitrogen oxide and water

$NH_4NO_{3\,(s)} \xrightarrow{Heat} N_2O_{(g)} + H_2O_{(g)}$

Effect of heat on nitrates

Nitrate	Product
Potassium Sodium	Metal nitrate + oxygen
Calcium Magnesium Aluminium Zinc Iron Lead Copper	Metal oxide + nitrogen (IV) oxide + oxygen
Silver Mercury	Metal + nitrogen (IV) oxide + oxygen
Ammonium	Dinitrogen oxide +water

Action of heat on sulphates

Sulphates are more stable than nitrate. It must heated strongly to decompose

Sulphate of alkalis and alkali earth metal do not decompose when heated

$Na_2SO_4 \xrightarrow{Heat}$ *no reaction*

$K_2SO_4 \xrightarrow{Heat}$ *no reaction*

Ammonium sulphate decompose on two stage on heating

First stage decompose to form ammonium hydrogen sulphate and ammonia gas

$(NH_4)_2SO_{4\,(s)} \xrightarrow{Heat} NH_4HSO_{4\,(l)} + NH_{3\,(g)}$

Second stage occur during ammonium hydrogen sulphate cooling to form ammonia and sulphuric acid

$NH_4HSO_{4\,(l)} \xrightarrow{Heat} H_2SO_{4\,(l)} + NH_{3\,(g)}$

Nb:

All ammonium salts decompose on heating, ammonium chloride decompose on heating to form hydrogen chloride and ammonia gas

$NH_4Cl_{(l)} \xrightarrow{Heat} HCl_{(g)} + NH_{3\,(g)}$

Uses of salts

i. **Control soil pH**
Calcium oxide added when soil is acidic and calcium sulphate (gypsum) added when soil is alkaline

ii. **Used as antacid**
Magnesium sulphate (Epsom salt) and sodium hydrogen carbonate are used to relieve heartburn and acid in the stomach

iii. **Used as inorganic fertilizer**
Inorganic fertilizers like ammonium sulphate, ammonium nitrate and calcium phosphate

iv. Sodium chloride used for seasoning and preserving food

v. Sodium carbonates used to soft hard water

vi. Ammonium chloride used as electrolyte in dry batteries

vii. Ammonium salts are used in the manufacture of plastic, synthetic fibre, dyes, explosives and pharmaceuticals

viii. Copper (II) sulphate is used as a fungicide

ix. Silver bromide is used in making photographic film

x. Calcium chloride is used as a drying agent and in freezing mixture

The Mole Concept and Related Calculations

Mole of substance

By defn: *Mole of substance is the amount of substance, equal to the quantity containing as many elementary units as there are atoms in 12 g of carbon-12*

Or

By defn: *Mole of substance is the amount of a substance which contains the Avogadro's number of particles*. SI unit of mole is **Mol** and its symbol in **n**

Nb:

Mole is the style of counting particles, same as shoes which sold in pair (items 2), exercise book sold in dozen (items 12), sconce sold in gross (items 144) etc

Avogadro's constant, L_A

The mass of 12 g of carbon-12 is 1.9927 x 10^{-23} g, what is the constant (Avogadro's constant) help to get 12g?

Mathematically:

$L_A \times 1.9927 \times 10^{-23}$ g = 12 g

$L_A = \frac{12}{1.9927 \times 10^{-23}}$

$\mathbf{L_A = 6.022 \times 10^{23}}$

Therefore: one mole of any substance contains 6.022 x 10^{23}g particulate entities (atoms, molecules or ions) like number of items two in pair and 12 in dozen

Mole Formula

From above

$L_A = \frac{\text{Number of particle entities } (N)}{\text{Amount of substance in mole (n)}}$

$N = n \times L_A$

$$n = N/L_A$$

Example

How many moles of nitrogen gas are there in 2.2 x 10^{12} molecules of the gas?

Data

$N = 2.2 \times 10^{12}$

$L_A = 6.022 \times 10^{23}$g

n = ?

Solution

n = ?

From: $n = N/L_A$

$n = N/L_A = \frac{2.2 \times 10^{12}}{6.022 \times 10^{23}} = 3.65 \times 10^{-12}$

n = 3.65 x 10^{-12} mol

Molar Mass

By Defn: *Molar mass of a substance is the mass of one mole of the substance expressed in grams per mole*. SI Unit of molar mass is **g Mol^{-1}**

Mathematically

$Mr = \frac{m}{n}$ – make n subject

Then: $n = \frac{m}{Mr}$

$$n = \frac{m}{Mr}$$

Where:

Mr = molar mass

m = mass of a substance

n = mole of a substance

But: $n = \frac{m}{Mr}$ and $n = N/L_A$

Finally: $n = \frac{m}{Mr} = N/L_A$

$$\frac{m}{Mr} = N/L_A$$

Nb:

i. Mr (have unit) = RAM (have no Unit)
ii. Mr (have unit) = RMM (have no Unit)
iii. Each molecular substance have its own molar mass
iv. Each atom have its own molar mass

Example

Determine the molar mass of

(a) Magnesium nitrate ($Mg(NO_3)_2$)

(b) Benzene (C_6H_6)

(RAM: Mg = 24, N = 14, O = 16, C = 12, H =1)

Solution

(a) Magnesium nitrate ($Mg(NO_3)_2$)

Mr = RMM = Mg+(2N + 3 x2O)

Mr = 24 +(2 x14 + 6 x 16)

Mr = 148 g mol^{-1}

(b) Benzene (C_6H_6)

Mr = RMM = 6C + 6H

Mr = 6 x 12 + 6 x 1

Mr = 78 g mol^{-1}

Example

The relative atomic mass of magnesium is 24

(a) How many moles are there in 35.8 g of magnesium?

(b) What is the mass of 3.58 moles of magnesium?

Solution

(a) Moles = ?

Mass = 35.8 g
RAM = Mr = 24
From: n = $\frac{m}{Mr}$
n = $\frac{m}{Mr} = \frac{35.8}{24}$ = 1.492
n = 1.492 moles

(b) Mass = ?
Moles = 3.58 moles
RAM = Mr = 24
From: n = $\frac{m}{Mr}$ – make m subject
m = n x Mr
m = 3.58 x 24
m = 85.92 g

Example

How many atoms are there in 8.68 g of magnesium?

Data

m = 8.68 g
Mr = 24 g mol^{-1}
L_A = 6.022 x 10^{23}g
N = ?

Solution

From: $\frac{m}{Mr} = {}^{N}/_{L_A}$ – make N subject
N = $\frac{m \times L_A}{Mr}$
N = $\frac{8.68 \times 6.022 \times 10^{23}}{24}$
N = 2.178 x 10^{23}
N = 2.178 x 10^{23} atoms

Example

How many atoms are there in 10.6 g of sodium carbonate (Na_2CO_3)?(Na = 23, C = 12, O = 16)

Data

m = 10.6 g
Mr = (23 x 2) + 12 + (16 x 3) = 106 g/mol
L_A = 6.022 x 10^{23}g
N = ?

Solution

From: $\frac{m}{Mr} = {}^{N}/_{L_A}$ – make N subject
N = $\frac{m \times L_A}{Mr}$
N = $\frac{10.6 \times 6.022 \times 10^{23}}{106}$
N = 6.022 x 10^{23}
N = 6.022 x 10^{23} atoms

Avogadro's law

States that

> "***Equal volumes of all gases, measure at same temperature and pressure contain the same number of particles***"

Molar volume of gases

By defn: Molar volume of a gas is *the volume of one mole of the gas expressed in decimetre cubic per mole at STP*. SI Unit of molar mass is **dm^3 mol^{-1}.** It also called **gram molecular volume (GMV) of a gas**

Mathematically

GMV = $\frac{v}{n}$ – make n subject
Then: n = $\frac{V}{GMV}$

$$n = \frac{V}{GMV}$$

Where:
GMV = molar volume of a gas
v = volume of a substance
n = mole of a substance

but: n = $\frac{m}{Mr}$, n = ${}^{N}/_{L_A}$ and n = $\frac{V}{GMV}$
finally: n = $\frac{m}{Mr} = {}^{N}/_{L_A} = \frac{V}{GMV}$

$$\frac{m}{Mr} = {}^{N}/_{L_A} = \frac{V}{GMV}$$

Nb:

i. STP means at standard temperature and pressure
ii. At STP a gas of 1 mole of any atom occupies 22.4 dm^3
  n = $\frac{V}{GMV}$ – make GMV subject
  GMV = $\frac{V}{n}$ (v = 22.4 dm^3 and n = 1 mole)
  GMV = $\frac{22.4}{1}$ = 22.4
  Therefore: at STP **GMV = 22.4 dm^3**
iii. **STP** defines *as an absolute pressure of 100KPa (1 bar or 1 atm) and a temperature of 273.15K or 0℃*

Example

How many moles of nitrogen gas is there in 5.2 litres at the gas at STP?

Data

V = 5.2 litres = 5.2 dm^3
GMV = 22.4 dm^3 mol^{-1}
n = ?

Solution

n = $\frac{V}{GMV}$
n = $\frac{5.2}{22.4}$
n = 0.232
n = 0.232 mol

Example

What is the volume of 8.0 moles of oxygen gas at STP?

Data

GMV = 22.4 $dm^3\ mol^{-1}$

n = 8.0 mol

V = ?

solution

$n = \frac{V}{GMV}$ - make v subject

v = n x GMV

v = 8.0 x 22.4

v = 179.2

v = 179.2 litres

Example

How many hydrogen molecules are there in

(a) 4 g of hydrogen gas?

(b) 0.1 mol of hydrogen gas at STP?

(c) 1.12 dm^3 of hydrogen gas at STP?

Solution

(a) m = 4 g

Mr = H_2 = 1 x 2 = 2 g/mol

$L_A = 6.022 \times 10^{23}$g

N = ?

Solution

From: $\frac{m}{Mr} = {N}/{L_A}$ – make N subject

$N = \frac{m \times L_A}{Mr}$

$N = \frac{4 \times 6.022 \times 10^{23}}{2}$

$N = 6.022 \times 10^{23}$

N = 1.2044 x 10^{24} molecules

(b) n = 0.1 mol

GMV = 22.4 dm^3

$L_A = 6.022 \times 10^{23}$ g

N = ?

Solution

From: $n = {N}/{L_A}$ – make N subject

$N = n \times L_A$

$N = 0.1 \times 6.022 \times 10^{23}$

$N = 6.022 \times 10^{22}$

N = 6.022 x 10^{22} molecules

(c) v = 1.12 dm^3

GMV = 22.4 dm^3

$L_A = 6.022 \times 10^{23}$ g

N = ?

Solution

From: $\frac{V}{GMV} = {N}/{L_A}$ – make N subject

$N = \frac{v \times L_A}{GMV}$

$N = \frac{1.12 \times 6.022 \times 10^{23}}{22.4}$

N = 3.011 x 10^{22} molecules

Molar solution

By defn: *Molar solution is a solution which contains 1 mole of the solute dissolved to make 1 litre of the solution*

Concentration

By defn: *Concentration is the quantity of the solute in the solution*. SI Unit of concentration is **g/dm³**

Mathematically

$$\text{Conc} = \frac{m}{v}$$

Where:

Conc = concentration

m = quantity (mass) of solute

v = volume of solvent

Molarity

By defn: *Molarity is the concentration of a solution expressed in moles per litre*. Also it called **molar solution.** SI Unit of molarity is **mol/dm³** or **M**

Mathematically

$$M = \frac{n}{v}$$

Where:

M = molarity

n = mole

v = volume of solvent

But: $n = \frac{m}{Mr}$ - - - - -1

$M = \frac{n}{v}$ - - - - - 2

Substitute eqn 1 into 2

$M = n \times \frac{1}{v}$

$M = \frac{m}{Mr} \times \frac{1}{v}$

$M = \frac{m}{Mr \times v}$

$$M = \frac{m}{Mr \times v}$$

Since: $M = \frac{m}{v} \times \frac{1}{Mr}$

But: $\text{Conc} = \frac{m}{v}$ - substitute into eqn above

$M = \frac{m}{v} \times \frac{1}{Mr}$

$M = \text{Conc} \times \frac{1}{Mr}$

$M = \frac{Conc}{Mr}$

$$M = \frac{Conc}{Mr}$$

Example

Calculate the molarity of the following solutions

(a) 4.0 g of sodium hydroxide (NaOH) in 250 cm^3 of the solution

(b) 2 moles of sodium carbonate (Na_2CO_3) into 5 litres of the solution

Solution

(a) Molarity of sodium hydroxide (NaOH)

m = 4.0 g
v = 250 cm^3 = 0.25 dm^3
Mr = NaOH = 23 + 16 +1 = 40g/ mol
M = ?

Solution

From: $M = \frac{m}{Mr \times v}$

$M = \frac{4}{40 \times 0.25}$

$M = \frac{4}{10}$

M = 0.4

M = 0.4 M

(b) Molarity of sodium carbonate

n = 2 moles
v = 5 litres = 5 dm^3
M = ?

Solution

From: $M = \frac{n}{v}$

$M = \frac{n}{v} = \frac{2}{5} = 0.4$

M = 0.4 M

Example

How many moles of potassium hydroxide are there in 0.5 dm^3 of a 0.2M potassium hydroxide solution?

Data
v = 0.5 dm^3
M = 0.2 M
n = ?

Solution

From: $M = \frac{n}{v}$ - substitute n subject

n = Mv = 0.2 x 0.5 = 0.1 moles

n = 0.1 mol

Dilution

By Defn: *Dilution is the process of lowering concentration by adding more solvent*. Concentrated solution is called **stock solution**

Dilution formula

Mole remain constant even if solution concentration lowered

Mathematically

$n_1 = n_2$

But: n = cv

Then: $n_1 = c_1v_1$ and $n2 = c_2v_2$

If: $n_1 = n_2 = c_1v_1 = c_2v_2$

Then: $c_1v_1 = c_2v_2$

$$c_1v_1 = c_2v_2$$

Where:

n_1 = mole of concentrated solution
n_2 = mole of diluted solution
c_1 = concentration of concentrated solution
v_1 = volume of concentrated solution
c_2 =concentration of diluted solution
v_2 = volume of diluted solution

Dilution Factor

By Defn: *Dilution Factor is the factor shows how times the volume of concentrated solution is diluted to obtain the diluted solution*

Mathematically

From: $c_1v_1 = c_2v_2$

Divide by v_1 and c_2 both sides

$$\frac{C_1}{C_2} = \frac{V_2}{V_1} = k$$

Where:

k = diluted factor

Example

What volume of 10 M of acetic acid is required to prepare 1.0 dm^3 of 0.50 M of acetic acid?

Data

c_1 = 10 M
c_2 =0.50 M
v_2 = 1.0 dm^3
v_1 = ?

Solution

From: $c_1v_1 = c_2v_2$ – make c_1 subject

$v_1 = \frac{C_2 \, x \, V_2}{C_1}$

$v_1 = \frac{0.5 \, x \, 1}{10}$

v_1 = 0.05

v_1 = 0.05 dm^3

Stoichiometry

By defn: Stoichiometry is the relationship between relative quantity of Reactant and products

Example of Stoichiometry

Consider the reaction below

$N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH3\ (g)$

i. **For molecule**

1 molecule of nitrogen gas requires **3** molecules of nitrogen gas to produce **2** molecules of ammonia gas

ii. **For mole**

1 mole of nitrogen gas requires **3** moles of nitrogen gas to produce **2** moles of ammonia gas

iii. **According to Avogadro's law**

1 volume of nitrogen gas requires **3** volumes of nitrogen gas to produce **2** volumes of ammonia gas

iv. **For ratio**

$N_2 : H_2 : NH_3 = 1:3:2$

Example

How many moles of nitrogen would react with excess hydrogen to produce 2.24 dm^3 of ammonia at STP?

Solution

From balanced equation

$N_{2\,(g)} + 3H_{2\,(g)} \rightarrow 2NH3\ (g)$

1 mole of $N_2 \xrightarrow{yields}$ 2 moles of NH_3

X moles of $N_2 \xrightarrow{yields}$ 2.24 dm^3 of NH_3

Nb: find mole of ammonia

$n = \frac{v}{GMV} = \frac{2.24}{22.4} = 0.1$ mol of NH_3

1 mole of $N_2 \xrightarrow{yields}$ 2 moles of NH_3

X moles of $N_2 \xrightarrow{yields}$ 0.1 mol of NH_3

Then: Cross multiplication

$X = \frac{0.1 \ x\ 1}{2} = 0.05$ mol

X = 0.05 mol

Example

Calculate the volume of carbon dioxide gas that will be produced at STP. When 10g of calcium carbonate is completely decomposed by heating as shown by the following equation

$CaCO_{3\,(s)} \xrightarrow{Heating} CaO_{\,(s)} + CO_{2\,(g)}$

Solution

From balanced equation above

1 mole of $CO_2 \xrightarrow{yields}$ 1 moles of $CaCO_3$

X volume of $CO_2 \xrightarrow{yields}$ 10 g of $CaCO_3$

Nb: find moles of $CaCO_3$

$n = \frac{m}{Mr} = \frac{10}{100} = 0.01$ mol of $CaCO_3$

1 mole of $CO_2 \xrightarrow{yields}$ 1 moles of $CaCO_3$

X volume of $CO_2 \xrightarrow{yields}$ 0.01 mol of $CaCO_3$

Then: Cross multiplication

$X = \frac{1\ x\ 0.01}{1} = 0.05$ mol

X = 0.01 mol of CO_2

Then: find volume of CO_2 at STP from calculated mol above

From: $n = \frac{v}{GMV}$ - make v subject

V = n x GMV = 0.01 x 22.4 = 2.24

V = 2.24 dm^3

Volumetric Analysis

By defn: *Volumetric analysis is a chemical procedure for determining the concentration of a solution*

Terms used

i. **standards solution**: *Standards solution is solution of known concentration*
ii. **Titration**: *Titration is a technique of adding standard solution to flask from burette*
iii. **Indicator**: Indicator is used to monitor a chemical change when the correct proportions have reacted
iv. **End point**: *End point is the point whereby the correct proportions have reacted completely*
v. **Standardization**: *standardization is a procedure used to determine the unknown concentration of solution*
vi. **Equivalent point of titration:** *Equivalent point of titration is the point whereby number of moles of base is equal to the number of moles of acid in a solution*

Standard Volumetric Apparatus

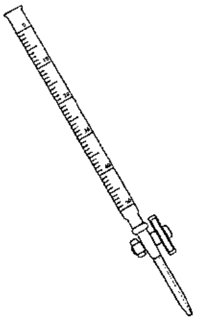
The follows apparatus used

i. Burette
ii. Pipette
iii. Volumetric flasks
iv. Conical flask
v. Filter funnel
vi. Retort stand with clamp
vii. White tile or paper
viii. Measuring cylinders
ix. Wash bottle
x. Beakers
xi. Dropper

Burette

Burette is a graduated tube with one open end and a stop tap at the other end

Diagram:



Nb:

i. Common burette has a capacity of 50 cm^3
ii. Reading of burette should be in two decimal places

How to clean burette

i. Clean by detergent and tap water. Rinse (remove soap or dirt) by using tap water until no foam
ii. Fill the burette with distilled water three times by allowing the distilled water to run through the stop tap each times
iii. Finally rinse the burette with (5 - 10)cm^3 of the reagent (titrant) to run through the stop tap each

Nb:

If there leakage in the burette, apply some petroleum jelly to the leaking part to stop the leakage

How to use burette

i. Clamp the burette in the retort stand
ii. Fill the reagent (titrant) by filter funnel up to above the zero mark
iii. Remove air bubble from the burette tip by rapid draining the titrant through the burette while gently tapping the tip
iv. Refill the burette and adjust its reading to zero and take the initial reading

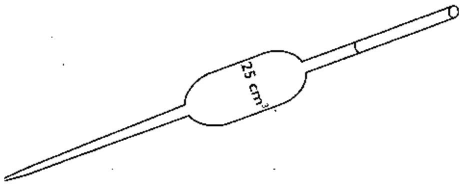
Nb:

i. Initial reading should note be zero
ii. Hold a black-stripped white card behind the meniscus when taking the reading in order to ensure the meniscus is clearly visible
iii. Solution filled in burette is called **titrant**
iv. View the meniscus horizontal to obtain correct reading which tend to avoid parallax error
v. During titration top of burette should be centre and dipped into the flask

Pipette

Pipette is a thin glass tube with a wide middle part used to measure and transfer definite volume of liquid or solution. It has a capacity of (20 or 25) cm^3

Diagram:



Nb:

- i. Graduated Mark on the upper part of the tube indicate the level to which the liquid should reach to measure the specific volume
- ii. Capacity of pipette always indicated at wide middle part of pipette
- iii. Pipette which deliver a fixed volume is called **volumetric or transfer pipette**
- iv. Pipette which deliver an any volume of liquid is called **measuring pipette**

How to clean pipette

Pipette cleaned in the same way as the burette

How to use pipette

It involves two steps include

- i. Fill the Analyte (reagent solution) by **sucking** or **pipette filter**
- ii. Pour Analyte into flask

How to fill pipette by pipette filter

- i. Press button 1 while at the same time squeezing the bulb to drive air out
- ii. Dip the tip into solution
- iii. Press button 2 to draw the solution beyond the graduated mark
- iv. Adjust solution until lowest meniscus is level with graduated mark by pressing button 3
- v. Place the pipette into a flask to put the measured solution(Analyte) by pressing button 3
- vi. Allow the last drop of the solution to drain out by placing the tip against the wall of flask

How to Fill pipette by sucking

- i. Suck the liquid from the upper end of the pipette until the solution passes the graduated mark
- ii. Quickly remove your mouth from the pipette and block the opening at the top by using your index finger
- iii. Adjust the level of the solution by slowly release the index finger to let the solution run out of the pipette until the lowest meniscus level corresponding with the graduated mark
- iv. Place the pipette into a flask to put the measured solution(Analyte)
- v. Remove the index finger from the pipette opening to release the solution from the pipette to flask

Nb:

- i. Do not suck poisonous, corrosive or toxic substances
- ii. Do not suck a liquid if you are not sure of its safety
- iii. Solution measure by pipette and poured into flask is called **Analyte**
- iv. Do not blow into the pipette to push left solution in pipette because required volume has already been released into the flask

Volumetric flasks

Volumetric flask is flask used to prepare standard solution from stock solution. It calibrated to contain specific volume of solution. It has different capacities ranging (250 – 5000) cm^3. It have graduated mark at its neck

Conical flask

Conical flask most used is 250 cm^3 which has a neck which enable easily held while swirling the contents inside

Nb: it should be rinsed with distilled water before using

Filter funnel

It used to pour a solution into the burette without spilling solution

Retort stand with clamp

It used to hold the burette in an upright position while performing volumetric analysis experiment

White tile or paper

It kept under conical flask to give a clear background for observing colour change at end point

Measuring cylinders

It used to measure reagent (titrant and Analyte) required during volumetric analysis experiment

Wash bottle

It used to hold during measurement of solid compound mass during preparation of standard solution

Beakers

It used to store reagent (titrant and Analyte) during volumetric analysis experiment

Dropper

It used to add the indicator into the solution inside conical flask

Standard Solution

By defn: *Standard Solution is a solution of known concentration*. It expressed in moles per litre (Mol/dm^3) and usually indicated by letter **M** for molarity

Types of standards solution

There are two types include

- i. Primary standards solution
- ii. Secondary standards solution

Primary standards solution

By defn: *Primary standards solution is one prepared by dissolving a known amount of primary standard in a specific volume of a known liquid*. For example

- i. Sodium carbonate (Na_2CO_3) for acid-base titration
- ii. Potassium dichromate ($K_2Cr_2O_7$) for redox titration

Characteristics of Primary standards solution

- i. High degree of purity
- ii. Should not decompose with time
- iii. Should not hygroscopic or efflorescent (no water content)
- iv. Not volatile
- v. Should be high soluble
- vi. Should have High molecular mass

Secondary standards solution

By defn: *Secondary standards solution is a one prepared by standardization using primary standards solution*. For example

- i. Most common acids like
  - (a) Hydrochloric acid (HCl)
  - (b) Dilute sulphuric acid (H_2SO_4)
- ii. Most common bases
  Sodium hydroxide (NaOH)

Nb:

Secondary standards solution also is called **standardize solution** because it obtained from standardized from primary standard solution

Preparation of standard solution

Standard solution prepared by dissolving a known amount of the primary standard in a known volume of liquid

Nb:

- i. Pure water used for aqueous solutions
- ii. Standard solution can be obtained by with another primary standard of another substance

Procedure for standard solution Preparation

- i. Calculate number of moles needed to make standard solution by consider required volume and concentration
- ii. Work out the molar mass of the substance
- iii. Using the data in steps 1 and 2, calculate the mass of the substance needed to prepare the standard solution
- iv. Carefully weigh the required mass of the substance
  - (a) Weigh empty watch glass and note reading (mw)
  - (b) Add the mass of substance to watch glass and Weigh watch glass together with mass of substance (mt)
  - (c) Subtract mass of watch glass and substance from empty watch glass to get mass of substance

    ms = mt - mw

    Where:

    ms = mass of substance

    mt = mass of substance and empty watch glass

    mw = mass of empty watch glass
- v. Transfer the primary standards into a beaker. Rinse the watch glass using distilled water from wash bottle and pour rinse water into the beaker
- vi. Stir the mixture in the beaker with glass rod until all the soluble is dissolved, then transfer the solution into a volumetric flask
- vii. Rinse the beaker and the glass rod using distilled water from a wash bottle and pour rinse water into the volumetric flask

viii. Add water to the solution to just below the graduated mark on the volumetric flask
ix. Top up the solution with water up to the graduated mark using a clean dropper
Nb: make sure the lowest part of the meniscus is exactly at the graduated mark
x. Stopper the flask and invert it several times to ensure the solution is homogenous
xi. Work out the molar concentration (Molarity) of the solution
xii. Label the solution correctly by indicating its name and concentration. For example 2M NaCl

Preparation of standard solution of common bases

Common bases are secondary standard so they prepared from standardization from primary standard (acids)

Preparation of standard solution of common mineral acids

Standard solution of mineral acids are prepared by dilution of the concentrated acids

Nb:

i. Concentrated acids are bought as **stock solution** from chemical shops
ii. **Molar concentration** does not indicated on the reagent bottles
iii. **Density** and **percentage purity** of the acids are indicated

Procedure for Preparation of standard solution of common mineral acids

i. Calculate molar concentration (Molarity) stock solution by using data indicated on reagent bottle, by the given formula

$$M = \frac{\text{density x percentage purity x 1000}}{\text{mr x 100}}$$

$$\mathbf{M} = \frac{\boldsymbol{density\ x\ percentage\ purity\ x\ 10}}{\boldsymbol{mr}}$$

ii. Find volume of concentrated by using dilution formula

$$\mathbf{C_cV_c = c_dV_d}$$

Where:

c_c = concentrated concentration
v_c = concentrated volume
c_d = diluted concentration
v_d = diluted volume

Nb:

Never add acid to water in order to avoid explosion

Example

What volume of sulphuric acid that is 98% of pure and has density of 1.84 g/cm^3 is needed to prepare 1 litre of 0.1M of sulphuric acid solution? (The molar mass of sulphuric acid is 98 g/mol)

Data

Percentage purity = 98%
Density = 1.84 g/cm^3
Mr = 98 g/mol
Cd = 0.1 M
Vd = 1litre = 1 md^3
Cc = ?
Vc = ?

Solution

First find Cc of sulphuric acids

From: Mc = $\frac{\text{density x percentage purity x 10}}{\text{mr}}$

Mc = $\frac{1.84 \text{ x } 98 \text{ x } 10}{98}$ = 18.4

Mc = 18.4 M

Then: calculate Vc

From: $C_cv_c = c_dv_d$ – make Vc subject

Vc = $\frac{C_d\ x\ V_d}{V_c} = \frac{0.1\ x\ 1}{18.4}$

Vc = 0.00543 dm^3 = 5.43 cm^3

Vc = 5.43 cm^3

Example

What volume of Nitric acid that is 68% of pure and has density of 1.42 g/cm^3 is needed to prepare 600 cm^3 of 0.4M of Nitric acid solution? (The molar mass of Nitric acid is 63 g/mol)

Data

Percentage purity = 88%
Density = 1.42 g/cm^3
Mr = 63 g/mol
Cd = 0.4 M
Vd = 600 cm^3 = 0.6 md^3
Cc = ?
Vc = ?

Solution

First find Cc of Nitric acid

From: Mc = $\frac{\text{density x percentage purity x 10}}{\text{mr}}$

Mc = $\frac{1.42 \text{ x } 68 \text{ x } 10}{63}$ = 15.3

Mc = 15.3 M

Then: calculate Vc

From: $C_cv_c = c_dv_d$ – make Vc subject

Vc = $\frac{C_d \, x \, V_d}{C_c}$ = $\frac{0.4 \, x \, 0.6}{15.3}$

Vc = 0.0157 dm^3 = 15.68 cm^3

Vc = 15.67 cm^3

Example

Halima wants to prepare a solution whose concentration is 0.4 M from 100 cm^3 of 2M hydrochloric acid. To what volume should she dilute the solution?

Data

Cd = 2 M

Vd = 100 cm^3 = 0.1 md^3

Cc = 0.4 M

Vc = ?

Solution

From: $C_cV_c = C_dV_d$ – make Vc subject

Vc = $\frac{C_d \, x \, V_d}{C_c}$ = $\frac{2 \, x \, 0.1}{0.4}$

Vc = 0.5 dm^3 = 500 cm^3

Vc = 500 cm^3

Titration

Titration involves the technique of adding standard solution (known solution) from burette to flask (unknown solution)

Nb:

i. Known solution is also called **titrant**
ii. Unknown solution is also known as **Analyte**

Condition suitable for Titration

i. Reaction must be fast
ii. Reaction must be irreversible
iii. Reaction must be represented by a single chemical equation
iv. Reaction must have definite end point

Types of titration reaction

There are three common reaction includes

i. Acid-base reaction
ii. Precipitation reaction
iii. redox reaction

Note: we will discuss only Acid-base reaction

Acid-Base titration

Acid-Base involves the technique of adding standard solution (Acid) from burette to flask (base) and vice versa until end point indicated by indicator by change in solution colour

Common acid-base indicator

Indicator which most used to change colour at end point is **Litmus paper**, **methyl orange** and **phenolphthalein**

Indicator with its colour changes in medium

Indicator	**Colour in acidic**	**Colour in basic**
Litmus	Red/pink	Blue
MO	Red/pink	Yellow/orange
POP	Colourless	Red/violet

Choice of indicator

It depends on the properties of the reactants consider the table below shows Choice to be used indicator

		ACID	
		Strong	**Weak**
BASE	**Strong**	MO, POP and Litmus	POP
	Weak	MO, Methyl red	No any

Procedure for Acid-Base Titration

The following are steps followed on performing acid-base titration

i. Clean the burette and the pipette before using them to remove impurities
ii. Use the retort stand to hold the burette upright and fill the burette with the titrant, usually an acid
iii. Read and record the initial reading of burette
iv. Pipette the Analyte usually a base(alkali) into conical flask
v. Add one/two drops of indicator to the base and note the colour of the solution
vi. Drain Titrant (acid) slowly from burette into the Analyte (alkali) , while carefully swirling/shake the content of the flask until **end point** reached, note final reading
vii. Work out the (**Mean Titre**) titrant volume used by subtract the initial reading from final reading of burette
viii. Repeat the procedure three more times to obtain consistent value which are within ± 0.2cm^3 of each other
ix. Using your results to find unknown concentration

Nb:

i. When end point is near (colour of indicator start to change) add titrant drop wise until end point reached
ii. The first titration is called pilot

iii. Pilot does not includes in calculation

Titration Formula

Since titrant (acid) and Analyte (alkali) each have its mole which is not the same

Mathematically

na = MaVa - - - - - - - -1

nb = MbVb - - - - - - - -2

Then: divive eqn1 from eqn2

$$\frac{\mathbf{MaVa}}{\mathbf{MbVb}} = \frac{\boldsymbol{na}}{\boldsymbol{nb}}$$

Where:

na = number of moles of the acid

Ma = molarity of acid

Va = volume of acid

nb = number of moles of the base

Mb = molarity of base

Vb = volume of base

Application of titration

Titration can be used to calculate/ find

i. Concentration of solution
ii. Moles of solution
iii. Relative atomic mass of element of solution
iv. Percentage purity
v. Water of crystallization

Concentration and mole of solution

Concentration (molarity) and mole of acid or base can be calculated with a standard solution

Example

25 cm^3 of the 0.098M sodium carbonate solution was titrated hydrochloric acid by using Methyl orange indicator. The following results were obtained

Volume Reading	Pilot	I	II	III
Final (Cm^3)	21.05	20.25	40.75	20.55
Initial (Cm^3)	0.00	0.00	20.25	0.00
Used (Cm^3)	21.05	20.25	20.50	20.55

Questions

(a) Methyl orange colour change from ……………. to ………………..

(b) Find mean titre of acid

(c) Write balanced equation for reaction

(d) Calculate number of moles of alkali used in the reaction

(e) Calculate number of moles of acid used in the reaction

(f) calculate concentration of the hydrochloric acid

Solution

(a) Methyl orange colour change from **yellow** to **pink**

(b) Find mean titre of acid

$Va = \frac{20.25+20.50+20.55}{3}$

Va = 20.525 = 20.53

Va = 20.53 cm^3

(c) balanced equation

$Na_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

(d) moles of alkali used in the reaction

vb = 25 cm^3 = 0.025 dm^3

Mb = 0.098

nb = ?

Solution

From: nb = vb x mb

nb = vb x mb = 0.025 x 0.098

nb = 0.00245

nb = 0.00245 mol

(e) moles of acid used in the rection

From balanced equation

2 moles of $HCl \xrightarrow{yields}$ 1 moles of Na_2CO_3

X mole $HCl \xrightarrow{yields}$ 0.00245 mol of Na_2CO_3

Then: Cross multiplication

X = na = $\frac{2 \ x \ 0.00245}{1}$ = 0.0049 mol

na = 0.0049 mol

(f) concentration of the acid

va = 20.53 cm^3 = 0.02053 dm^3

na = 0.0049 mol

Ma = ?

Solution

From: na = va x ma – make Ma subject

Ma = $\frac{na}{va} = \frac{0.0049}{0.02053}$ = 0.239

Ma = 0.239 M

Alternatively

From balanced equation

vb = 25 cm^3 = 0.025 dm^3

Mb = 0.098M

nb = 0.00245 mol

na = 0.0049 mol

va = 20.53 cm^3 = 0.02053 dm^3

Ma = ?

From: $\frac{\text{MaVa}}{\text{MbVb}} = \frac{na}{nb}$ – make Ma subject

Ma = $\frac{\text{Mb x Vb x na}}{\text{va x nb}} = \frac{0.098 \text{ x } 0.025 \text{ x } 0.0049}{0.02053 \text{ x } 0.00245}$

Ma = $\frac{0.098 \text{ x } 0.025 \text{ x } 0.0049}{0.02053 \text{ x } 0.00245}$ = 0.239

Ma = 0.239 M

Example

25 cm^3 of sodium hydroxide solution was titrated with 0.1M of hydrochloric acid. The following results were obtained

Volume Reading	**Pilot**	**I**	**II**	**III**
Final (Cm^3)	21.05	20.25	40.75	20.55
Initial (Cm^3)	0.00	0.00	20.25	0.00
Used (Cm^3)	21.05	20.25	20.50	20.55

Determine the molar concentration of the sodium hydroxide solution

Relative Atomic Mass of Element

RAM of unknown element of acid or base can be determined with a standard solution

Example

Make a solution of metal carbonate by dissolving 2.12 g in water to make 250 cm^3 solutions. 25 cm^3 of metal carbonate (X_2CO_3) solution was titrated with 0.25M hydrochloric acid by using Methyl orange indicator. The following results were obtained

Volume Reading	**Pilot**	**I**	**II**	**III**
Final (Cm^3)	17.00	16.10	32.00	46.10
Initial (Cm^3)	0.00	0.00	16.10	30.00
Used (Cm^3)	17.00	16.10	15.90	16.10

Questions

(a) Find the average volume of acid
(b) Write balanced equation for reaction
(c) Calculate number of moles of acid used in the reaction
(d) number of moles of base used in the reaction
(e) Calculate molarity of base (mol/dm^3)
(f) Calculate concentration (g/dm^3) of base
(g) Calculate relative molecular mass of the metal carbonate
(h) Calculate relative atomic mass of X
(i) Name the meta X

Solution

(a) Find mean titre of acid

Va = $\frac{16.10+15.90+16.10}{3}$ = 16.03

Va = 16.03 cm^3

(b) balanced equation

$X_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2XCl_{(aq)} + CO_{2\,(g)} + H_2O_{(l)}$

(c) moles of acid used in the reaction

va = 16.03 cm^3 = 0.01603 dm^3
Ma = 0.25 M
na = ?

Solution

From: na = va x ma
na = va x ma = 0.01603 x 0.25
na = 0.004
na = 0.004 mol

(d) moles of base used in the reaction

From balanced equation

2 mole of $HCl \xrightarrow{yields}$ 1 moles of X_2CO_3
0.004 mole of $HCl \xrightarrow{yields}$ X of X_2CO_3

Then: Cross multiplication

X = nb = $\frac{0.004\ x\ 1}{2}$ = 0.0049 mol

nb = 0.002 mol

(e) molarity of base (mol/dm^3) of the base

vb = 25 cm^3 = 0.025 dm^3
nb = 0.002 mol
Mb = ?

Solution

From: nb = vb x mb – make Mb subject

Mb = $\frac{nb}{vb} = \frac{0.002}{0.025}$ = 0.08

Mb = 0.08 M

(f) concentration (g/dm^3) of base

m = 2.12 g
v = 250 cm^3 = 0.25 dm^3
Conc = ?

Solution

From: conc = m/v
Conc = m/v = 2.12/0.25 = 8.48 g/dm^3
Conc = 8.48 g/dm^3

(g) relative atomic molecular mass of the metal carbonate

Mb = 0.08 M
Conc = 8.48 g/dm^3
Mr = ?

Solution

From: M = conc/Mr – make Mr Subject
Mr = conc/M = 8.48/0.08 = 106
Mr = 106 g/ mol

(h) Calculate relative atomic mass of X

From: Mr = sum of RAM of all atoms
106 = 2x + 12 + 16 x 3
106 = 2x + 12 + 48
106 = 2x + 60
2x =106 – 60 = 46
x = 23 g/ mol

(i) metal X is **Sodium** due to its RAM which is **23 g/mol**

Percentage purity

By defn: *Percentage purity of a substance is the percentage of pure substance in a sample*

Mathematically

Percentage purity = $\frac{\text{mass of pure}}{\text{mass of impure}}$ x 100%

Note

Percentage purity + Percentage impurity = 100%

Example

Make a solution of sodium carbonate by dissolving 6.63 g of the impure sodium carbonate in water to make 250 cm^3 solutions. 25 cm^3 of metal carbonate solution was titrate 0.5M hydrochloric acid by using Methyl orange indicator. The following results were obtained

Volume Reading	**Pilot**	**I**	**II**	**III**
Final (Cm^3)	16.00	16.20	32.45	16.00
Initial (Cm^3)	0.00	0.00	16.10	0.00
Used (Cm^3)	16.00	16.20	16.25	16.10

Questions

(a) Find the average volume of acid
(b) Write balanced equation for reaction
(c) Calculate number of moles of acid used in the reaction
(d) number of moles of base used in the reaction
(e) Calculate molarity of base (mol/dm^3)
(f) Calculate mass of base
(g) Calculate percentage purity
(h) Calculate Percentage impurity

Solution

(a) Find mean titre of acid

Va = $\frac{16.20+16.25+16.10}{3}$ = 16.18

Va = 16.18 cm^3

(b) balanced equation

$Na_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

(c) moles of acid used in the reaction

va = 16.18 cm^3 = 0.01618 dm^3
Ma = 0.5 M
na = ?

Solution

From: na = va x ma
na = va x ma = 0.01618 x 0.5
na = 0.008
na = 0.004 mol

(d) moles of base used in the reaction

From balanced equation

2 mole of $HCl \xrightarrow{yields}$ 1 moles of Na_2CO_3

0.008 mole of $HCl \xrightarrow{yields}$ X of Na_2CO_3

Then: Cross multiplication

X = nb = $\frac{0.008 \times 1}{2}$ = 0.0049 mol

nb = 0.004 mol

(e) molarity of base (mol/dm^3) of the base

vb = 25 cm^3 = 0.025 dm^3
nb = 0.004 mol
Mb = ?

Solution

From: nb = vb x mb – make Mb subject

Mb = $\frac{nb}{vb} = \frac{0.004}{0.025}$ = 0.16

Mb = 0.16 M

(f) mass of base

nb = 0.004 mol
mb = 0.16M
v = 250 cm^3 = 0.25 dm^3
Mr = 106 g/mol
m = ?

Solution

From: M = $\frac{m}{v \times \text{Mr}}$ – make m subject

m = Mr x v x M = 106 x 0.25 x 0.16 = 4.24 g

m = 4.24 g

(g) percentage purity

Mass of pure = 4.24 g
Mass of impure = 6.63 g
Percentage purity = ?

Solution

From:

Percentage purity = $\frac{\text{mass of pure}}{\text{mass of impure}}$ x 100%

Percentage purity = $\frac{4.24}{6.63}$ x 100% = 63.95%

Percentage purity = 63.95%

(h) percentage impurity

Percentage purity = 63.95%
Percentage impurity = ?

From:

Percentage purity + Percentage impurity = 100%
63.95% + Percentage impurity = 100%
Percentage impurity = 100% - 63.95%
Percentage impurity = 36.05%

Water of crystallization

By defn: *Water of crystallization is the water bound with the crystals of a substance*

Example

Make a solution of hydrated Sodium carbonate ($Na_2CO_3.XH_2O$) by dissolving 38.9 g to make one litre of solution. 25 cm^3 of hydrated Sodium carbonate solution was titrated with 0.24M hydrochloric acid by using POP indicator. The following results were obtained

Volume Reading	**Pilot**	**I**	**II**	**III**
Final (Cm^3)	28.95	28.40	28.45	38.50
Initial (Cm^3)	0.00	0.00	0.00	10.00
Used (Cm^3)	28.95	28.40	28.45	28.50

Questions

(a) Find the average volume of acid
(b) Write balanced equation for reaction
(c) Calculate number of moles of acid used in the reaction
(d) number of moles of base used in the reaction
(e) Calculate molarity of base (mol/dm^3)
(f) Calculate concentration (g/dm^3) of base
(g) Calculate relative molecular mass of the hydrated metal carbonate
(h) Calculate relative atomic mass of X

Solution

(a) Find mean titre of acid

$Va = \frac{28.40+28.45+28.50}{3} = 28.45$

Va = 28.45 cm^3

(b) balanced equation

$Na_2CO_{3(aq)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

Nb: crystallization water does not involve in reaction

(c) moles of acid used in the reaction

va = 28.45 cm^3 = 0.02845 dm^3
Ma = 0.24 M
na = ?

Solution

From: na = va x ma
na = va x ma = 0.02845 x 0.24
na = 0.0068
na = 0.004 mol

(d) moles of base used in the reaction

From balanced equation

2 moles of $HCl \xrightarrow{yields}$ 1 moles of Na_2CO_3
0.0068 mole of $HCl \xrightarrow{yields}$ X of Na_2CO_3

Then: Cross multiplication

X = nb = $\frac{0.0068 \, x \, 1}{2}$ = 0.0034 mol

nb = 0.0034 mol

(e) molarity of base (mol/dm^3) of the base

vb = 25 cm^3 = 0.025 dm^3
nb = 0.0034 mol
Mb = ?

Solution

From: nb = vb x mb – make Mb subject

$Mb = \frac{nb}{vb} = \frac{0.0034}{0.025} = 0.13656 = 0.136$

Mb = 0.137 M

(f) concentration (g/dm^3) of base

m = 38.9 g
v = 1 litre = 1dm^3
Conc = ?

Solution

From: conc = m/v
Conc = m/v = 38.9/1 = 38.9 g/dm^3
Conc = 38.9 g/dm^3

(g) relative atomic molecular mass of hydrated metal carbonate

Mb = 0.137 M
Conc = 39.9 g/dm^3
Mr = ?

Solution

From: M = conc/Mr – make Mr Subject
Mr = conc/M = 38.9/0.136 = 286
Mr = 286 g/ mol

(h) Calculate relative atomic mass of X

From: Mr = sum of RAM of all atoms

$Na_2CO_3.XH_2O$ = 2Na + C + 3O + X(2H + O)
286 = (2 * 23) + 12 + (16 * 3) + x(1*2 + 16)
286 = 46 + 12 + 48 + x18
286 = 106 + x18
18x = 286 -106 = 180
18x = 180
x = 10

Application of volumetric analysis

In different field volumetric analysis are used as follows

1. **Medicine**
   - i. Used to determine concentration of virus/bacteria in a blood sample
   - ii. Used to determine amount of acid which can be neutralized by antacid tablet
2. **Industries**
   - i. Used to determine amount of acetic acid in vinegar
   - ii. Used to analyse the acidity of fruit juices
   - iii. Used to analyse the household ammonia (used as a cleaning fluid)

3. **Analysis of water**
   Used to determine hardness of water

4. **Agriculture**
   Used to determine composition of soil substances contained, Substance include nitrogen, potassium and phosphorous

5. **Other application**
   1. Used to determine percentage of iron in iron ore
   2. Used to determine salt content in brine (water containing dissolved salt)
   3. Used to determine percentage mass of copper in a copper salt

Ionic Theory and Electrolysis

Electrolysis

By Defn: *Electrolysis is the process in which an electric current is passed through the electrolytes causing the Chemical Reaction*

Terms used

i. **Free electron or ion :** *Free electron or ion is the electron or ions which can move at any point within a compound or atom*

ii. **Conductor**: *Conductor is a substance which allows electricity to pass through*. Example , copper, iron etc
Reason: conductor has *free electron or ion*

iii. **Non-conductor (insulator)**: *Non-conductor is a substance which does not allow electricity to pass through*. Example wood
Reason: Insulator has not *free electron or ion*

iv. **Poor conductor**: *Poor conductor is a substance which allow only small amount of electricity to pass through*. Example Water, ethanol, paraffin etc
Reason: poor conductor has very few *free electron or ion*

v. **Migration**: *Migration is the movement of an ions to the electrode*

vi. **Reduction**: *Reduction is the gain of electrons to become stable*

vii. **Oxidation**: *Oxidation is the loss of electrons to become stable*

Electrolyte

By Defn: Electrolyte is the solution/molten state which its ions dissociated into free ions thus allowing Electric current to pass through it. It may be solution of Acids, Bases or Salts.

Non Electrolytes

By Defn: Non Electrolytes is the solution or molten compound which Electric current cannot pass through it

Questions

i. Explain why Molten copper are non-electrolytes but conduct electricity
ii. Explain why solution of sugar cannot conduct electricity

Electrolytic cell

Electrolytic Cell is any vessel whereby electrolysis carried out. It contain **electrolyte**, **battery** and **electrode**

Electrode

By Defn: Electrode is the component of the cell which makes contact with the electrolyte to enable electric current to enter and leave the electrolytes

Types of electrode

There are two types include
i. Cathode
ii. Anode

Cathode

By Defn: cathode is the electrode which the electron leaves the electrolyte
Or
By Defn: cathode is the electrode which is attached to the negative terminal of the battery
Or
By Defn: cathode is the electrode where Reduction takes place

Anode

By Defn: anode is the electrode which the electron enter the electrolyte
Or
By Defn: anode is the electrode which is attached to the positive terminal of the battery
Or
By Defn: anode is the electrode where Oxidation takes place

Nb:

i. Oxidation reaction takes place at the anode
ii. Reduction reaction takes place at the cathode
iii. Sometimes the anode may be oxidized and dissolve into the electrolyte
iv. Cathode Attracts Cations
v. Anode Attracts anions
vi. Cation discharged at cathode
vii. Anion discharged at anode
viii. Always Products formed at anode is a non-metal or 0_2 (g)
ix. Always Products formed at cathode is metal or H_2 (g)

Inert Electrodes

By Defn: Inert Electrode is electrode which do not undergo any changes during electrolysis. For example **platinum** and **carbon (graphite) electrode**

Ionic Theory

Ionic compound is composed with ions (Cation and anion) which carry electric current through an electrolyte

i. Cation carry electric to cathode
ii. Cation loose electron to cathode
iii. Anion gain electron to cathode

When Ionic compound is solid

Solid Ionic compound cannot conduct electric current because ions are not mobile due to strong force of attraction between Cation and anion

When Ionic compound is molten

Molten Ionic compound can conduct electric current because ions are mobile due to weaker force of attraction between Cation and anion so form free ions

When Ionic compound solution

Solution Ionic compound can conduct electric current because it dissociate into ions, which are free to move within the solution

Example

i. copper (II) sulphate solution form ions
   $CuSO_4 \rightarrow Cu^{2+} + S0_4^{2-}$
ii. silver nitrate solution form ions
   $AgNO_3 \rightarrow Ag^{+} + NO^{3-}$

Nb:

In general, all acids, bases and salts are ionized in solution but not organic compounds

Types of Electrolytes

There are two types of Electrolytes includes

i. Weak Electrolyte
ii. Strong Electrolyte

Weak electrolytes

By Defn: Weak electrolytes are the one which dissociation partial into ions when in solution then recombine to form the molecules. **Example** Ammonium chloride, Ethanoic acid, Methanoic acid etc

Strong Electrolytes

By defn: Strong Electrolytes are the one which Dissociate completely into ions when in solution/molten. **Example** Sodium Chloride, Sulphuric Acid, Hydrochloric Acid, Nitric Acid

NB:

i. The Strong electrolyte is High Electrical Conductivity
ii. Weak electrolyte is partially Electrical Conductivity
iii. Weak electrolyte is all compound undergo reversible reaction

Concentration of Electrolytes

Concentration of Electrolyte is the quantity of the solute in the electrolyte

Strength of Electrolytes

Strength of Electrolyte is phenomenon whether as electrolyte is weak or strong electrolyte

Nb:

i. Electrolyte can have the same concentration but vary in strength
ii. Electrolyte can have the similar strength but different concentration

Concentration and Strength of Electrolytes

Electrolytes	Concentration	Strength
6 M HCl 6M ethanoic acid	Same	strong weaker
6M ethanoic acid 1 M HCl	More Conc Low Conc	Weaker Strong
4 M HCl 4M H_2SO_4	Same	Both strong
2M ethanoic acid 2M aqueous ammonia	Same	Both weak

Mechanism of Electrolysis

When an electric current is passed through an electrolyte in an electrolytic cell the free ions move to the electrodes, The movement of an ions to the electrolyte is referred to as migration, Cation migrates towards the cathode while anions migrates towards anodes

Factors Affect the Discharge on Ions

At the electrodes, some of the ions gain or lose electrons; this has the effect of discharging the ions.

i. The case of discharge of ion
ii. The concentration of the ions
iii. The nature of the electrode

Ease of Discharge

It is determined by the position of the element in the Electrochemical Series

Electrochemical Series

By Defn: *Electrochemical Series is an arrangement of Elements depend on their Ease in Gaining Electrons*

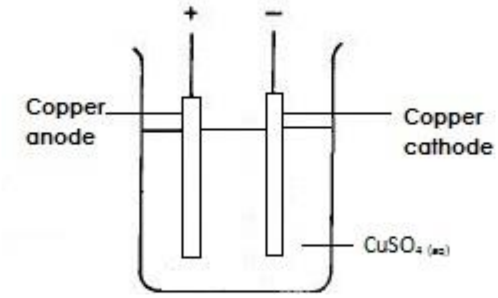
Electrochemical Series

Metal ions and hydrogen	Least readily discharge	Non-metal ions
K^+	↑ Increasing ease	NO_3^-
Ca^{2+}		SO_4^{2-}
Na^+		Cl^-
Mg^{2+}		Br^-
Al^{3+}		I^-
Zn^{2+}		OH^-
Fe^{2+}		
Pb^{2+}		
H^+		
Cu^{2+}	Most readily discharge	
Hg^{2+}		
Ag^+		

Example

Electrolysis of copper (II) sulphate solution with graphite electrodes

Diagram



Component

Copper (II) sulphate ($CuSO_4$)
Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$CuSO_{4(aq)}$	$Cu^{2+}_{(aq)}$	$SO_4^{2-}{}_{(aq)}$
$H_2O_{(l)}$	$H^+_{(aq)}$	$OH^-_{(aq)}$

Migration

cathode	Anode
$Cu^{2+}_{(aq)}$	SO_4^{2-}
H^+	$OH^-_{(aq)}$

Discharge

From Electrochemical Series copper Cation will discharge at cathode and Hydroxyl anion will discharge at anode

At cathode: $Cu^{2+}_{(aq)} + 2e \rightarrow Cu_{(s)}$

At Anode: $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e$

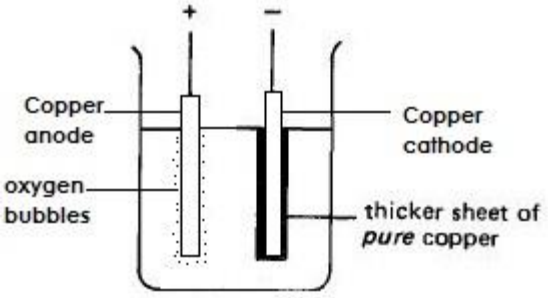
Overall equation for reaction

$2Cu^{2+}_{(aq)} + 4OH^-_{(aq)} \rightarrow 2Cu_{(s)} + 2H_2O_{(l)} + O_{2(g)}$

Product

Copper metal will deposited at cathode, oxygen gas will produced at anode and water remain in the solution

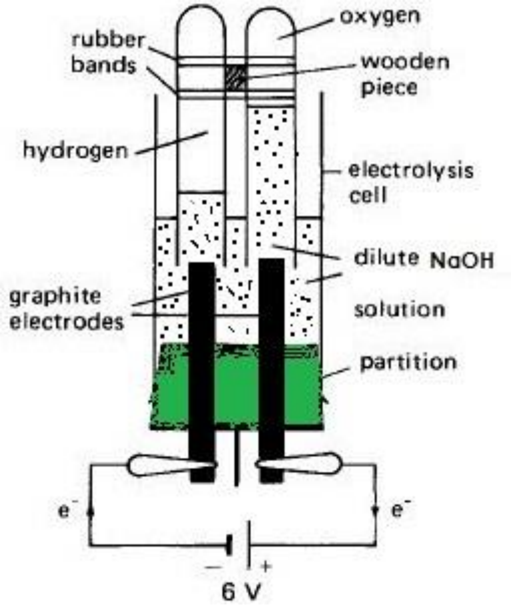
Diagram



Example

Electrolysis of sodium hydroxide solution with carbon cathode

Diagram



Component

Sodium hydroxide (NaOH)
Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$NaOH_{(aq)}$	$Na^+_{(aq)}$	$OH^-_{(aq)}$
$H_2O_{(l)}$	$H^+_{(aq)}$	$OH^-_{(aq)}$

Migration

cathode	Anode
$Na^+_{(aq)}$	$OH^-_{(aq)}$
$H^+_{(aq)}$	$OH^-_{(aq)}$

Discharge

From Electrochemical Series Hydrogen Cation will discharge at cathode and Hydroxyl anion will discharge at anode

At cathode: $2H^+_{(aq)} + 2e \rightarrow H_{2\,(g)}$

At Anode: $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e$

Overall equation for reaction

$4H^+_{(aq)} + 4OH^-_{(aq)} \rightarrow 2H_{2\,(g)} + 2H_2O_{(l)} + O_{2(g)}$

Product

Hydrogen gas will produced at cathode, oxygen gas will produced at anode and water remain in the solution

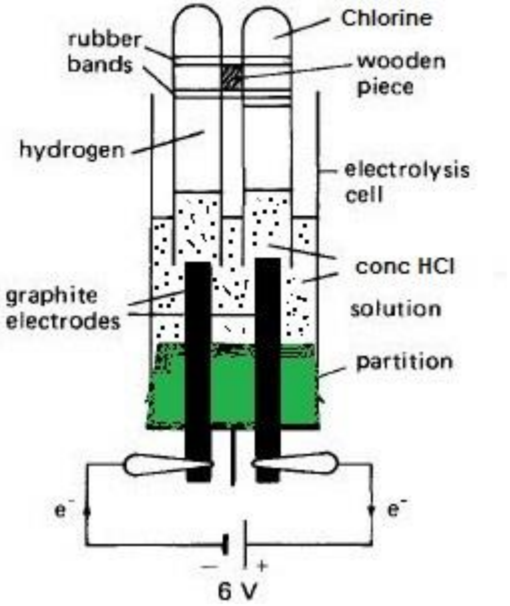
Concentration of Ions

A high concentration of ions tends to favour their discharge of the ions

Example

Electrolysis of the concentrated solution of Hydrochloric Acid with Carbon Electrode

Diagram



Component

Hydrochloric Acid (HCl)

Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$HCl_{(aq)}$	$H^+_{(aq)}$	$Cl^-_{(aq)}$
$H_2O_{(l)}$	$H^+_{(aq)}$	$OH^-_{(aq)}$

Migration

cathode	Anode
$H^+_{(aq)}$	$Cl^-_{(aq)}$
$H^+_{(aq)}$	$OH^-_{(aq)}$

Discharge

From Electrochemical Series Hydrogen Cation will discharge at cathode and according to Concentration of Ions Chlorine anion will discharge at anode instead of hydroxyl anion

At cathode: $2H^+_{(aq)} + 2e \rightarrow H_{2\,(g)}$

At Anode: $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e$

Overall equation for reaction

$2H^+_{(aq)} + 2Cl^-_{(aq)} \rightarrow H_{2\,(g)} + Cl_{2(g)}$

Product

Hydrogen gas will produced at cathode and chlorine gas will produced at anode

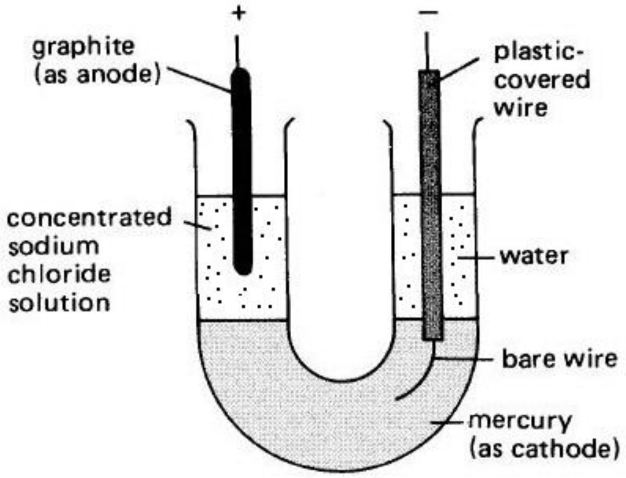
Nature of the Electrode Used

The Nature of electrode used, Especially the Cathode, also Determines which ions are discharged

Example

Electrolysis of sodium chloride solution with mercury cathode

Diagram



Component

Sodium chloride (NaCl)

Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$NaCl_{(aq)}$	$Na^+_{(aq)}$	$Cl^-_{(aq)}$

$H_2O_{(l)}$	$H^+_{(aq)}$	$OH^-_{(aq)}$

Migration

cathode	Anode
$Na^+_{(aq)}$	$Cl^-_{(aq)}$
$H^+_{(aq)}$	$OH^-_{(aq)}$

Discharge

From Nature of the Electrode Used Sodium Cation will discharge at cathode and according to Electrochemical Series Hydroxyl anion will discharge at anode

At cathode: $Na^+_{(aq)} + e \rightarrow Na_{(s)}$

At Anode: $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e$

Overall equation for reaction

$4Na^+_{(aq)} + 4OH^-_{(aq)} \rightarrow 4Na_{(s)} + 2H_2O_{(l)} + 2O_{2(g)}$

Product

Sodium metal will deposited at cathode which dissolve in mercury to form **Sodium Amalgam** and chlorine gas will produced at anode

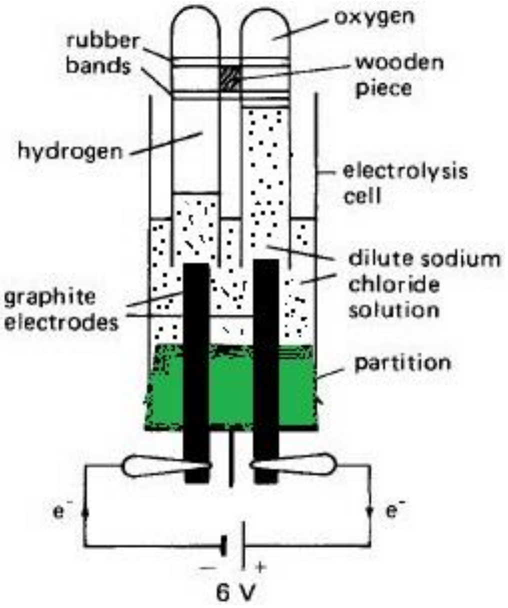
Electrolysis of selected electrolytes

The following is the selected electrolytes we are going to study

i. Electrolysis of dilute sodium chloride solution with carbon electrode
ii. Electrolysis of sodium hydroxide solution with carbon electrode
iii. Electrolysis of copper (II) sulphate solution with carbon electrode
iv. Electrolysis of copper (II) sulphate solution with copper electrode
v. Electrolysis of dilute sulphuric acid with carbon electrode
vi. Electrolysis of molten potassium iodide with carbon electrode

Electrolysis of dilute sodium chloride solution with carbon electrode

Diagram



Component

Sodium chloride (NaCl)

Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$NaCl_{(aq)}$	$Na^+_{(aq)}$	$Cl^-_{(aq)}$
$H_2O_{(l)}$	$H^+_{(aq)}$	$OH^-_{(aq)}$

Migration

cathode	Anode
$Na^+_{(aq)}$	$Cl^-_{(aq)}$
$H^+_{(aq)}$	$OH^-_{(aq)}$

Discharge

From Electrochemical Series Hydrogen Cation will discharge at cathode and Hydroxyl anion will discharge at anode

At cathode: $2H^+_{(aq)} + 2e \rightarrow H_{2\,(g)}$

At Anode: $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e$

Overall equation for reaction

$4H^+_{(aq)} + 4OH^-_{(aq)} \rightarrow 2H_{2\,(g)} + 2H_2O_{(l)} + O_{2(g)}$

Product

Hydrogen gas will produced at cathode and oxygen gas will produced at anode

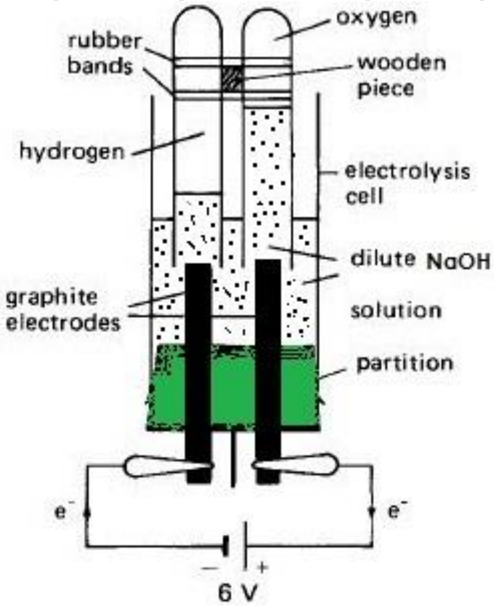
Nb:

As process continue element of water will decrease and finally NaCl become concentrated and results discharge chloride anion to produce chlorine gas

At Anode: $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e$

Electrolysis of sodium hydroxide solution with carbon electrode

Diagram



Component

Sodium hydroxide (NaOH)
Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$NaOH_{(aq)}$	$Na^+_{(aq)}$	$OH^-_{(aq)}$
$H_2O_{(l)}$	$H^+_{(aq)}$	$OH^-_{(aq)}$

Migration

cathode	Anode
$Na^+_{(aq)}$	$OH^-_{(aq)}$
$H^+_{(aq)}$	$OH^-_{(aq)}$

Discharge

From Electrochemical Series Hydrogen Cation will discharge at cathode and Hydroxyl anion will discharge at anode

At cathode: $2H^+_{(aq)} + 2e \rightarrow H_{2\,(g)}$

At Anode: $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e$

Overall equation for reaction

$4H^+_{(aq)} + 4OH^-_{(aq)} \rightarrow 2H_{2\,(g)} + 2H_2O_{(l)} + O_{2(g)}$

Product

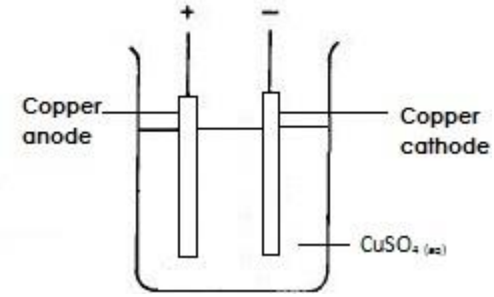
Hydrogen gas will produced at cathode, oxygen gas will produced at anode and water remain in the solution

Observation

Bubbles at electrode due to the formation of gases

Electrolysis of copper (II) sulphate solution with carbon (graphite) electrode

Diagram



Component

Copper (II) sulphate ($CuSO_4$)
Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$CuSO_{4\,(aq)}$	$Cu^{2+}_{(aq)}$	$SO_4^{2-}{}_{(aq)}$
$H_2O_{(l)}$	$H^+_{(aq)}$	$OH^-_{(aq)}$

Migration

cathode	Anode
$Cu^{2+}_{(aq)}$	SO_4^{2-}
H^+	$OH^-_{(aq)}$

Discharge

From Electrochemical Series copper Cation will discharge at cathode and Hydroxyl anion will discharge at anode

At cathode: $Cu^{2+}_{(aq)} + 2e \rightarrow Cu_{(s)}$

At Anode: $4OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e$

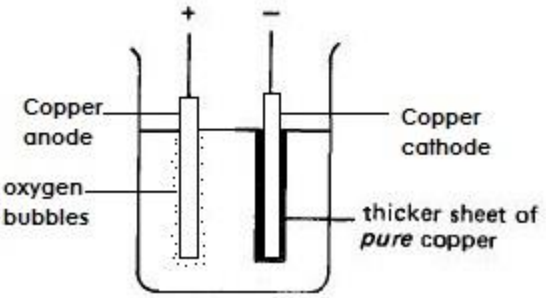
Overall equation for reaction

$2Cu^{2+}_{(aq)} + 4OH^-_{(aq)} \rightarrow 2Cu_{(s)} + 2H_2O_{(l)} + O_{2(g)}$

Product

Copper metal will deposited at cathode, oxygen gas will produced at anode and water remain in the solution

Diagram

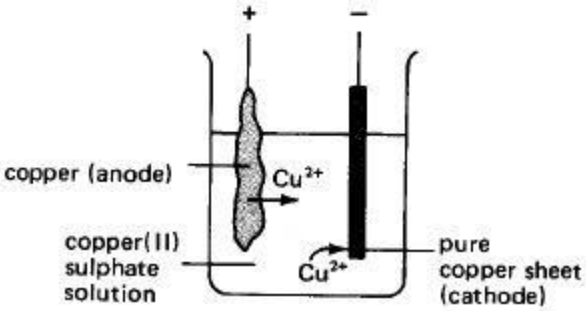


Observation

i. Solution turn blue colour due to the colour of hydrated copper (II) sulphate
ii. Mass of cathode increased due to deposition of copper metal
iii. Mass of anode remains constant
iv. Bubbles at anode due to the formation of oxygen gas

Electrolysis of copper (II) sulphate solution with copper electrode

Diagram



Component

Copper (II) sulphate ($CuSO_4$)

Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$CuSO_{4\,(aq)}$	$Cu^{2+}{}_{(aq)}$	$SO_4^{2-}{}_{(aq)}$
$H_2O_{\,(l)}$	$H^+{}_{(aq)}$	$OH^-{}_{(aq)}$

Migration

cathode	Anode
$Cu^{2+}{}_{(aq)}$	SO_4^{2-}
H^+	$OH^-{}_{(aq)}$

Discharge

From Electrochemical Series copper Cation will discharge at cathode and according to nature of anode used, copper anode will dissolved to form copper (II) ions into solution

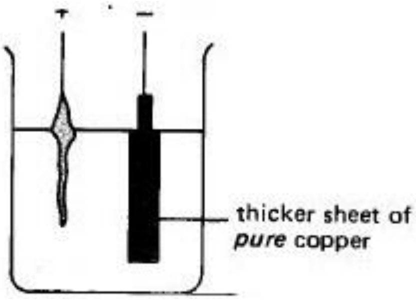
At cathode: $Cu^{2+}{}_{(aq)} + 2e \rightarrow Cu_{\,(s)}$

At Anode: $Cu_{\,(s)} \rightarrow Cu^{2+}{}_{(aq)} + 2e$

Product

Copper metal will deposited at copper cathode

Diagram



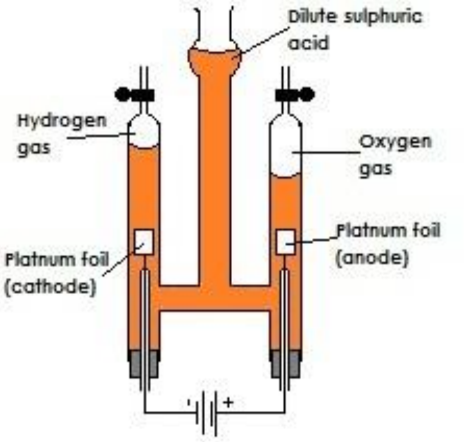
Observation

i. Solution turn blue colour due to the colour of hydrated copper (II) sulphate
ii. Mass of cathode increased due to deposition of copper metal
iii. Mass of decrease because copper anode dissolved in solution
iv. Intensity of the blue colour of the solution remain the same
v. Concentration of copper (II) ions remains constant in the solution

Electrolysis of dilute sulphuric acid with carbon electrode

It conducted in electrolytic cell known as Hoffman's voltammeter

Diagram:



Component

Sulphuric Acid (H_2SO_4)

Water (H_2O)

Dissociation (Ions presents)

compound	Cation	Anion
$H_2SO_{4\,(aq)}$	$H^+{}_{(aq)}$	$SO_4{}^{2-}{}_{(aq)}$
$H_2O_{\,(l)}$	$H^+{}_{(aq)}$	$OH^-{}_{(aq)}$

Migration

cathode	Anode
$H^+{}_{(aq)}$	$SO_4{}^{2-}{}_{(aq)}$
$H^+{}_{(aq)}$	$OH^-{}_{(aq)}$

Discharge

From Electrochemical Series Hydrogen Cation will discharge at cathode and Hydroxyl anion will discharge at anode

At cathode: $2H^+{}_{(aq)} + 2e \rightarrow H_{2\,(g)}$

At Anode: $4OH^-{}_{(aq)} \rightarrow 2H_2O_{(l)} + O_{2(g)} + 4e$

Overall equation for reaction

$4H^+{}_{(aq)} + 4OH^-{}_{(aq)} \rightarrow 2H_{2\,(g)} + 2H_2O_{(l)} + O_{2(g)}$

Product

Hydrogen gas will produced at cathode, oxygen gas will produced at anode and water remain in the solution

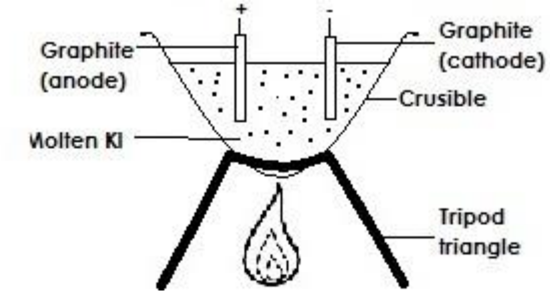
Observation

i. Volume of hydrogen collected is approximately twice that of oxygen because oxygen is more soluble in water

ii. Since involves element of water is called **electrolysis of water**
iii. As process continue element of water will decrease and finally sulphuric acid become concentrated

Electrolysis of molten potassium iodide with carbon electrode

Diagram



Component: potassium iodide (KI)

Dissociation (Ions presents)

compound	Cation	Anion
$KI_{(l)}$	$K^{+}{}_{(l)}$	$I^{-}{}_{(l)}$

Migration

cathode	Anode
$K^{+}{}_{(l)}$	$I^{-}{}_{(l)}$

Discharge

Because only potassium Cation presents it will discharge at cathode and Iodide anion will discharge at anode

At cathode: $K^{+}{}_{(l)} + e \rightarrow K_{(s)}$

At Anode: $2I^{-}{}_{(l)} \rightarrow I_{2(g)} + 2e$

Overall equation for reaction

$2K^{+}{}_{(l)} + 2I^{-}{}_{(l)} \rightarrow I_{2(g)} + I_{2(g)}$

Product

Potassium metal will deposited at cathode, Iodine gas will produced at anode

Faraday Laws of Electrolysis

The quantity (number of moles) of a substance produced at an electrode is depends on three factors include

i. Quantity of electricity passing through the electrolyte per unit time
ii. Amount of time taken by the electric current to pass through the electrolyte
iii. The charge on an ion

Term used

i. **Coulomb**: *One Coulomb is the quantity of electric charge passes through at a given point in a circuit when a current of 1 ampere flows for 1 second*
ii. **Faraday (F)**: *one Faraday is the quantity of electric charge carried by one mole of electrons*
iii. **Faraday constant:** *Faraday constant is the amount of electric charge carried by one mole of electron*
iv. **Electrochemical Equivalent (Z)**: *Electrochemical Equivalent is the mass of the substance discharged/dissolved when 1couloumb of electricity is passed through an electrolyte*. Its SI Unit is **g/c**
v. **Chemical Equivalent:** *Chemical Equivalent is the weight in grams of a substance that combines with (displaces) one gram of hydrogen*. It usually found by dividing the formula weight by its Valence
vi. **Electroplating:** *electroplating Is the electrical deposition of one metal on another*

Category of Faraday Laws of Electrolysis

There are two includes

i. Faraday's first law
ii. Faraday's Second law

First Faraday Law

The law state that

"***The mass liberated during electrolysis is directly proportional to the Quantity of Electricity transferred at that Electrode***"

Mathematically

$M \propto Q$ – remove proportionality constant

$M = ZQ$

But: $Q = It$

Now: $M = ZIt$

But: $Z = \frac{Mr}{VF}$

Then: $M = \frac{Mr}{VF} \times It = \frac{I \times t \times Mr}{VF}$

$$\mathbf{M} = \frac{I \times t \times Mr}{VF}$$

From: $M = ZQ$ – make Z subject

$Z = \frac{M}{Q}$ = **g/c**

SI Unit of Z is **g/c**

Where:

M = the mass liberated during electrolysis
Q= the Charge (Quantity of Electricity)
Z = Electrochemical Equivalent
t = time taken for current to pass through
I = Current Electricity
Mr = Relative Atomic Mass
V = Valence (number of charge)

Electrochemical Equivalent of substances

substance	Z (g/c)
Hydrogen	1.045×10^{-5}
Silver	1.008×10^{-3}
Oxygen	8.290×10^{-5}
Copper	3.290×10^{-4}
Gold	6.810×10^{-4}
chromium	1.800×10^{-4}

Example

How long should a 5A be passed through a solution of silver chloride in order to deposit 3.24 Kg of silver at the cathode ($Z = 1.118 \times 10^{-3}$ g/c)

Data

M = 3.24 kg = 0.00324 g
Z = 0.001118×10^{-3} g/c
1F = 96500 C
I = 5A
t = ?

Solution

From: M=ZIt – make t subject

$t = \frac{M}{I\ x\ Z} = \frac{0.00324}{5\ x\ 0.001118} = 0.58$ s

t = 0.58 s

Faraday's Constant

By Defn: Faraday's Constant is the amount of electric Charge carried by one mole (n) of electrons

Since:

1 mole of electron, N = 1.602×10^{-19} C
1 mole of electron (L_A) = 6.022×10^{23} electrons

From: N = nL_A – make n subject
n =N/L
n = $1.022 \times 10^{-19} / 6.022 \times 10^{23}$
n = $9.647 \times 10^{4} \approx 96500$C

From: definition of faraday constant
1n = 1F

1n =1F = 1e = 96500C

Example

A current of 3.2A is passed through a solution of copper (II) sulphate for 30 minutes. What is the mass of copper deposited at the cathode (Cu = 63.5, S = 32, O = 16)

Data

I = 3.2 A
t = 30 min = 1800 sec
Mr = 63.5 g/mol
v = 2
F = 96500 C
m = ?

Solution

From: $M = \frac{I\ x\ t\ x\ Mr}{\text{VF}}$

$M = \frac{I\ x\ t\ x\ Mr}{\text{VF}} = \frac{3.2\ x\ 1800\ x\ 63.5}{2\ \text{x}\ 96500}$

M = 1.895 = 1.90

M = 1.90 g

Example

Calculate the mass of magnesium metal that will be produced during the electrolysis during the electrolysis of molten magnesium chloride if a current of 1.93 A is passed through for 16 minutes and 40 seconds (Mg = 24, Cl = 35.5)

Data

I = 1.93 A
t = 16 min + 40 sec = 1000 sec
Mr = 24 g/mol
v = 2
F = 96500 C
m = ?

Solution

From: $M = \frac{I\ x\ t\ x\ Mr}{\text{VF}}$

$M = \frac{I\ x\ t\ x\ Mr}{\text{VF}} = \frac{1.93\ x\ 1000\ x\ 24}{2\ \text{x}\ 96500}$

M = 0.24

M = 0.24 g

Example

A steady current of 2 A is passed through a solution containing ions of a metal M^{2+} for nine minutes. The mass of metal M is that liberated is 0.3555 g. calculate the relative atomic mass of metal M and name metal M

Data

I = 2 A
t = 9 min = 540 sec
v = 2
F = 96500 C
m = 0.3555 g
Mr = ?

Solution

From: $M = \frac{I\ x\ t\ x\ Mr}{\text{VF}}$ – make Mr subject

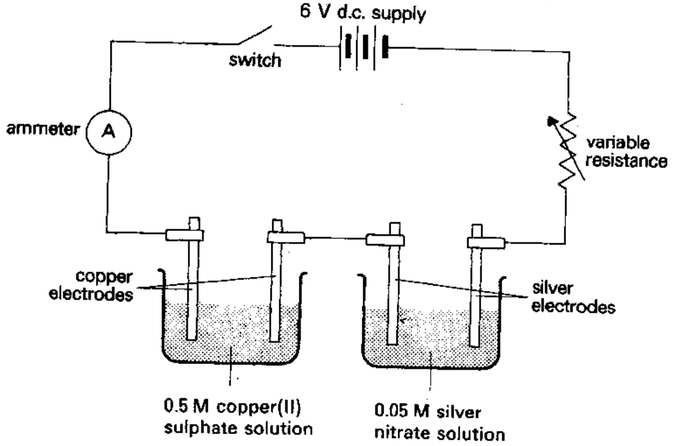
$Mr = \frac{M\ x\ V\ x\ F}{I\ x\ t} = \frac{0.3555\ \ x\ 2\ x\ 96500}{2\ \text{x}\ 540}$

Mr = 63.529 = 63.5

Mr = 63.5 g/mol and metal M is copper

Second Faraday Law

Consider the diagram below



The law state that

"***When the same Charge (Quantity of Electric Current) Passes through Different Electrolyte during electrolysis, the mass liberated is directly proportional to the Chemical Equivalent***"

Mathematically: $M = KE$

But: K = 1

Then: M = E

But: E = Mr/V

Where:

M = the mass liberated during electrolysis

K = the Constant

E = the Chemical Equivalent

Mr = Relative Atomic Mass

V = Valence (number of charge)

For First Electrolyte

M1 = E1 …………… (1)

For Second Electrolyte

M2 = E2 …………… (2)

Then: Divide Equation (1) to Equation (2)

$$\boldsymbol{\frac{M1}{M2} = \frac{E1}{E2}}$$

Then: Substitute eqn E = Mr/V into eqn M = E

$M = E = \frac{Mr}{V}$

$M = \frac{Mr}{V}$ – divide both sides with Mr

$\frac{M}{Mr} = \frac{1}{V}$

But: $\frac{M}{Mr} = n$

$\mathbf{n = \frac{1}{V}}$

Form above relation second faraday law can also be states as

The law state that

"***When the same Quantity of Electric Current Passes through Different Electrolyte during electrolysis, the relative number of moles of elements deposited are inversely proportional to the number of charges on the ions***"

For First Electrolyte

$n1 = \frac{1}{v1}$…………… (1)

For Second Electrolyte

$n2 = = \frac{1}{v2}$ …………… (2)

Then: Divide Equation (1) to Equation (2)

$$\boldsymbol{\frac{n1}{n2} = \frac{V2}{v1}}$$

Example

A current of 10 000A is passed through an electrolytic cell for purifying copper for 12hrs

(a) What mass of pure copper is deposited at the cathode?

(b) What mass of aluminium would be deposited if the cell was changed to refine aluminium?

(Cu=63.5, Al=27 and $Z_{Cu}=3.29 \times 10^{-4}$)

Solution:

(a) Data

I = 10 000 A

t = 12 hrs = 720 min = 43 200 sec

Mr = 63.5 g/mol

v = 2

F = 96500 C

M1 = ?

Solution

From: $M1 = \frac{I\ x\ t\ x\ Mr}{\mathrm{VF}}$

$M1 = \frac{I\ x\ t\ x\ Mr}{\mathrm{VF}} = \frac{10000\ x\ 43200\ x\ 63.5}{2\ x\ 96500}$

M1 = 142 134.715 g = 142.1 kg

M1 = 142.1 Kg

(b) Data

Copper

M1 = 142.1 Kg

$E1 = \frac{Mr}{V} = \frac{63.5}{2} = 31.75$

Copper

M2 = ?

$E2 = \frac{Mr}{V} = \frac{27}{9} = 9$

Solution

From: $\frac{M1}{M2} = \frac{E1}{E2}$ – make M2 subject

$M2 = \frac{M1\ x\ E2}{E1} = \frac{142.1\ x\ 9}{31.75} = 40.28$

M2 = 40.28 Kg

Example

A current flowing through an electrolyte cell deposits 0.25 g of silver at a certain time internal. How much copper would be deposited from a solution of Copper (II) sulphate in the same time internal using the same current? (Ag=108 Cu=63.5)

Data

Silver

M1= 0.25 g

E1=Mr/v = 108/1 =108

Copper

E2 = Mr/V = <u>63.5</u>/2 = 31.75

M2 = ?

Solution

From: $\frac{M1}{M2} = \frac{E1}{E2}$ – make M2 subject

$M2 = \frac{M1 \text{ x } E2}{E1} = \frac{0.25 \text{ x } 31.75}{108} = 0.073495$

M2 = 0.074 g

Example: Lambert chap. 6, Qn 7, 6th Edition

What mass of silver and what volume of oxygen (measured at STP) would be liberated in electrolysis by 9650 coulombs of electricity?

Data: Silver

Mr = 108 g/mol

Q = 9650 C

v = 1

F = 96500 C

M1 = ?

Solution

From: $M = \frac{Q \: x \: Mr}{VF}$

$M = \frac{Q \: x \: Mr}{VF} = \frac{1960 \: x \: 108}{1 \text{ x } 96500}$

M = 10.8 g

M = 10.8 g

Volume of oxygen at STP

Data: Silver

Mr = 16 g/mol

Q = 9650 C

v = 1

F = 96500 C

GMV = 22400 cm^3

First: find moles of oxide ions

From: $M = \frac{Q \: x \: Mr}{VF}$ – divide by Mr both sides

$\frac{M}{mr} = n = \frac{Q}{VF} =$

$n = \frac{Q}{VF} = \frac{9650}{2 \text{ x } 96500} = 0.05$ moles of O^{2-}

n = 0.05 moles of O^{2-}

Then: $2O^{2-} \rightarrow O_2 + 4e$

Therefore:

2mole of O^{2-} = 1mole of O_2

0.05 moles of O^{2-} = x mole of O_2

X = (0.05 x 1)/2 = 0.025

X = 0.025 Moles

Then: n = V/GMV – make V subject

V = n x GMV = 0.025 x 22400

V = 0.025 x 22400 = 560 cm^3

V = 560 cm^3

Example: Lambert chap. 6, Qn 8, 6th Edition

How many moles of electrons are required to produce by electrolysis?

(a) 27grams of aluminium?

(b) 8 grams of oxygen?

(a) **Data**

M = 27g

Mr = 27g/mol

na = m/Mr = 27/27 = 1mole

ne = ?

From: $Al^{3+} + 3e \rightarrow Al$

3mole of e = 1mole of Al

x moles e = 1 mole of Al

x = (3x1)/1 = 3moles

ne = 3moles

(b) **Data**

M = 8g

Mr = O_2 = (16 x 2) = 32g/mol

na = m/Mr = 8/32 = 0.25mole

ne = ?

From: $2O^{2-} \rightarrow O_2 + 4e$

4mole of e = 1mole of O_2

x moles of e = 0.25 mole of O_2

x = (4 * 0.25)/1 = 1mole

ne = 1moles

Example:Lambert chap.6,Qn11(b),6th Edition

Calculate the mass of each product of electrolysis of copper (II) sulphate solution by using platinum electrode if the current were stopped after the passage of 0.01faraday

Example: Lambert chap. 6, Qn 14, 6th Edition

0.02 moles of electrons were passed through a solution of sodium hydroxide using platinum electrode

(a) Give the names of the gases evolved and the name or signs of the electrodes at which they were produced

(b) Draw a labelled diagram of a suitable apparatus for this electrolysis and for the collection of the product

(c) Represents the reactions taking place at the electrodes by ionic equations

(d) Calculate number of moles of each gas produced and also the volume which each gas occupied at STP

(e) Calculate the time required to complete the passage of 0.02 faradays if a current of 2A were passed through the solution

(f) Write an equation to represent the reaction which would take place if the volumes of gases mentioned in (d) were mixed and ignited. State the number of moles of the product which would be formed

Example: Lambert chap. 6, Qn 16, 6th Edition

An element X has a relative atomic mass of 88. When a current of 0.5A was passed through the fused chloride of X for 32 minutes and 1o second, 0.44g of X was deposited at the cathode

(a) Calculate the number of faraday needed to liberate 1 mole of X

(b) Write the formula for the X ions

(c) Write the formula for the hydroxide of X

Example: Lambert chap. 6, Qn 17, 6th Edition

0.2 faraday of electricity were passed through solution of (a) Copper (II) sulphate (b) dilute sulphuric acid. Calculate the mass of copper liberated in (a) and the volume of hydrogen evolved at STP in (b)

Application of Electrolysis

The following are some of industrial application of electrolysis.

i. It used for Production of gases

ii. It used for Electroplating

iii. It used to Purification of copper

iv. It used in Extraction of Most Reactive Metal

Chemical Kinetics and Equilibrium

In this topic we will discuss the following

i. Chemical kinetics
ii. Chemical equilibrium

Chemical kinetics

By defn: *Chemical kinetics is the study of the rate of chemical reactions*

Rate of Chemical Reaction

By defn: *Rate of Chemical Reaction is the measure of the progress of the reaction per unit time*. It determined by measuring amount of reactants used up or amount of product formed at particular time taken

Mathematically

Rate = $\frac{\text{amount of reactant used}}{\text{time taken}}$

Or

Rate = $\frac{\text{amount of product formed}}{\text{time taken}}$

Nb:

Amount of reactants used up or amount of product formed at particular time taken can be a volume or mass

Collision theory

Reaction occurs due to approach and collision of reactant particles (atoms, ions or molecules) which possess a certain minimum amount of energy that result chemical reactions

Nb:

i. Not all collisions succeed in producing a chemical reaction
ii. succeed collisions which producing a chemical reaction is called **effective collision**

Activation Energy

By defn: *Activation Energy is the minimum energy possessed by reactant particles in order to undergo a chemical reaction*

Nb:

i. Activation Energy is used to break the bonds in the reactants so that new bonds can be formed in the products
ii. All reactants particle must possess Activation Energy for a complete reaction to occur

Comparison of rate of chemical reaction

Rate of chemical reaction can be fast or slow, consider the following Rate of chemical reaction

High rate of chemical reaction

High rate of chemical reaction are all chemical reaction which takes short time to complete reaction, for example

i. Neutralization of an acid and base
ii. Reaction of both colourless potassium iodide and lead nitrate to formed yellow **lead iodide**
   $KI + Pb(NO_3)_2 \rightarrow PbI_2 + K(NO_3)$
iii. Precipitation of many substance like silver chloride (Formation of silver halides)
   By defn: halide is the compound formed whereby one element is a group VII element (halogens)

Low rate of chemical reaction

Low rate of chemical reaction are all chemical reaction which takes long time to complete reaction, for example

i. Combination of hydrogen and oxygen in absence of catalyst
ii. Decomposition of hydrogen peroxide in absence of manganese (IV) oxide catalyst
   $H_2O_{2\,(l)} \rightarrow 2H_2O_{(l)} + O_{2\,(g)}$
iii. Rusting
   $4Fe_{(s)} + 3O_{2\,(g)} \xrightarrow{XH_2O} 2Fe_2O_3.xH_2O_{(s)}$

Factors affecting rate of chemical reaction

The follows are main factors that affect the rate of chemical reaction

i. Change in Temperature
ii. Concentration
iii. Surface area of reactant
iv. Addition of Catalyst
v. Change in Pressure
vi. Light

Change in Temperature

Increases the temperature tends to increases the rate of chemical reaction by increase more effective collision of reactants particles by increase kinetic energy and activation energy of reactant particles

Concentration

Increases the concentration tends to increases the rate of chemical reaction by increases more effective collision of reactants particles by increased likelihood of reactant particles

Surface area of reactant
Increases the Surface area tends to increases the rate of chemical reaction by increases more effective collision of reactants particles by increase more number of reactant particles to collides

Addition of catalyst
Catalyst increases the rate of chemical reaction by lowering the activation energy required to start a reaction

Change in Pressure
From Boyle's law pressure and volume are inversely related so increase in pressure tend to increase rate of chemical reaction by decrease volume of reactants result greater chance of collision

Light
Light increase rate of reaction some reaction like photosynthesis process in plant, present of light favour production of carbohydrate and when absent no photosynthesis process happen

Types of Chemical Reaction
There are two types of chemical reaction includes

i. Irreversible Reaction
ii. Irreversible Reaction

Irreversible Reaction
By defn: *Irreversible Reaction is the kind of chemical reaction which proceeds only in forward direction*. It represent by a single arrow which means proceeds in *forward* direction (→). For example Reaction between magnesium metal and dilute hydrochloric acid to form zinc chloride salt and hydrogen gas

$Zn\ (s) + 2HCl\ (aq) \rightarrow ZnCl_2\ (aq) + H_2\ (g)$

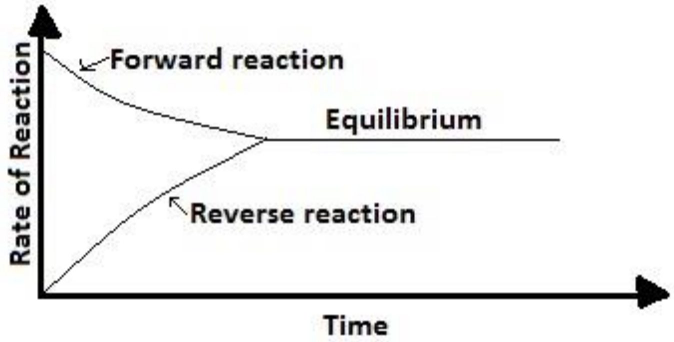
Reversible Reaction
By defn: *reversible Reaction is the kind of chemical reaction which proceeds forward and backward direction*. It represent by an double arrow which means proceeds in *forward* and backward direction (⇌).For example on gently heating ammonium chloride decopose to form ammonia and hydrogen

$NH_4Cl\ (s) \rightleftharpoons NH_3\ (g) + HCl\ (g)$

Chemical equilibrium
By defn: *Chemical equilibrium is the relative stability of the reactant and the products*

Equilibrium reaction
By defn: *Equilibrium reaction Is the reversible reaction whereby reaction attain equilibrium point in closed system*

Diagram:



Terms used

i. **Closed system**: *Closed system is the situation of reversible reaction where no product (s) or reactant (s) escape to the outside environment*
ii. **Equilibrium point**: Equilibrium point is the point whereby the rate of forward reaction and backward reaction are the same
iii. **Dynamic equilibrium**: *Dynamic equilibrium is the situation whereby reaction goes both forward and backward direction at the same time*

Nb:

i. At equilibrium the rate of product formed and product changed back to reactant are the same

Different between equilibrium reaction and simple reversible reaction

Equilibrium reversible	Simple reversible reaction
Dynamic in nature	Does in forward and backward and finally stops
Must be in closed system	Not in closed system
Reaches an equilibrium point	Not Reaches an equilibrium point

Le Chatelier's Principle

It states that

"If a system at equilibrium is subjected to change, processes occur which tend to counteract the change"

Or

"If stress is applied to a system at equilibrium, the system readjusts, if possible, to reduce the effect of the stress"

Factors affect position of equilibrium

The factors affect position of equilibrium include the following

i. Concentration
ii. Pressure
iii. Temperature

Concentration

The reaction always shift (proceeds) from the side of high concentration to low concentration

Pressure

Pressure depends on number of particles reactants side and product side to determine the direction of reaction. Increase in pressure cause reaction to shift (proceeds) from the side of high number of particles to low number of particles

Nb: Pressure affects only gaseous components

Example

Consider the reaction of reddish brown nitrogen dioxide to form yellow Dinitrogen tetraoxide

$2NO_2\ (g) \rightleftharpoons N_2O_{4\ (g)}$

Reactant particle = 2

Product particle = 1

Increase in pressure will favour forward direction since reactant has high number of particle and vice versa

Example

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

Reactant particle = 4

Product particle = 2

Increase in pressure will favour forward direction since reactant has high number of particle and vice versa

Example

$CH_4(g) + H_2O(g) \rightleftarrows CO(g) + 3H_2(g)$,

Reactant particle = 2

Product particle = 4

This type of reactions favour low pressure forward direction since products has high number of particle and vice versa

Example

$CO_{\ (g)} + H_2O_{\ (g)} \rightleftarrows CO2_{(g)} + H_{2(g)}$

Reactant particle = 2

Product particle = 2

Has equal number of gaseous molecules on both sides. Changing the overall pressure will not affect the state of equilibrium

Example

$H_2(g) + Cl_2(g) \rightleftarrows 2HCl_{(g)}$

Reactant particle = 2

Product particle = 2

Has equal number of gaseous molecules on both sides. Changing the overall pressure will not affect the state of equilibrium

Example

Determine whether the following reactions favor high or low pressures?

(a) $2SO_2(g) + O_2(g) \rightleftarrows 2\ SO_3(g)$
(b) $PCl_5(g) \rightleftarrows PCl_3(g) + Cl_2(g)$
(c) $CO(g) + 2H_2(g) \rightleftarrows CH_3OH(g)$
(d) $N_2O_4(g) \rightleftarrows 2\ NO_2(g)$
(e) $H_2(g) + F_2(g) \rightleftarrows 2\ HF(g)$

Solution

(a) high pressures
(b) high pressures
(c) high pressures
(d) low pressures
(e) high or low pressures will not affect the state of equilibrium

Temperature

Temperature affect equilibrium in two dimensions either reaction is

i. Endothermic reaction
ii. Exothermic release reaction

Endothermic reaction

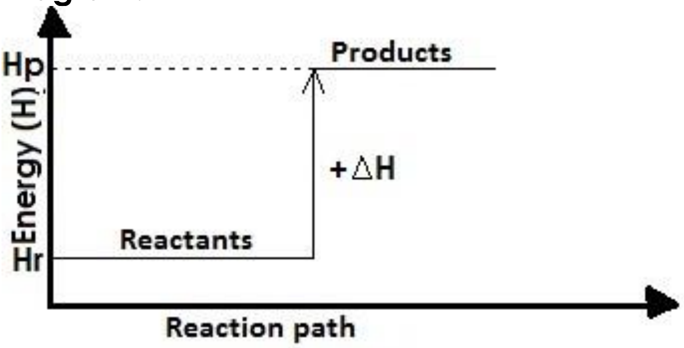
By defn: *Endothermic reaction is the reaction absorbs heat energy from surrounding*. Increase in temperature favour endothermic reaction. It denoted by $+\Delta H$ kJ mol $^{-1}$. For Example

i. Dissolving ammonium chloride in water
ii. Dissolving ammonium nitrate in water
iii. Mixing water and potassium chloride
iv. Photosynthesis

Energy level diagram

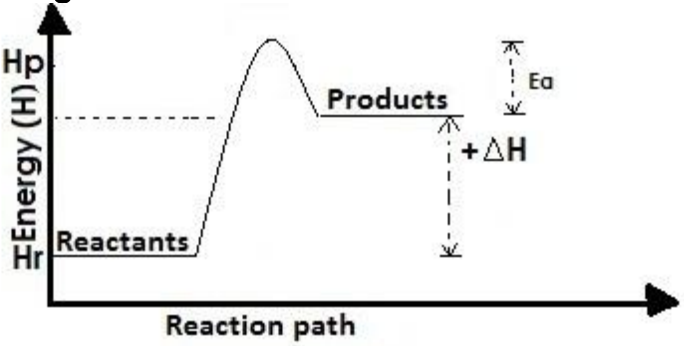
Energy (heat) change can be represented on a graph paper in which x-axis represents energy and y-axis represents reaction path

Diagram:



Activation energy (AE) also can be shown in an energy level diagram

Diagram:



Where

Ea = activation energy

ΔH = +ΔH = (Hp – Hr) = endothermic energy

Hp = final (product) temperature

Hr = initial (reactant) temperature

Exothermic release reaction

By defn: *Exothermic reaction is the reaction release heat energy from surrounding.* Increase in temperature favour exothermic reaction. It denoted by -ΔH kJ mol^{-1} for Example

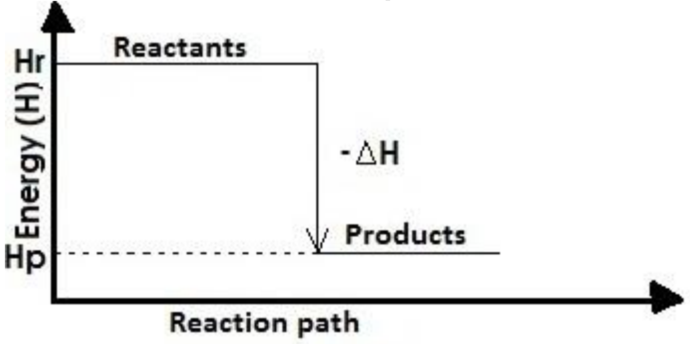
i. Combustion reactions

ii. Mixing of water and strong acids like Concentrated HCl

Energy level diagram

Energy (heat) change can be represented on a graph paper in which x-axis represents energy and y-axis represents reaction path

Diagram:



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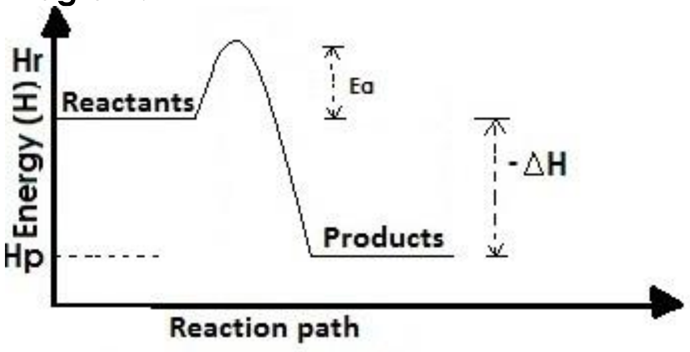


Where

Ea = activation energy

ΔH = -ΔH = (Hp – Hr) = exothermic energy

Hp = final (product) temperature

Hr = initial (reactant) temperature

Example

Determine whether the following reactions favour high or low temperature?

(a) $2SO_2(g) + O_2(g) \rightleftarrows 2\ SO_3(g)$ ΔH = -180 kJ

(b) $CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$ ΔH = -46 kJ

(c) $CO_{(g)} + Cl_{2(g)} \rightleftarrows COCl_{2(g)}$ ΔH = -108.3 kJ

(d) $N_2O_4(g) \rightleftarrows 2\ NO_2(g)$ ΔH = +57.3 kJ

(e) $CO_{(g)} + 2H_{2(g)} \rightleftarrows CH_3OH_{(g)}$ ΔH = -270 kJ

Solution

(a) Favour low temperature

(b) Favour low temperature

(c) Favour low temperature

(d) Favour high temperature

(e) Favour low temperature

Example

A solution of sodium hydroxide is added to a solution of hydrochloric acid

(a) Given that both solution are at room temperature of 18°C, what type of reaction takes place if the final steady temperature of reaction mixture is 36°C

(b) Draw an energy level diagram for the reaction

Solution

(a) **Data**

Hp = 36°C

Hr = 18℃

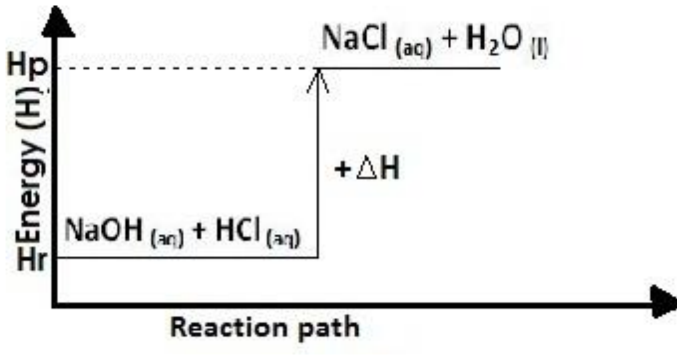
ΔH = ?

From: ΔH = (Hp – Hr)= (36 – 18) ℃ = 18℃

ΔH = +18℃

The reaction is endothermic reaction

(b)



Nb:

1. The study of energy change that accompany chemical reactions is called **Thermochemistry**
2. Energy (kinetic and potential)used to breaking intermolecular bond
3. The sum of kinetic energy and potential energy is called **heat content** or **enthalpy**
4. The energy gained or lost during chemical reaction when molar quantity are reacting is called **enthalpy change in chemical reaction**
5. enthalpy change in chemical reaction has a SI unit of **kJ mol** $^{-1}$
6. enthalpy change in chemical reaction It denoted by **delta H (ΔH)**
7. enthalpy change in chemical reaction is obtained by subtract heat content of reactant (Hr) from heat content of product (Hp)
   Mathematically
   $$\Delta H = (Hp - Hr)$$

Industrially Important Chemical Equilibrium

Many important processes in chemical industries involve shifting equilibrium to make the most of product at the lowest cost. The following are some of the examples

1. Haber Process
2. Contact Process
3. Production of Lime

Haber process

In the Haber process, nitrogen and hydrogen gases are fixed to form ammonia

$N_{2(g)} + 3\,H_{2(g)} \rightleftarrows 2\,NH_{3(g)}$ ΔH = -92 kJ

The reactants should mixed in stoichiometric proportions of nitrogen and hydrogen (that is, 1 volume of N_2 to 3 volume of H_2) and carrying out the reaction at high pressure, the percent yield of ammonia is between (15 - 20)%

Effect of temperature

The reaction is exothermic reaction but in this process temperature supplied is about 250 °C. This temperature is high enough to enable the production of ammonia to proceed at acceptable rate

Effect of pressure

Pressure about (200-300) atm supplied to enable the production of ammonia to proceed at acceptable rate. Ammonia condenses to a liquid under conditions at which nitrogen and hydrogen exist as gases

Effect of catalyst

Iron is used as catalyst to speed up the reaction

Effect of Concentration

However, equilibrium is shifted to the right by adding more N_2 and H_2 gases and simultaneously removing the ammonia as it is formed

Nb:

1. The unreacted nitrogen and hydrogen are recycled, together with the newly added batch of reactants
2. In the above process, hydrogen is obtained from natural gas by the following reactions
   $CH_4(g) + H_2O(g) \rightleftarrows CO(g) + 3H_2(g)$
   $2CH_4(g) + O_2(g) \rightleftarrows 2CO(g) + 4H_2(g)$

Contact Process

The production of sulfuric acid starts with the following steps, include

1. formation of sulfur dioxide
2. formation of sulfur trioxide
3. formation of disulfuric acid
4. formation of sulfuric acid

Formation of sulfur dioxide

Formation of sulfur dioxide gas can be done by the following methods

1. burning sulfur in dry air

$2S(s) + O_2(g) \rightarrow 2\mathbf{SO_2}(g)$

ii. combustion of hydrogen sulfide
$2H_2S(g) + 3O_2(g) \rightarrow 2\mathbf{SO_2}(g) + 2H_2O(g)$

iii. roasting processes of metal sulfides such as FeS_2 and $FeCuS_2$
$4FeS_2(s) + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$
$4FeCuS_2(s) + 7O_2(g) \rightarrow 2Fe_2O_3(s) + 4CuS(s) + 4SO_2(g)$

Formation of Sulfur Trioxide

The next step, in the contact process, sulfur dioxide is converted to sulfur trioxide (SO_3) according to the following equation, which is **exothermic** and **reversible**

$2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g) \quad \Delta H = -198\ kJ$

Effect of Pressure

The forward reaction favors high pressure. Product formation is also favoured by carrying out the reaction at high pressure

Effect of Temperature

The forward reaction favors low temperature but at low temperature the reaction is very, very slow because the reaction has a very activation energy. The reaction is normally carried out at temperature between (400 – 500) ℃. Increasing the temperature much higher will speed up reaction, but lowers the product yield. Thus, the temperature condition is compromised - high enough to make the reaction proceeds at a reasonable rate but low enough that it gives a reasonable yield

Effect of Catalyst

To attain the equilibrium faster, vanadium pentaoxide or platinum is used as catalyst

Effect of concentration

The reaction is also driven in the forward direction, favoring the formation of SO_3, by continuously adding SO_2 and O_2 and simultaneously removing SO_3.

Formation of Disulfuric Acid

The SO_3 gas is dissolved in liquid (concentrated) sulfuric acid to form disulfuric acid

$SO_3(g) + H_2SO_4(l) \rightarrow \mathbf{H_2S_2O_7}(l)$

Formation of Sulfuric Acid

disulfuric acid, $H_2S_2O_7$, is allowed to react with water to form sulfuric acid

$H_2S_2O_7(l) + H_2O(l) \rightarrow \mathbf{2H_2SO_4}(l)$

Production of Lime

Lime is produced by heating calcium carbonate:

$CaCO_3(s) \rightleftarrows CaO(s) + CO_2(g)$

The reaction is carried out at high temperature (900 - 1000 °C) and the equilibrium is shifted to the right by continuously removing the CO_2 gas

Used of Lime

i. it is used for making mortar
ii. it is used for making plasters
iii. it is used as a cheap base in industry
iv. it is used for treating acidic soil and in basic metal processing
v. it is used to manufacture of glasses
vi. it used in water purification

Extraction and Properties of Metals

Metals

By defn: *Metals is the elements which form positive ions by losing electrons*

Nb:

i. Since metals They form positive ions by losing electrons are also known as **electropositive elements**
ii. The most abundant metal in the earth's crust is **aluminium**
iii. The second most abundant metal in the earth's crust is **iron**
iv. Metals are present on the left side of the periodic table

Groups		I	II	III	IV	V	VI	VII	VIII
Periods	1	$^{1}_{1}H$							$^{4}_{2}He$
	2	$^{7}_{3}Li$	$^{9}_{4}Be$	$^{11}_{5}B$	$^{12}_{6}C$	$^{14}_{7}N$	$^{16}_{8}O$	$^{19}_{9}F$	$^{20}_{10}Ne$
	3	$^{23}_{11}Na$	$^{24}_{12}Mg$	$^{27}_{13}Al$	$^{28}_{14}Si$	$^{31}_{15}P$	$^{32}_{16}S$	$^{35.5}_{17}Cl$	$^{36}_{18}Ar$
	4	$^{39}_{19}K$	$^{40}_{20}Ca$						

v. Example of Some of the metals are Iron, Aluminium, Copper, Silver, Gold, Platinum, Zinc, Tin, Lead, Mercury, Sodium, Potassium and Magnesium
vi. Metals exist in nature either in *free element* (gold, silver and platinum) or in *compound form* (metals oxides, carbonates, sulphates or complex compound (more than one compound))
vii. **Minerals** is a Metallic compound occur in the earth crust together with impurities (sand, mud, rock particles etc)
viii. **Ore** is a mineral that contain large portion of metallic compound that has an economic value
ix. **Mining** is the process of extracting ore or minerals from the ground

Physical properties of metals

i. They are Good electrical conductors
ii. They are Good heat conductors
iii. They are **Malleable** (ability to bend or to be hammered into other shapes without breaking)
iv. They are **Ductile** (ability to drawn (stretched) into wire)
v. They are **shiny luster**
vi. They are Opaque as thin sheet
vii. They are Solid at room temperature except Mercury
viii. The branch of science concerned with the properties production and purification of metal I called **Metallurgy**

Chemical Properties of Metals

Chemical strength against Physical strength

Physical strength refers to the ability of the metal to withstand force on it without breaking. Physical strength also is known as **tensile strength**

Chemical strength refers to the measure of how readily metal takes part in a chemical reaction. May be very

i. reactive, least reactive and Unreactive metals Very reactive metals include K, Na etc
ii. Least reactive metals include Gold, silver etc

Redox reaction involve metals

When metal combine chemically with other substance, metals give electrons to the other element. This tendency to lose electrons and form Cation is called **Electropositivity**

Reducing Power of metal

It refers to the ability of metals to lose the electrons in the outer most shell

Example

Lithium [2:1] is more difficult to lose electrons because it is very closer to nuclear which experience strong nuclear force than potassium [2:8:8:1] because the outermost shell electrons are not near to the strong nuclear force

Nb:

i. More difficult to lose require more energy (poor ability)
ii. Easily to lose require low energy (more ability)
iii. Reducing power increase down the group and decrease across the period from left to right due to increase number of electrons to make noble gas (more stable)

Reactivity series of metals

Reactivity series refers to the arrangement of metals according to the reducing power or reactivity

Nb:

The high the reducing power the more reactive

Reactivity series of some metals

K	Potassium	most reactive
Na	Sodium	
Ca	Calcium	
Mg	Magnesium	
Al	Aluminium	
C	Carbon	
Zn	Zinc	
Fe	Iron	
Sn	Tin	
Pb	Lead	
H	Hydrogen	
Cu	Copper	
Ag	Silver	
Au	Gold	least reactive
Pt	Platinum	

Displacement reaction involving metals

Takes place when most reactive atom, element or radical takes place of least reactive of another

Example

Consider the reaction of

Iron metal and hydrochloric acid to form iron (iii) chloride and hydrogen gas

$2Fe(s) + 6HCl\ (aq) \longrightarrow 2FeCl_3\ (aq) + 3H_2\ (g)$

Iron takes place of Hydrogen

Example

When iron metal is added to blue colour of copper (ii) sulphate changes to pale green due to formation of iron (ii) sulphate solution.

$Fe(s) + CuSO_4\ (aq) \longrightarrow 2FeSO_4\ (aq) + Cu(s)$

Iron takes place of copper

Nb:

Magnesium reacts with hydrochloric acid more vigorous than zinc because it found higher in the reactivity series than zinc

Example

When zinc metal is added to blue colour of copper (ii) sulphate changes to brown due to formation of zinc (ii) sulphate solution.

$Zn(s) + CuSO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + Cu(s)$

Iron takes place of copper

Carbon and Hydrogen in the reactivity series

Due to importance reference of carbon and hydrogen in the extraction of metals and in the reaction of the metals with water it is included in the reactivity series. They are reducing agents just like a metal even is non-metal

Carbon

Carbon due to its reducing power is placed between aluminium and zinc in the reactivity series. Metals below zinc are extracted by reducing their oxides by using carbon or carbon monoxide. Metals above carbon in reactivity series are extracted by electrolysis

$2CuO\ (s) + C(s) \longrightarrow 2Cu(s) + CO_2\ (g)$

$2PbO\ (s) + C(s) \longrightarrow 2Pb(s) + CO_2\ (g)$

Hydrogen

Hydrogen due to its reducing power is placed between lead and copper in the reactivity series

Nb:

i. Metals below hydrogen cannot react with acid because hydrogen are most reactive than those below hydrogen in reactive series
ii. The reaction is similar to the reaction with water
iii. The metal which cannot replace hydrogen whether in acid or water are used in jewellery like copper, silver, gold and platinum.

$Zn_{(s)} + 2HCl_{\ (aq)} \longrightarrow 2ZnCl_{2\ (aq)} + H_{2\ (g)}$

$Mg_{(s)} + 2HCl_{\ (aq)} \longrightarrow MgCl_{2\ (aq)} + H_{2\ (g)}$

Uses of Metals

Metals or alloys (mixture of metals) they have a number of uses in our daily life as

i. Used to make cooking utensils
ii. Used to make electric wires
iii. Used to make sewing machines
iv. Used to make body of cars
v. Used to make body of trains
vi. Used to make body of ships
vii. Used to make body of aeroplanes

Extraction of metals

By defn: *Extraction of metal is the process whereby pure metal obtained from an ore*

Stages of the extraction of metals

There are four common stages include

1. Concentration of the Ore
2. Roasting of Sulphides to Oxide
3. Reduction
4. Purifying the Metal

Concentration of the Ore

It involves the removing the impurities present in the metal ore

Method used to remove impurities

Impurities is removed by the follows methods

1. Dressing
2. Calcination

Dressing

Dressing is the removal of impurities from the metal Ore without decomposing the ore chemically

Nb:

1. The main impurities which are removed during the dressing of metal ores are Sand, Limestone, Quartz, Silicates
2. Ore is broken down into small pieces which are then ground to fine powder
3. Fine powder fed into water tanks containing frothing chemical for **froth flotation**

Calcination

Calcination is heating of metal ore of hydrated oxide or carbonate in the absence of Air below its melting point

$\text{Metal oxide.}XH_2O \xrightarrow{Heat} \text{Metal oxide}_{(s)} + XH_2O_{(g)}$

$\text{Metal carbonate} \xrightarrow{Heat} \text{Metal oxide}_{(s)} + CO_{2\,(g)}$

Nb:

1. small molecules such as *water*, *carbon dioxide* or *Sulphur dioxide* are usually expelled from the ore
2. Calcination and roasting take place in a furnace

Roasting of Sulphides to Oxide

If metal ore occur as sulphides, the concentrated ore is heated in air to convert the ore from sulphide compound to Oxide compound

$\text{Metal sulphide} \xrightarrow{Heat} \text{metal oxide}_{(s)} + SO_2\,(g)$

Chemical equation

$2Cu_2S(s) + 3\,O_2\,(g) \longrightarrow 2SO_2\,(g) + 2Cu_2O\,(s)$

$2FeS\,(s) + 2O_2\,(g) \longrightarrow 2SO_2\,(g) + 2FeO\,(s)$

Nb:

1. Roasting usually involve greater chemical change such as oxidation or chlorination
2. Roasting take place in a furnace

Reduction

Reduction is the process whereby oxygen is removed from a metal oxide

NB

1. Reduction by carbon is called **Smelting**
2. Reduction by heating in the presence of air is called **Autoreduction**
3. Reduction by passing electricity in the compound solution is called **electrolysis**
4. Reduction by forming precipitate is called **precipitation**
5. Reduction by forming amalgam is called **amalgamation**
6. Impure metal from reduction is known as **crude Metal**

Method used to extract different metal ore

Autoreduction	Less electropositive metal oxides and sulphides such a lead, mercury and copper. HgS is reduced to mercury using this method
Electrolysis	The oxides, hydroxide or chlorides of more reactive metal like sodium, calcium, magnesium and aluminium
Precipitation	The oxides of less reactive metals. A solution containing the metal's ion is reacted with a more reactive metal. The more reactive metal displaces the less

	reactive metal from the solution
Amalgamation	Less reactive metals like silver and gold. The finely crushed ore is brought into contact with mercury which forms an alloy (*amalgam*) with the metal

Purifying the Metal

Purifying the Metal Is the process whereby crude Metal Purified to get pure metal

Methods used to Purifying the Metal

1. Distillation of crude metal
2. Oxidation of crude metal
3. Electro-refining(Electrolysis) of crude metal

Distillation of crude metal

The crude metal is heated in a furnace until the pure metal evaporates, leaving behind the impurities. The vapour is then collected and condensed in separated chamber

Oxidation of crude metal

The molten crude metal is heated in air in furnace. The impurities are oxidized and escape as a **vapour** or form of **scum** over the molten metal. The scum is then removed by skimming

Nb:

1. Skimming is the remove a substance from the surface of a liquid
2. Skimming is used only when the impurities have a greater affinity for oxygen than the metal
3. Affinity is the degree to which a substance tends to combine with another

Electrolysis of crude metal

The crude metal is moulded into blocks and made the anode of an electrolytic cell. The cathode is usually made up of a thin plate of the pure metal. *When a current is passed the anode dissolves and the pure metal is deposited on the cathode*. The soluble impurities go into solution while the insoluble impurities settle down below the anode as **anode mud** or **sludge**

Nb:

1. crude metal contains impurities such as other metals, non-metals such as Silicon and phosphorus and unreduced oxides and sulphides of the metals
2. Some impurities are also introduced in the process when preparing the metal ore for reduction

Extraction of most reactive metals

It found in compound, the most reactive metal is all four above in reactivity series like **potassium**, **sodium**, **calcium**, **magnesium** and **aluminium**. It can by the following methods

Concentration of the Ore

It involves the removing the impurities present in the metal ore; it may by Dressing or Calcination

Roasting of Sulphides to Oxide

If metal ore occur as sulphides, the concentrated ore is heated in air to convert the ore from sulphide compound to Oxide compound

Reduction

Most reactive metal reduced by **electrolysis** to obtain a pure metal

Purifying the Metal

Most reactive Metal forming crude Metal Purified to get pure metal whether by Distillation of crude metal or Oxidation of crude metal or Electro-refining(Electrolysis) of crude metal

Extraction of Sodium

Sodium does not occur naturally as a free element. This is because it is too reactive. However, it is abundant different compound such as

1. $NaCl$ - common salt
2. $NaNO_3$ - chile salt petre
3. $Na_2SO_4.10H_2O$ - Glauber's salt
4. $Na_2B_4O_7.10H_2O$ - Borax (sodium tetraborate sodium borate)

Nb: The main ore used is NaCl

Extraction methods

Concentration of the Ore

The sodium chloride is collected

Roasting of Sulphides to Oxide

Since sodium chloride does not contain sulphur it is not roasted

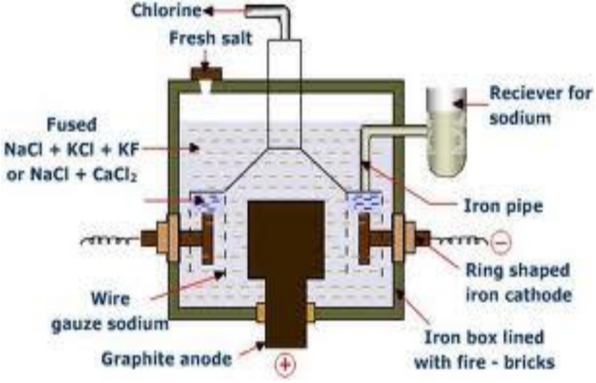
Reduction

Sodium chloride reduced by electrolysis to obtain a crude metal

Electrolysis to obtain a pure metal

Molten mixture of *Sodium chloride (NaCL)* and *Calcium Chloride ($CaCl_2$)* in a **Downs cell** at 600°C. The cell has a graphite anode and a circular iron cathode, both covered and with proper outlets

Diagram:



Nb:

1. Calcium Chloride ($CaCl_2$) is added to sodium chloride to lower the melting point of sodium chloride from 774°C to about 600°C
2. Sodium and chlorine produced would react violently if allowed to come into contact
3. steel gauze (Diaphragm) around the anode to keep the two products apart introduced to prevent reaction between Sodium and chlorine produced
4. The large Graphite anode is used to facilitate maximum oxidation of chlorine ions to chlorine gas
5. The large Graphite anode is used maximizes the formation of sodium metal at cathode

Component

Molten sodium Chloride (NaCl)

Molten Calcium chloride ($CaCl_2$)

Dissociation (Ions presents)

compound	Cation	Anion
$NaCl_{(l)}$	$Na^{+}_{(l)}$	$Cl^{-}_{(l)}$
$CaCl_{2\,(l)}$	$Ca^{2+}_{(l)}$	$Cl^{-}_{(l)}$

Migration

cathode	Anode
$Na^{+}_{(l)}$	$Cl^{-}_{(l)}$
$Ca^{2+}_{(l)}$	$Cl^{-}_{(l)}$

Discharge

From concentration Sodium Cation will discharge at cathode and chlorine anion will discharge at anode

At cathode: $Na^{+}_{(l)} + e \rightarrow Na_{(s)}$

At Anode: $Cl^{-}_{(l)} \rightarrow Cl_{2(g)} + e$

Product

Chlorine liberated at the cathode rises up through a pipe and gets collected in a receiver in the molten state and chlorine will produced at anode and water remain in the solution

Nb:

1. Chlorine collects in the inverted trough (Hood) placed over the cathode, rises up the pipe, and is tapped off through an iron vessel
2. The sodium metal is collected upwards because of its low density which makes it to float over the mixture

Purifying the sodium Metal

The sodium metal collected from the Downs cell contains some Calcium, which is also formed through electrolysis. Calcium crystallizes when the mixture cools and a relatively pure sodium metal is obtained

Extraction of aluminium

Aluminium does not occur naturally as a free element. This is because it is too reactive. However, it is abundant different compound such as

i. $Al_2O_3.2H_2O$ - bauxite
ii. Na_3AlF_6 - Cryolite
iii. $KAlSi_3O_8$ - felspar
iv. $Al_2Si_2O_7.2H_2O$ - Kaolin

Nb: The main ore used is bauxite and Cryolite

Extraction methods

Concentration of the Ore

The bauxite is collected, crushing and then purified from iron and silicon impurities by **Hall process**

Hall process

i. Aluminium powder ore is heated to bright redness with sodium carbonate to form sodium aluminate ($NaAlO_2$), water and carbon dioxide
   $Al_2O_3.2H_2O_{(s)} + Na_2CO_{3\,(s)} \rightarrow NaAlO_{2\,(l)} + 2H_2O_{(l)} + CO_{2\,(g)}$
ii. Molten mass is removed with the water while the insoluble iron and silicon oxides are left behind as residual
iii. Molten mass is removed with the water is heated at (50 – 60)℃ to in carbon dioxide stream to form precipitate of of aluminium hydroxide and sodium carbonates
   $NaAlO_{2\,(l)} + 2H_2O_{(l)} + CO_{2\,(g)} \rightarrow Al(OH)_{3\,(s)} + Na_2CO_{3\,(aq)}$
iv. Aluminium hydroxide is filtered off, washed, dried then calcinated at 1500℃ to give **alumina**
   $Al(OH)_{3\,(s)} \rightarrow Al_2O_{3(l)} + 2H_2O_{(l)}$

Roasting of Sulphides to Oxide

Since bauxite does not contain sulphur it is not roasted

Reduction

Alumina is reduced by electrolysis to obtain impure aluminium

Electrolysis to obtain a impure aluminium

Alumina and Cryolite (Na_3AlF_6) mixed and introduced in a electrolytic cell

Diagram:

Nb:

i. Cryolite (Na_3AlF_6) is added to alumina to lower the melting point of alumina to about (800 – 900)℃
ii. When electrolysis conducted at high temperature aluminium formed would vaporize
iii. Cryolite (Na_3AlF_6) is added to improve the electrical conductivity of alumina

Component

Molten Alumina - $Al_2O_{3(l)}$

Dissociation (Ions presents)

compound	Cation	Anion
$Al_2O_{3(l)}$	$Al^{3+}_{(l)}$	$O^{2-}_{(l)}$

Migration

cathode	Anode
$Al^{3+}_{(l)}$	$O^{2-}_{(l)}$

Discharge

At cathode: $Al^{3+}_{(l)} + 3e \rightarrow Al_{(s)}$

At Anode: $2O^{2-}_{(l))} \rightarrow 2O_{2(g)} + 4e$

Purifying the sodium Metal

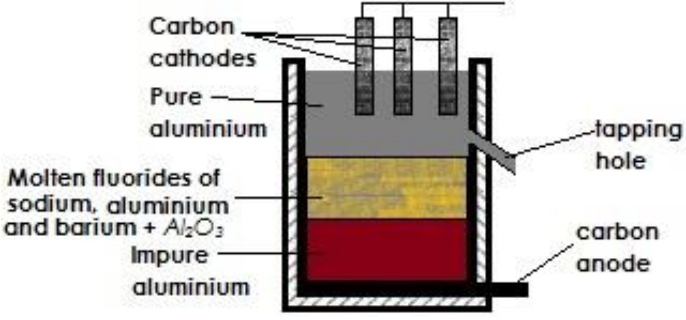
The crude aluminium (99% pure) contains impurities such as small quantities of iron, silicon, alumina and carbon is purified further by electrolysis in Hooper's electrolytic cell

Electrolysis to obtain pure aluminium

Hooper's electrolytic cell

It made up of an iron tank lined on the inside with carbon as anode. the tank has three different layers of molten substance

Diagram:



Nb:

i. The bottom layer contains impure molten aluminium containing copper and silicon to increase the density
ii. The middle layer contains a mixture of fluorides of sodium, barium and aluminium in fused form (electrolyte)
iii. The top layer contains pure molten aluminium which together with the

carbon rods as cathode which suspended from above

Mechanism

The impure aluminium passes from bottom layer to the middle layer and aluminium formed in the middle layer passes to the top layer as pure aluminium and the process continues to obtain pure aluminium about 99.99% tapped from the tapping hole

Question

Why most reactive metal reduced by smiting?

Answer:

They have a greater affinity for oxygen than carbon therefore they will react with carbon to form metal carbide

Extraction of relatively reactive metals

It found in compound, the most reactive metal is all three below the most reactivity series in the reactivity series like **zinc**, **iron** and **Lead**. It can by the following methods

Concentration of the Ore

It involves the removing the impurities present in the metal ore; it may by Dressing or Calcination

Roasting of Sulphides to Oxide

If metal ore occur as sulphides, the concentrated ore is heated in air to convert the ore from sulphide compound to Oxide compound

Reduction

Moderate reactive metal reduced by **smelting** to obtain a pure crude metal

Purifying the Metal

Moderate reactive Metal forming crude Metal Purified to get pure metal either by Distillation of crude metal or Oxidation of crude metal or Electro-refining(Electrolysis) of crude metal

Extraction of Iron

Iron does not occur naturally as a free element. This is because of it is relatively reactive. However, it is abundant different compound such as

i. Fe_2O_3 - Haematite Contains about 70%
ii. Fe_3O_4 - Magnetite Contains about 72.4%
iii. $Fe_2O_3 . H_2O$ Limonite
iv. $FeCO_3$ - Siderite or Spathic iron ore
v. FeS_2 - Iron pyrites

Nb: The main ore used is Haematite

Extraction methods

Concentration of the Ore

In this metallurgical operation, the ore is concentrated by removing impurities like soil etc. The process involves the crushing and washing of ore

Calcination

The concentrated ore is now heated in the presence of air in shallow kilns. The following changes occur during the roasting process

(a) The process performed to remove water

$$Fe_2O_3 . XH_2O_{(s)} \longrightarrow Fe_2O_3{}_{(s)} + XH_2O_{(l)}$$

(b) The process performed to remove Carbon dioxide gas when Siderite ($FeCO_3$) used as ore

$$FeCO_3{}_{(s)} \longrightarrow FeO_{(s)} + CO_2{}_{(g)}$$

(c) The process performed to remove impurity of sulphur and escape as a gas

$$S_{(s)} + O_2{}_{(g)} \longrightarrow SO_2{}_{(g)}$$

(d) The process performed to remove impurity of arsenic and escape as a gas

$$4As_{(s)} + 3O_2{}_{(g)} \longrightarrow 2As_2O_3{}_{(g)}$$

(e) The process of heating Ferrous oxide (Iron (II) Oxide) is also oxidized to ferric oxide (Iron (III) Oxide)

$$FeO_{(s)} + O_2{}_{(g)} \longrightarrow Fe_2O_3{}_{(s)}$$

Roasting of Sulphide to Oxide

If metal ore Iron pyrites (FeS_2) used is heated in air to convert the ore from sulphide compound to Oxide compound

$$2FeS (s) + 2O_2 (g) \longrightarrow 2SO_2 (g) + 2FeO (s)$$

Reduction

Moderate reactive metal reduced by **smelting** to obtain a crude metal

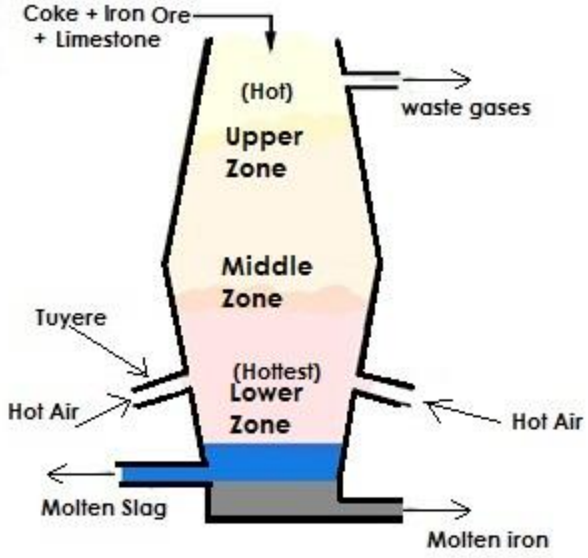
Smelting (Reduction of ore)

The process of reduction is carried out in a **Blast Furnace**

Structure of blast furnace

The blast furnace is a cylindrical tower like structure about 25m to 35m high. It has an outer shell of steel. Inside of furnace is lined with fire bricks. The top of the furnace is closed by a cup-cone feeder. Small opening near the base known as **Tuyeres**

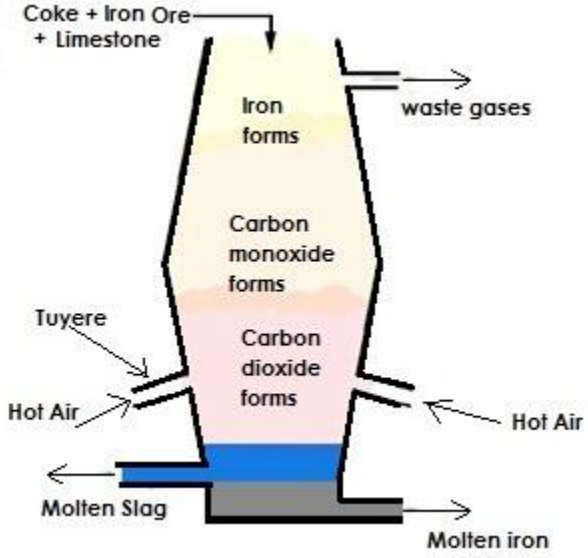
Diagram:



How iron smelted

The ore is mixed with Carbon (*Coke*) and Limestone (*$CaCO_3$*) and introduced into the furnace from the top. Blasts of hot air are blown into the furnace through Tuyeres

Diagram:



The Upper Zone Reduction

The zone is near the top of the furnace. The temperature range in this zone is 300°C - 800°C. In this zone

i. The carbon burns in oxygen of the hot air to form carbon dioxide

$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

ii. The carbon dioxide formed react more coke to form carbon monoxide

$CO_{2(g)} + C_{(s)} \longrightarrow CO_{(g)}$

iii. The carbon monoxide formed reduce ferric oxide (Iron (III) Oxide) to **spongy Iron**

$FeCO_{3(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2(g)}$

iv. when Siderite ($FeCO_3$) present

$Fe_2O_{3(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2(g)}$

Nb:

i. The main reducing agent in the blast furnace is carbon monoxide and not carbon

ii. Iron obtained is called **Spongy Iron because** the temperature in this zone is too low to melt iron

iii. When iron ore is reduced, part of the limestone decompose at 600°C to lime and carbon dioxide

$CaCO_3 (s) \longrightarrow CaO (s) + CO_2 (g)$

iv. The limestone also react more coke to form carbon monoxide

$CaCO_{3(s)} + C (s) \longrightarrow CaO_{(s)} + CO_{(g)}$

The Middle Zone reduction

The zone is lower zone of reduction. The temperature range in this zone is 900°C - 1200°C. The following are the reaction that takes place in this zone

i. The carbon dioxide reduced to carbon monoxide. this reaction is accompanied by heat absorption

$CO_2 (g) + C (s) \longrightarrow CO (g)$

ii. At about 1000°C, calcium Carbonates is almost completely decomposed to lime

$CaCO_3 (s) \longrightarrow CaO (s) + CO_2 (g)$

iii. The lime (Calcium oxide) combines with the silica presences as **impurity** in the ore to form Calcium silicate (**Fusible Slag**)

$CaO (s) + SiO_2 (s) \longrightarrow CaSiO_3 (l)$

iv. A flux is a mixture of chemicals that react with impurities to form **Slag**

The Lower Zone reduction

The zone is lowest and hottest part of furnace. The temperature range in this zone is 1200°C - 1500°C. The following are the reaction that takes place in this zone

i. The carbon burns in oxygen of the hot air to form carbon dioxide

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

The spongy iron melts in this zone at about 1300°C and collects at the bottom

ii. The carbon monoxide formed reduce ferric oxide (Iron (III) Oxide) might have escaped the reduction process in the middle zone to spongy Iron

$Fe_2O_{3\,(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2\,(g)}$

Nb:

1. At the bottom of the furnace, the molten iron sinks while the fusible slag, being less dense, floats over the molten iron forming a separate layer
2. Separate layer of slag prevents iron from being oxidized by the hot air
3. The slag and iron are periodically removed through different outlets
4. The mixture of water gases containing nitrogen, carbon dioxide and carbon monoxide are known as **blast furnace gases**
5. The mixture is burnt in air to produce heat which is used for pre-heating the air blast coming in through the tuyeres
6. The iron obtained from the blast furnace is an impure variety known as **Pig Iron**

Purifying the Metal

Pig iron is further purified by re-smelting it with coke and lime in another furnace called **Cupola**. The molten iron from the cupola is poured into moulds desired shapes. The iron thus obtained is called **Cast Iron**

Extraction of copper

Copper occurs in both free and combined states. Most copper occurs in compound form, mainly as sulphides and oxides. The main ores of copper are

i. copper pyrites - ($CuFeS$)
ii. copper glance - (Cu_2S)
iii. cuprite - (Cu_20)
iv. malachite - [$CuCO_3.Cu(OH)_2$]
v. azurite - [$2CuCO_3.Cu(OH)_2$]

NB: Main ore used is copper pyrites

Concentration of the Ore

The powdered ore is concentrated to remove impurities such as galena (PbS)

Roasting of Sulphides to Oxide

The concentrated ore is heated strongly in the presence of excess air in a special furnace

i. The copper pyrites decompose to form copper (I) and iron (II) sulphides

$2CuFeS_{(s)} + 0_{2(g)} \longrightarrow 4Cu_2S_{(s)} + 2FeS_{(s)} + S0_{2(g)}$

ii. Part of the sulphides may be oxidized to their respective oxides

$2Cu_2S(s) + 30_2(g) \longrightarrow 2Cu_2O(s) + 2S0_2(g)$

$2FeS(s) + 30_2(g) \longrightarrow 2FeO(s) + 2S0_2(g)$

iii. As the roasting proceeds, any moisture present in the ore evaporates

iv. Impurities such as sulphur, arsenic and antimony oxides are also removed as a gas

$S(s) + 0_2(g) \longrightarrow S0_2(g)$

$4As(s) + 30_2g) \longrightarrow 2As_2O_3\,(g)$

$4Sb(s) + 30_2(g) \longrightarrow 2Sb_2O_3\,(g)$

v. The roasting process results in a mixture of sulphides and oxides of copper and iron

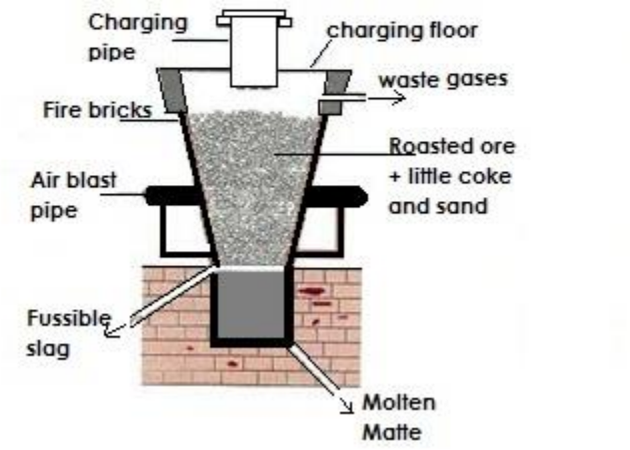
Reduction

Moderate reactive metal reduced by **smelting** to obtain a pure crude metal

Smelting (Autoreduction)

The roasted ore is mixed with coke and sand and heated in the presence of excess air in a water jacketed blast furnace as shown

Diagram:



How copper ore smelted (Autoreduction)

Consider the follow is chemical reaction which takes place in the blast furnace

1. oxidation of iron (II) sulphide which started during the roasting process continues
   $2FeS(s) + 30_2(g) \longrightarrow 2FeO(s) + 2S0_2(g)$
2. The iron (II) oxide formed combines with sand to form a fusible slag:
   $FeO(s) + Si0_2(s) \longrightarrow FeSiO_3(l)$
3. The copper (I) oxide also reacts with iron (II) sulphide to form **matte** (iron (II) oxide and copper (I) sulphide)
   $Cu_2O(s) + FeS(s) \longrightarrow CuS(s) + FeO(s)$

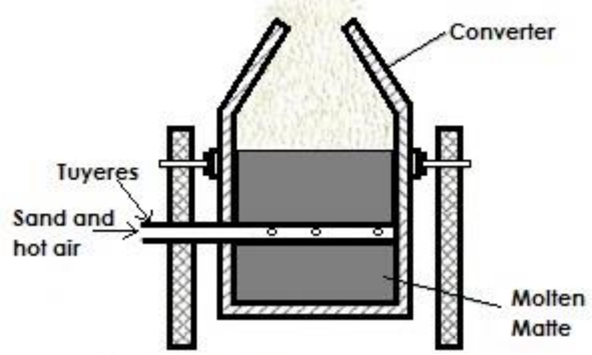
Nb:

1. The above reaction takes place because iron has a greater affinity for oxygen than copper
2. The matte is taken out through the outlet at the bottom

Conversion

The molten matte is then transferred to a **Bessemer converter** for Conversion. This is a pear-shaped furnace made of steel. The furnace is fitted with pipes known as **tuyeres** on the sides. Sand and hot air are blown through these pipes

Diagram:



The following reactions take place in the converter

1. Iron (II) sulphide reacts with oxygen to form iron (II) oxide
   $2FeS(l) + 30_2(g) \longrightarrow 2FeO(l) + 2S0_2(g)$
2. The iron (II) oxide formed reacts with sand (silicon dioxide) to form slag
   $FeO(l) + Si0_2(s) \longrightarrow FeSiO_3(l)$
3. Some of the copper (I) sulphide is oxidized to copper (I) oxide
   $2Cu_2S(s) + 30_2(g) \longrightarrow 2Cu_2O(s) + 2S0_2(g)$
4. Copper (I) oxide is reduced by copper (I) sulphide to copper
   $2Cu_2O(s) + Cu_2S(s) \longrightarrow 6Cu(l) + S0_2(g)$

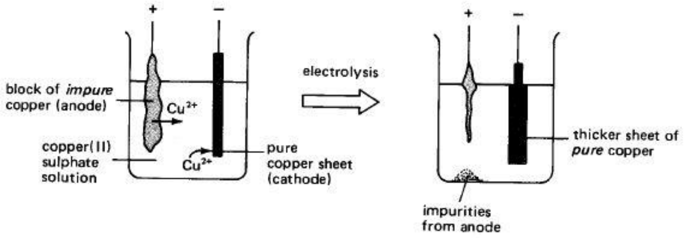
Nb:

1. This is self-reduction of copper because the substances involved are both copper compounds
2. The molten metal is poured out into sand moulds and allowed to stand to cool
3. On cooling, any dissolved sulphur dioxide escapes leaving blisters on the surface of the copper
4. The copper obtained from the Bessemer converter is therefore known as **blister copper**

Purifying of copper

Blister copper is refined further by electrolysis in copper (II) sulphate solution. The blister copper is cast into blocks and made the anode. The cathode is made up of a sheet of pure copper

Diagram:



At the anode

Blister copper is oxidized (**blister copper** dissolved) to copper (II)ions

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

At the cathode

The copper ions move to the cathode. At the cathode, copper (II) ions are reduced to copper metal

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

Product

The copper is deposited on the cathode sheet and the pure plate will become larger in size

Compounds of Metals

By Defn: *A compound is a substance formed by the chemical Combination of two or more elements.* Metals react with other substances, especially non- metals, to form different compounds. The compounds of metals include:

i. Metal oxides
ii. Metal hydroxides
iii. Metal Hydrogen Carbonates
iv. Metal carbonates
v. Metal nitrates
vi. Metal chlorides
vii. Metal sulphates

Metal Oxides

By defn: *Metal oxides an oxide is a compound formed by the combination of oxygen and metal elements*

Nb:

i. Metal oxides are compounds of the metals with oxygen
ii. Oxides they are binary compounds means contain two elements, one of which must be oxygen

Preparation of metal oxides

Metal oxides can be prepared using two methods namely:

i. Direct method
ii. Indirect method

Preparation oxides by direct methods

In the direct method, a metal is directly heated in oxygen to give a metal oxide

Sodium oxide

Sodium burns in air with a persistent yellow flame to form sodium peroxide which is a **pale yellow solid**

$2Na(s) + O_2(g) \rightarrow Na_2O\ (s)$

When sodium is exposed to air, it reacts with the oxygen of the air to form sodium oxide (Na_20) which is a **whitish-grey solid**

$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$

Nb:

i. sodium is stored under oil to prevent react with oxygen at room temperature
ii. Sodium oxide is also formed when sodium is burnt in a limited supply of air
iii. When sodium peroxide dissolves in water at room temperature, it forms an alkaline solution and Oxygen gas
$2Na_2O_{2(s)} + 2H_20_{(l)} \rightarrow 4NaOH_{(aq)} + O_{2(g)}$

iv. When sodium peroxide dissolves in ice-cold water, it forms an alkaline solution and sodium peroxide forms hydrogen peroxide
$2Na_2O_{2(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_2O_{2(l)}$

v. Sodium oxide reacts with water to give sodium hydroxide
$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

vi. Depending on the degree of heating, sodium peroxide and sodium oxide can be formed at the same time
$6Na(s) + 20_2(g) \rightarrow Na_20_2(s) + 2Na_2O(s)$

Magnesium oxides

Magnesium burns in air with a very brilliant white flame to form a **white solid** of magnesium oxide

$2Mg(s) + 0_2(g) \rightarrow 2MgO(s)$

Magnesium oxide reacts with water to form basic magnesium hydroxide

$MgO\ (s) + H_20(l) \rightarrow Mg(OH)_2(aq)$

Calcium oxides

Calcium burns in air with a red flame to form calcium oxide which is **white**

$2Ca(s)+ 0_2(g) \rightarrow 2CaO(s)$

Calcium oxide reacts with water to form basic calcium hydroxide

$CaO(s)+ H_20(l) \rightarrow Ca(OH)_2(aq)$

Nb:

i. Calcium hydroxide is sparingly soluble in water
ii. Metals high in the reactivity series such as sodium and potassium readily react with oxygen directly to form oxides
iii. Magnesium and calcium also react with air to form an oxide coating on the metals

Preparation of oxides by indirect methods

The indirect methods of preparing oxides by

i. Decomposing compound by heating it to give the oxide

ii. Preparing a compound which is then decomposed by heating to give the oxide

Decompose compound by heating to oxide

1. The carbonates of **zinc**, **lead**, **copper** and **iron** decompose on heat to form metal oxide and carbon dioxide
   i. Copper carbonate decomposes to give copper (II) oxide
   $CuCO_3(s) \rightarrow CuO(s) + C0_2(g)$

   ii. Zinc carbonate, which is white in colour, decomposes to give zinc oxide and carbon dioxide
   $ZnCO_3(s) \rightarrow ZnO(s) + C0_2(g)$

   iii. Lead carbonate decomposes to the lead (II) oxide which is reddish-brown when hot and yellow when cold:
   $PbCO_3(s) \rightarrow PbO(s) + C0_2(g)$

   iv. Iron (II) carbonate decomposes to give iron (II) oxide which is black
   $FeCO_3(s) \rightarrow FeO(s) + C0_2(g)$

   v. The iron (II) oxide formed is immediately oxidized to iron (III) oxide
   $4FeO(s) + 0_2(g) \rightarrow 2Fe_2O_3(s)$

   vi. Magnesium carbonate decomposes only on strong heating to give magnesium oxide
   $MgCO_3(s) \rightarrow MgO(s) + C0_2(g)$

   vii. Calcium carbonate, like magnesium carbonate, will only decompose when strongly heated
   $CaCO_3(s) \rightarrow CaO(s) + C0_2(g)$

Nb:

i. Alkali metal carbonates such as sodium carbonate do not decompose when heated
ii. oxides of Alkali metals cannot therefore be prepared using this method
iii. carbonates such as those of zinc, iron, lead and copper decompose to metal oxides on heating

2. Metal hydroxide when heated decompose to give oxide and water
   i. A green Copper (II) hydroxide when heated decompose to give black copper oxide and water
   $Cu(OH)_2 \rightarrow CuO + H_20$

   ii. White Zinc hydroxide when heated decompose to give Yellow zinc oxide and water
   $Zn(OH)_2 \rightarrow ZnO + H_20$

   iii. White Lead hydroxide when heated decompose to give Reddish Brown lead oxide when hot and yellow when cool and water
   $PbOH \rightarrow PbO + H_20$

   iv. Reddish Brown Iron (III) hydroxide when heated decompose to give Reddish Brown irin (II) oxide and water
   $Fe(OH)_3 \rightarrow Fe_20_3 + H_20$

   v. White Magnesium hydroxide when heated decompose to give white magnesium oxide and water
   $Mg(OH)_2 \rightarrow MgO + H_20$

   vi. White Aluminium (III) hydroxide when heated decompose to give white aluminium (III) oxide and water
   $Al(OH)_3 \rightarrow Al_20_3 + H_20$

Nb:

i. The hydroxides of lithium, sodium and potassium are stable and do not decompose on heating
ii. Hydroxides of silver, gold and mercury do not exist
iii. Hydroxides such as those of zinc, iron, lead and copper decompose to metal oxides on heating

Preparing a compound which is then decomposed by heating to give the oxide

Copper reacts with Nitric acid to form brown fumes of nitrogen dioxide and copper nitrate

$Cu_{(s)} + 4HN0_{3(l)} \rightarrow Cu(N0_3)_{2(aq)} + 2N0_{2(g)} + 2H_2O_{(l)}$

When the blue solution of copper nitrate is heated to dry to blue *crystals of copper nitrate* and when heating is continued, the copper nitrate decomposes to form copper

(II) oxide, nitrogen dioxide gas and oxygen gas

$2Cu(N0_3)_2(aq) \rightarrow 2CuO(s) + 4N0_2(g) + 0_2(g)$

Nb:

i. Copper (II) oxide is left as a *black residue*
ii. Nitrogen dioxide is observed as brown fumes

ClassifiCation of metal oxides

Metal oxide grouped into various categories based on their solubility and their reactions with acids and bases, includes

i. Soluble metal oxides
ii. Insoluble metal oxides
iii. Basic metal oxides
iv. Amphoteric oxides

Soluble metal oxides

Soluble metal oxides readily dissolve in water to form a metal hydroxide solution. They include potassium, sodium and magnesium oxides. Soluble metal oxides are known as **alkalis**

$K_2O_{(s)} + H_2O_{(l)} \rightarrow KOH_{(s)}$
$Na_2O_{(s)} + H_2O_{(l)} \rightarrow NaOH_{(s)}$
$CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$

Magnesium oxide reacts with water to form a basic solution of magnesium hydroxide

$MgO_{(s)} + H_2O_{(l)} \rightarrow Mg(OH)_{2(s)}$

Insoluble metal oxides

Insoluble metal oxides do not dissolve in water. Most metal oxides are insoluble in water. Aluminium oxide, zinc oxide, lead (II) oxide, copper (II) oxide and iron (II) and (III) oxides do not react with water

Basic metal oxides

Basic metal oxides react with acids to give a salt and water as the only products. Basic metal oxides include all the oxides of *Group I metals*

$PbO\ (s) + 2HCl\ (aq) \rightarrow PbCl\ (s) + H_20\ (l)$
$PbO\ (s) + H_2S0_4\ (aq) \rightarrow PbSO_4(s) + H_20\ (l)$

Basic metal oxides readily dissolve in water to form a metal hydroxide solution

$K_2O_{(s)} + H_2O_{(l)} \rightarrow KOH_{(aq)}$
$Na_2O_{(s)} + H_2O_{(l)} \rightarrow NaOH_{(aq)}$
$Li_2O_{(s)} + H_2O_{(l)} \rightarrow LiOH_{(aq)}$

Amphoteric oxides

Amphoteric oxides are the metal oxides which have both acidic and basic characteristics. The oxides of aluminium, zinc and lead react with both acid and base

Reaction with base

$Al_2O_3 + NaOH \rightarrow Al(OH)_3 + Na_2O$
$ZnO + NaOH \rightarrow Zn(OH)_2 + Na_2O$

Reaction with acid

$Al_2O_3 + HCl \rightarrow AlCl_3 + H_2O$
$ZnO + HCl \rightarrow ZnCL_2 + H_2O$

Chemical properties of metal oxides

1. **Reaction of metal with water**

   Metal oxides react differently with water. Most of the metal oxides are not soluble in water

   When calcium oxide is added to water, some of it reacts with water to form basic calcium hydroxide:

   $CaO(s) + H_20(l) \rightarrow Ca(OH)_2(aq)$

   Nb:

   Calcium hydroxide is sparingly soluble in water. It forms calcium and hydroxide ions:

   $Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 0H^-(aq)$

   The solution of calcium hydroxide in water is called **lime water** when exhaled air is blown through the, lime water; a white precipitate (calcium carbonate) is formed. Exhaled air contains a large proportion of carbon dioxide

   $Ca(OH)_2(aq) + CO_2(g)\ CaCO_3(s) + H_20(l)$

2. **Reaction of metal oxides with acids and alkalis**

   Most metal oxides react with acids to form a salt and water and Amphoteric oxides react with both and alkalis

Table below shows the reactions of metal oxides with dilute mineral acids

Metal oxides	Reaction
Dilute nitric acid	
Calcium oxide (CaO)	$CaO(s)+2HN0_3(aq) \rightarrow Ca(N0_3)_2(aq) + H_20(l)$
Magnesium oxide (MgO)	$MgO(s)+2HN0_3(aq) \rightarrow Mg(N0_3)_2(aq) + H_20(l)$
Aluminium oxide (Al203)	$Al_20_3(s)+6HN0_3(aq) \rightarrow 2Al(N0_3)_3(aq) + 3H_20(l)$
Iron(II) oxide	$FeO(s)+2HN0_3(aq) \rightarrow$

(FeO)	$Fe(N0_3)_2(aq) + H_20(l)$
Lead(II) oxide (PbO)	$PbO(s)+2HN0_3(aq)\rightarrow Pb(N0_3)_2(aq) + H_20(l)$
Copper(II) oxide (CuO)	$CuO(s)+2HN0_3(aq)\rightarrow Cu(N0_3)_2(aq) + H_20(l)$
Dilute hydrochloric acid	
Calcium oxide (CaO)	$CaO(s)+2HCl(aq) \rightarrow CaCl_2(aq) + H_20(l)$
Magnesium oxide (MgO)	$MgO(s)+2HCl(aq)\rightarrow MgCl_2(aq) + H_20(l)$
Aluminium oxide(A1203)	$Al_20_3(s)+6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_20(l)$
Iron (II) oxide (FeO)	$FeO(s) + 2HCl(aq) \rightarrow FeCl_2(aq)+ H_20(l))$
Lead (II) oxide (PbO)	$PbO(s) + 2HCl(aq) \rightarrow PbCl(s) + H_20(l)$
Copper (II) oxide (CuO)	$CuO(s)+2HCl(aq) \rightarrow CuCl_2(aq) +H_20(l)$
Dilute sulphuric acid	
Calcium oxide (CaO)	$CaO(s) +H_2SO_4(aq)\rightarrow CaSO_4(s) + H_20(l)$
Magnesium oxide (MgO)	$MgO(s)+H_2SO4(aq)\rightarrow MgSO_4(aq) + H_20(l)$
Aluminium oxide(A1203)	$A1_20_3(s) + 3H_2SO_4(aq) \rightarrow A1_2(SO_4)_3(aq)+ 3H_20(l)$
Iron (II) oxide (FeO)	$FeO(s)+H_2SO_4(aq)\rightarrow FeSO_4(aq) + H_20(l)$
Lead (II) oxide (PbO)	$PbO(s) + H_2SO_4(aq)$ $PbSO_4(s) + H_20(l)$
Copper (II) oxide(CuO)	$CuO(s) + H_2SO_4(aq)$ $CuSO_4(aq) + H_20(l)$

Nb:

i. Magnesium, aluminium, zinc and lead oxides are basic oxides. They react with dilute nitric acid to form a salt and water only.

ii. Aluminium, zinc and lead oxides react with both the sodium hydroxide and the nitric acid. They are amphoteric oxides.

iii. Dilute sulphuric acid and hydrochloric acids cannot be used with lead (II) oxide because they form insoluble salts:
$PbO (s) + 2HCl (aq) \rightarrow PbCl (s) + H_20 (l)$
$PbO (s) + H_2S0_4 (aq) \rightarrow PbSO_4(s) + H_20 (l)$
The insoluble salts form a coating on the oxides, thus preventing further reaction.

iv. Metal oxides react with dilute acids to form salt and water only

v. The calcium sulphate formed from the reaction of calcium oxide with dilute sulphuric acid is sparingly (slightly) soluble in water

vi. Dilute nitric acid reacts with metal oxides to form the metal nitrate and water. All metal nitrates are soluble in water.

vii. Dilute hydrochloric acid reacts with metal oxides to give the metal chlorides and water

viii. The reaction between lead (II) oxide and dilute hydrochloric acid stops as soon as it starts
Reason: This is due to the formation of lead (II) chloride which is insoluble; the lead (II) chloride forms a coating on the lead (II) oxide, thus preventing further reaction

ix. Dilute sulphuric acid reacts with metal oxides to give metal sulphates and water

x. The reactions involving calcium oxide with sulphuric acid produces insoluble calcium sulphate and stops as soon as it starts
Reason: The sulphates form a coating on their respective metal oxides, thus preventing further action on the metal oxides

xi. The reactions involving lead (II) oxide with sulphuric acid produces insoluble lead (II) sulphate and stops as soon as it starts
Reason: The sulphates form a coating on their respective metal oxides, thus preventing further action on the metal oxides

Uses of metal oxides

The following are the uses of metal oxide

i. Calcium oxide used to prepare calcium carbide
ii. Calcium oxide used as Refactors in furnace to Lining of furnaces

iii. Calcium oxide used in Formation of slag in extraction of iron
iv. Calcium oxide used as Drying agent in preparation of ammonia gas and ethanol
v. Calcium oxide used to Make mortar (CaO + sand + water) for stick brick together and to plaster building
vi. Calcium oxide used to manufacture cement (mixture of calcium silicate and aluminates)
vii. Calcium oxide used as lime material to treat soil
viii. Magnesium oxide is used as lining for open-heath and steel furnaces because it have high melting point (2800)℃
ix. Zinc oxide used as a white pigment in paints, filter in rubber
x. Zinc oxide used as a component of glazes, enamels and antiseptic ointments
xi. Aluminium oxide used as an abrasive (capable of polishing or cleaning a hard surface by rubbing or grinding)

Metal Hydroxides

By Defn: *Metal Hydroxides is any inorganic compound that contains the hydroxyl group (-OH)*

Nb:

i. Most Metal Hydroxides are base
ii. The Alkali Metal Hydroxides such as Sodium Hydroxide are very soluble in water and are very strong Base

Preparations of Metal Hydroxides by Direct Method

The Metals those have high in the Reactivity Series are reacted with water to form the Hydroxide and hydrogen gas (effervescence)

$Ca + 2H_2O \rightarrow Ca(OH) + H_2$
$Na + 2H_2O \rightarrow Na(OH) + H_2$
$K + 2H_2O \rightarrow K(OH) + H_2$
$Mg + 2H_2O \rightarrow Mg(OH) + H_2$

Nb:

The Hydroxide of metal below hydrogen in the reactivity series cannot be prepared by the direct method

Preparation of Metal Hydroxides by Indirect Method

The Hydroxide is obtained by reaction between Alkalis (Base) with Salts to form Hydroxide. See the Example Below.

$ZnCl_2 + NaOH \rightarrow Zn(OH)_2 + NaCl$
$CuCl_2 + NaOH \rightarrow Cu(OH)_2 + NaCl$
$FeCl_3 + NaOH \rightarrow Fe(OH)_3 + NaCl$

ClassifiCation of Metal Hydroxides

It classified by their Solubility in water, and Reaction with Acid and Base. They classified into three, includes

i. Soluble Hydroxides
ii. Insoluble Hydroxides
iii. Basic Hydroxides
iv. Amphoteric Hydroxides

Soluble Hydroxide

Most metal hydroxides are soluble in water and hydroxide of Magnesium and Calcium are sparing soluble in water

Insoluble Hydroxide

Alkali metal hydroxides and metal hydroxides of zinc, Lead and Aluminium are insoluble in water

Basic Hydroxide

All hydroxides are basic in Nature it react with Acid to form Salt and Water

Amphoteric Hydroxide

When excess Sodium Hydroxide is added to the insoluble metal hydroxides of zinc, Lead and Aluminium, They dissolve to form Complex ions. These hydroxides are said to be Amphoteric. They react both with Acid and Base

$Zn(OH)_2 + NaOH \rightarrow Na_2ZnO_2 + 2H_2O$

$Pb(OH)_2 + NaOH \rightarrow Na_2PbO_2 + 2H_2O$

$Al(OH)_3 + NaOH \rightarrow Na_2AlO_2 + 2H_2O$

Chemical Properties of Metal Hydroxides

1: **Action on Heating**

Hydroxides of metals high in the reactivity series do not decompose on heating but the left decompose to give a metal oxide and water

$Pb(OH)_2 \rightarrow PbO + H_2O$

2: **Action on Acids**

Metal hydroxides react with mineral acids to give a Salt and Water

$NaOH + HCL\ NaCl + H_2O$

Uses of Metal Hydroxides

The following include some of the uses

i. Calcium Hydroxide (slake lime) Uses as **Liming Material** in soil treatment
ii. Hydroxide of Aluminium and Magnesium uses as **Antacids** to neutralize stomach acid
iii. Calcium Hydroxide uses to make **mortal**
iv. Calcium Hydroxide Used in Bleaching of pulp to prepare ($Ca(HSO_3)_2$) sulphite pulp (used in making parer and artificial silk) from wood
v. Manufacture of paints
vi. Uses in Qualitative Analysis
vii. Calcium Hydroxide used to soft water
viii. Sodium Hydroxide used in Extraction of Aluminium from Bauxite Ore

Metal Carbonates

By defn: *Metal Carbonates are formed when both hydrogen atoms in carbonic acid (H_2CO_3) are replaced by a metal*

Preparation of Metal Carbonates

They are two method used to prepare carbonates, includes

i. Soluble carbonates
ii. Insoluble carbonates

Soluble carbonates

Soluble carbonates prepared by reacts corresponding Alkali with Carbon dioxide

$2NaOH\ (aq) + CO_2 \rightarrow Na_2CO_3 + H_2O$

Nb:

i. The Crystalline Sodium Carbonate is known as **Washing Soda**
ii. Sodium, Potassium and Ammonium carbonate are the only soluble carbonate

Insoluble carbonates

All Insoluble Metal Carbonate prepared by precipitate Method. Any soluble carbonate can be reacted with other soluble salt of the Metal

$CaCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow CaCO_{3(s)} + 2NaCl_{\ (aq)}$

$MgCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow MgCO_{3(s)} + 2NaCl_{\ (aq)}$

$ZnCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow ZnCO_{3(s)} + 2NaCl_{\ (aq)}$

$FeCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow FeCO_{3(s)} + 2NaCl_{\ (aq)}$

$CuCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow CuCO_{3(s)} + 2NaCl_{\ (aq)}$

$2PbCl_{(aq)} + Na_2CO_{3(aq)} \rightarrow Pb_2CO_{3(s)} + 2NaCl_{\ (aq)}$

Nb:

i. Potassium carbonates can be used in place of Na_2CO_3
ii. Na_2CO_3 is not used to prepare carbonate of Lead, Zinc and Copper. Instead of precipitating simple carbonates of Lead, Zinc and Copper. Na_2CO_3 also precipitate basic Carbonates of these metals, that is $ZnCO_3.Zn(OH)_2$, $CuCO_3.Cu(OH)_2$ and $PbCO_3.Pb(OH)_2$ respectively.
iii. Aluminium Carbonate (Al_2CO_3) and Iron(II) Carbonate $Fe_2(CO)_3$ does not exist

ClassifiCation of Metal Carbonates

They classified into two due to Solubility in water, includes

i. Soluble carbonates
ii. Insoluble carbonates

Soluble Carbonates
All Alkali metal carbonates include of Sodium, Potassium and so on is soluble in water

Insoluble Carbonates
All left metal carbonates include of Calcium, Magnesium, Zinc, Iron (III) and Copper are soluble in water

Chemical Properties of Metal Carbonates
1. **Action on Heating**
Carbonates of metals high in the reactivity series do not decompose on heating but the left decompose to give a metal oxide and Carbon dioxide.
$MgCO_3Pb(OH)_2 \rightarrow MgO + CO_2$

2. **Action on Diluted Acids**
Metal carbonates s react with mineral acids to give a Salt, Carbon dioxide and Water.
$Na_2CO_3 + 2HCL \rightarrow 2NaCl + H_2O + CO_2$

Test for Carbonates
1. The carbon dioxide from carbonates after *decomposes* or *neutralization* forms a **white precipitation** with lime water (Calcium Hydroxide).
$CaOH + CO_2 \rightarrow CaCO_3$
This is used as a *confirmatory test* for Metal Carbonates

2. The soluble Carbonates when react with Magnesium Sulphate solution which is soluble in water form **white precipitation** of Magnesium carbonates which is insoluble Salt.
$Na_2CO_{3(aq)} + MgSO_{4(aq)} \rightarrow 2NaSO_{4(aq)} + MgCO_{3(s)}$

Uses of Hydrogen Carbonates
i. Sodium carbonate Used to soft water
Sodium carbonate is used to remove both temporary and permanent hardness of water. It reacts with the ions to form insoluble carbonates
Temporary water
$Ca(HCO_3)2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaHCO_3(aq)$

Permanent water
$MgSO_4(aq) + Na_2CO_3(aq) \rightarrow MgCO_3(s) + Na_2SO_4(aq)$
The insoluble carbonates are then filtered out

ii. **Manufacture of glass**: Glass is made by heating *sand*, *calcium carbonate* and *sodium carbonate* together, at a temperature of 1300°C to 1400°C
$CaCO_3(s) + Si0_2(s) \rightarrow CaSiO_3(s) + C0_2(g)$
$Na_2CO_3(s) + Si0_2(s) \rightarrow Na_2SiO_3(s) + C0_2(g)$
NB: Glass is a mixture of sodium and calcium silicates

iii. Sodium Carbonates is used in the qualitative analysis of reactions involving carbonates because it is soluble in water

iv. Sodium carbonate is also used in quantitative analysis because the moisture it absorbs from the air can readily be removed by heating without decomposing the salt

v. Sodium carbonates used to Manufacture of sodium Hydroxide
$Na_2CO_3 + Ca(OH)_2 \rightarrow 2NaOH + CaCO_3$

vi. Sodium carbonates is used to Manufacture of water Glass
When Sodium Carbonates is heated together with Silicon dioxide form A concentration solution of Sodium Silicates ($NaSiO_3$) in water known **Water Glass**
$Na_2CO_3 + SiO_2 \rightarrow NaSiO_3 + CO_2$

Uses of water glass
(a) It is used as a Preservative for Eggs
(b) It is used as an adhesive in paper making and in television tubes

Metal Hydrogen Carbonates

By defn: Metal Hydrogen Carbonates are *formed when only one hydrogen atoms in carbonic acid (HCO_3) are replaced by a metal*

Preparation of Metal Hydrogen Carbonates

1. Reaction between concentrated Sodium Hydroxide (NaOH) and Excess Carbon dioxide. The reaction takes place in two stages includes

   First Stage

   $NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$

   Second Stage

   $Na_2CO_3 + H_2O + CO_2 \rightarrow NaHCO_3$

2. The Calcium carbonates also prepared as the Sodium Carbonate. The reaction takes place in two stages includes

   First Stage

   $CaOH + CO_2 \rightarrow CaCO_3 + H_2O$

   Second Stage

   $CaCO_3 + H_2O + CO_2 \rightarrow CaHCO_3$

Nb:

When Calcium hydrogen carbonate boiled it decompose to form calcium carbonate, carbon dioxide and water. Magnesium hydrogen carbonate can also prepared using the procedure as Calcium hydrogen carbonate prepared above.

Chemical Properties of Metal Hydrogen Carbonates

1. **Action on Heating**

Hydrogen carbonates whether in solution or solid form Decompose on heating to give a metal carbonate and Carbon dioxide

$CaHCO_3 \rightarrow CaCO_3 + H_2O + CO_2$

$NaHCO_3 \rightarrow NaCO_3 + H_2O + CO_2$

2. **Action on Diluted Acids**

Metal Hydrogen carbonates s react with mineral acids to give a Salt, Carbon dioxide and Water

$NaHCO_3 + HCL \rightarrow NaCl + H_2O + CO_2$

Test for Hydrogen Carbonates

1. The carbon dioxide from Hydrogen carbonates after decomposes or neutralization forms a **white precipitation** with lime water (Calcium Hydroxide).

$CaOH + CO_2 \rightarrow CaCO_3$

This is used as a **confirmatory test** for Metal hydrogen carbonates

2. The Hydrogen Carbonates when react with Magnesium Sulphate solution which is soluble in water form soluble salt of Magnesium hydrogen Carbonates

$NaHCO_3\ (aq) + MgSO_4\ (aq) \rightarrow 2NaSO_4\ (aq) + Mg(HCO_3)_2(aq)$

But: when heated Magnesium hydrogen Carbonate salt decompose to form white precipitation of Magnesium Carbonates which is insoluble Salt.

$Mg(HCO_3)2(aq) \rightarrow MgCO_3(s) + H_2O(l) + CO_2(g)$

Nb:

i. All Metal Hydrogen Carbonates are soluble in water
ii. The Hydrogen carbonates of Aluminium, Zinc, Iron, Lead, and Copper do not exist

Uses of Hydrogen Carbonates

i. Sodium hydrogen carbonates used to make Baking soda

ii. Sodium Hydrogen Carbonates act as Antacid which neutralizes the Hydrochloric Acid in the stomach

Metal Nitrates

By Defn: *Metal Nitrates are the Salts delivered from Nitric Acid*

Preparations of Metal Nitrates

There are different methods of prepare Metal Nitric. These include

i. Reaction between metal with dilute Nitric Acid
$Na_{(s)} + 2HNO_{3\,(aq)} \rightarrow 2NaNO_{3\,(aq)} + H_{2\,(g}$
$Mg_{(s)} + 2HNO_{3\,(aq)} \rightarrow Mg(NO_3)_{2\,(aq)} + H_{2\,(g}$
$Cu_{(s)} + 2HNO_{3\,(aq)} \rightarrow Cu(NO_3)_{2\,(aq)} + H_{2\,(g}$

ii. Reaction between metal Hydroxide with dilute Nitric Acid
$NaOH_{(aq)} + HNO_{3(aq)} \rightarrow NaNO_{3\,(aq)} + H_2O_{(l)}$

iii. Reaction between metal Oxides with dilute Nitric Acid
$CuO_{(s)} + 2HNO_{3\,(aq)} \rightarrow Cu(NO_3)_{2(aq)+}H_2O_{(l)}$

iv. Reaction between metal Carbonates with dilute Nitric Acid
$CuCO_{3(s)} + 2HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + CO_{2(g)} + 2H_2O_{(l)}$

v. Reaction between metal Hydrogen carbonates with dilute Nitric Acid
$CuHCO_{3(s)} + HNO_{3(aq)} \rightarrow Cu(NO_3)_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

Nb:

i. Nitric Acid, unlike other acid, does not give hydrogen gas with Metal, except the acid is very diluted about one percentage by mass
$Mg_{(s)} + 2HNO_{3\,(aq)} \rightarrow Mg(NO_3)_{2\,(aq)} + H_{2\,(g)}$

ii. **Metal reacts with concentrated nitric acid to give a *Nitrate of metal* among other products**
The other product depend the concentration of the nitric acid. Nitrogen gas (**Brown gas**) is the mainly gas given off when Metals react with concentrated nitric acid

Magnesium reacts with concentrated nitric acid to form a solution of magnesium nitrate and nitrogen (IV) oxide gas
$Mg_{(s)} + 4HNO_{3(aq)} \rightarrow Mg(NO_3)_{2(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$

Zinc does not give nitrogen dioxide with concentration nitric acid instead ammonium nitrate is formed
$4Zn_{(s)} + 10HNO_{3(aq)} \rightarrow 4Zn(NO_3)_{2(aq)} + NH_4NO_{3(aq)} + 3H_2O_{(g)}$

Copper Metal reacted with concentrated nitric Acid to give a *blue solution* of Copper nitrate and Brown fumes of Nitrogen (iv) oxide gas
$Cu(s) + 4HNO_3(l) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$

When moderately concentration nitric Acid is used, nitrogen monoxide gas (NO) is formed instead of Nitrogen (IV) oxide.
$3Cu(s) + 8HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2NO(g) + H_2O(l)$

The solution should not be evaporated to dryness because Nitrate will undergo thermal decomposing

The reaction of nitric acid with aluminium and Iron stops soon after starting due to the formation of an Oxide layer on the Metals surfaces. The Oxide layer prevents further reaction between the Acid and the Metals

iii. **Dilute nitric acid reacts with metal hydroxides in a neutralization reaction to give a salt and water**
A blue solution of copper nitrate is formed when copper carbonate reacts with dilute nitric acid
$CuCO_3(s) + 2HN0_3\ (aq)\ Cu(N0_3)_2(aq) + C0_2(g) + H_20\ (l)$
When the solution is heated to saturation then cooled, blue crystals of copper nitrate are formed

Sodium carbonate, a colourless solution of sodium nitrate is formed
$Na_2CO_3(s) + 2HN0_3\ (aq)\ 2NaNO_3\ (aq) + C0_2\ (g) + H_20\ (l)$
White crystals of sodium nitrate are formed when the solution is heated to saturation, and then cooled

iv. **Reactions between dilute nitric acid and metal hydroxides are neutralization reactions**

The acid reacts with sodium hydroxide to form sodium nitrate and water

$NaOH\ (aq) + HNO_3\ (aq) \rightarrow NaNO_3\ (aq) + H_20(l)$

White crystals of sodium nitrate are formed when the solution of sodium nitrate is heated to saturation then cooled

v. **Reactions between dilute nitric acid and metal oxides are neutralization reactions**

Zinc oxide forms a colourless solution of zinc nitrate. This is shown in the equation below

$ZnO_{(s)} + 2HN0_{3\ (aq)} \rightarrow Zn(N0_3)_{2(aq)} + H_2O_{\ (l)}$

White zinc crystals are formed when the colourless solution is heated to saturation

Copper (II) oxide reacts with dilute nitric acid to form a blue solution of copper nitrate

$CuO(s) + 2HNO_3(aq) \rightarrow Cu(NO_3)_{(aq)} + H_2O_{\ (l)}$

The solution forms **blue crystals** when heated to saturation then cooled

Calcium oxide forms a colourless solution of calcium nitrate. The solution forms white crystals when the saturated solution is cooled

$CaO_{(s)} + 2HN0_{3\ (aq)} \rightarrow Ca(N0_3)_{2(aq)} + H_20_{(l)}$

Chemical Properties of Metal Nitrates

The following Metal Nitrates IdentifiCation by their production on heating

i. All Nitrate of Sodium and Potassium decompose to gives Metal Nitrite and Oxygen gas

$NaNO_3\ (aq) \rightarrow NaNO_2\ (s) + O_2\ (g)$

$KNO_3\ (aq) \rightarrow KNO_2\ (s) + O_2\ (g)$

ii. All Nitrate of Calcium, Magnesium, Aluminium, Zinc, Iron, Lead and Copper decompose to gives Metal Oxide, Nitrogen dioxide and Oxygen gas

$2Ca(NO_3)_{2(s)} \rightarrow 2CaO_{(s)} + 4NO_{2\ (g)} + O_{2\ (g)}$

$2Cu(NO_3)2_{(s)} \rightarrow 2CuO_{\ (s)} + 4NO_{2\ (g)} + O_{2\ (g)}$

$2Pb(NO_3)2_{(s)} \rightarrow 2PbO_{\ (s)} + 4NO_{2\ (g)} + O_{2\ (g)}$

$2Zn(NO_3)2_{(s)} \rightarrow 2ZnO_{\ (s)} + 4NO_{2\ (g)} + O_{2\ (g)}$

iii. All Nitrate of Silver and Mercury decompose to gives Metal, Nitrogen Dioxide and Oxygen gas

$AgNO_3\ (s)\ 2Ag\ (s) + 2NO_2\ (g) + O_2\ (g)$

$HgNO_3\ (s)\ 2Hg\ (s) + 2NO_2\ (g) + O_2\ (g)$

Test for Nitrates

The follows is different tests of nitrate, include

i. Decomposition of metal nitrates
ii. Metal nitrate React with Copper
iii. Brown Ring Test

Decomposition of metal nitrates

When metal nitrate except of most reactive metal decompose on heating and always the **Reddish Brown Fumes** of Nitrogen dioxide (NO_2) are observed

Metal nitrate React with Copper

Any Metal nitrate will readily dissolve in water to form solution and react with metal to form brown **fumes** of Nitrogen dioxide (NO_2) are observed

Brown Ring Test

When concentration sulphuric acid is poured down the side of the test tube, it moves down and settles at the bottom of the test tube contain the mixture of the prepared Iron (II) Sulphate and Metal Nitrate. A brown ring forms between the layer forms between the layer of concentration Sulphuric Acid and the Mixture of the solution of Metal nitrates and Iron sulphate, if the test solution is a Nitrate

Concentration sulphuric acid + (Iron (II) Sulphate + Metal Nitrate) → brown ring

Nb:

Brown ring test is the best test since all Nitrate form this Brown Ring

How Brown Ring Formed

i. Concentrated sulphuric acid react with Nitrate ion to form Nitric acid

$H_2SO_4\ (l) + 2NO_3^-(aq) \rightarrow 2HNO_3(aq) + SO_4^{2-}$

ii. Nitric acid Oxidizes Iron (II) Sulphate to form Iron (III)

$Fe^{2+} \rightarrow Fe^{3+}$

iii. Nitric acid itself reduced to nitrogen Monoxide

$4HNO_{3\ (aq)} + 4NO_{\ (aq)} + 2H_2O_{\ (l)} + 3O_{2\ (g)}$

iv. The nitrogen Monoxide combine with some of the remaining Iron (II) Sulphate to form a **Dark Brown Complex**
$FeSO4_{(aq)} + NO_{(g)} \rightarrow FeSO4.NO_{(aq)}$

Nb:

i. If the solution is disturbed the Brown ring disappears
Reason: This is because concentrated Sulphuric Acid and Water mix, produce allot of heat which helps to decompose the Dark Brown Complex which is a very Unstable Compound
$FeSO4.NO_{(aq)} \rightarrow FeSO4_{(aq)} + NO_{(g)}$

ii. The formation of the brown complex is a reversible chemical reaction
$FeSO4.NO_{(aq)} \rightleftharpoons FeSO4_{(aq)} + NO_{(g)}$

Uses of Metal Nitrates

i. **Agriculture**: Nitrogen fertilizers are mainly Nitrate. They include Ammonium Nitrate, Potassium Nitrate, and calcium nitrate

ii. **Photography**: Silver Nitrate Solution reacts with Potassium Bromide to form Silver bromide.
$2AgNO_3(aq) + KBr_{(aq)} \rightarrow 2AgBr_{(s)} + KHO_{3\,(aq)}$
Photographic films and plates contain an emulsion in form of Silver Bromide which decomposes to small amount of Silver on exposure to Light
$2AgBr(s) \rightarrow 2Ag\ (s) + Br_2\ (g)$
The photochemical change involving Silver Bromide is the key reaction in Black and White photography

iii. **Antiseptics**: Is the one which used to kill Germs on the Skin. **Silver Nitrate Compound and Silver Sulphadiazine** have been used to prevent the infection of burns and some eye infections and to destroy Warts

iv. **Weapons**: Gun powder is a mixture of **potassium Nitrate, Charcoal and Sulphur**. Ammonium Nitrate is also used in making explosives and blasting agents which are used in mines and quarries

v. **Food Preservation**: Nitrates and Nitrites are used in Curing meats and fish, Not only to kill Bacteria but also to produce a characteristic flavour and give meat a pink or Red colour
How: Potassium and Sodium Nitrate is used as a source of Nitrite (NO_2), the nitrite breaks down in the meat into Nitric Oxide (NO) which helps to prevent Oxidation of Meat and fish.

Metal Chlorides

By defn: Chlorides are salts that are derived from hydrochloric acid

Preparation of metal chlorides

Metal chlorides are prepared using common methods used to prepare other salts. Include

i. Precipitation (for insoluble chlorides)
ii. Metal reacts with dry chlorine gas
iii. Reaction of hydrochloric acid with an alkali
iv. Reaction of hydrochloric acid with a metal oxide
v. Reaction of hydrochloric acid and a metal carbonate
vi. Reaction of hydrochloric acid with a metal

Preparation by Precipitation method

When Silver nitrate solution reacts with dilute hydrochloric acid to form silver chloride

$AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$

Also lead nitrate reacts with dilute hydrochloric acid to form lead chloride

$Pb(N0_3)_2(aq) + 2HCl(aq) \rightarrow PbCl(s) + 2HN0_3\ (aq)$

Nb:

i. Silver and lead chlorides are insoluble in water. They are prepared using the precipitation method

ii. When **white** solids silver chloride exposed to light, silver chloride decompose to from **purple** silver metal and chlorine gas
$2AgCl(s)\ 2Ag(s) + Cl_2\ (g)$

iii. when **white solids** lead chloride exposed to light, lead chloride decompose to from **white** of lead metal and chlorine gas
$2PbCl(s)\ 2Pb(s) + Cl_2\ (g)$

Preparation of chlorides

The following is the methods used to prepare chlorides, includes

i. Preparation by direct method
ii. Preparation by Reaction between Hydrochloric Acid with an Alkali
iii. Preparation by reaction between hydrochloric acid with a metal oxide
iv. Preparation by reaction between hydrochloric acid with a metal Carbonates
v. Preparation by reaction between hydrochloric acid with a metal

Preparation by direct method

i. When chlorine gas passed over heated iron the sublimes solid **reddish-brown** Iron (III) chloride is formed. It involves two stages

First stage

The iron (II) Chloride is formed first. The equation for this reaction is as follows.

$Fe(s) + Cl_2\ (g) \rightarrow FeCl_2\ (s)$

Second stage

Chlorine being a strong oxidizing agent oxidizes iron (II) chloride to iron (III) chloride

$2FeCl2(s) + Cl_2\ (g) \rightarrow 2FeCl_3(s)$

Nb: Iron (III) chloride is a ***deliquescent*** *substance*. When it is exposed to air, it absorbs water vapour to form a solution

ii. Zinc and chlorine react to form zinc chloride
$Zn(s) + Cl_2\ (g) \rightarrow ZnCl_2\ (s)$

iii. Aluminium chloride can also be prepared using the same method.
$2Al(s) + 3Cl_2(g) \rightarrow 3Al_2Cl_3(s)$

Preparation by Reaction between Hydrochloric Acid with an Alkali

i. Sodium hydroxide reacts with dilute hydrochloric acid in a neutralization reaction to form **sodium chloride** and **water**
$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_20(l)$

ii. Potassium hydroxide neutralized by dilute hydrochloric acid.
$KOH\ (aq) + HCl\ (aq) \rightarrow KCl\ (aq) + H_20\ (l)$

iii. Calcium hydroxide neutralized by dilute hydrochloric acid
$Ca(OH)_{2(aq)} + 2HCl_{(aq)} \rightarrow CaCl_{2\ (aq)} + H_20_{\ (l)}$

Nb: Sodium chloride, calcium chloride and potassium chloride are all **soluble in water**

Preparation by reaction between hydrochloric acid with a metal oxide

i. Zinc oxide reacts with hydrochloric acid to give a Colourless solution of zinc chloride
$ZnO(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_20(l)$
White crystals of zinc chloride are formed when the solution is boiled to saturation then cooled

ii. Iron (III) oxide, which is **reddish-brown** in colour, reacts with dilute hydrochloric acid to give *a reddish-brown solution of iron (III) chloride*
$Fe_20_{3(s)} + 6HCl_{(aq)} \rightarrow 2FeCl_{3\,(aq)} + 3H_20_{(l)}$

iii. Copper (II) oxide reacts with dilute hydrochloric acid to form a ***green** solution of copper (II) chloride*
$CuO(s) + 2HCl(aq) \rightarrow CuCl(aq) + H_20(l)$
The solution crystallizes to form green crystal of copper (II) chloride

iv. Calcium oxide reacts with dilute hydrochloric acid to form a *colourless solution of calcium chloride*
$CaO(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_20(l)$
The solution crystallizes to form white crystals when a saturated solution of calcium chloride is cooled

Nb:

i. The reaction between hydrochloric acid and lead oxide cannot therefore be used to prepare lead chloride
ii. When dilute hydrochloric acid is added to the lead oxide, the reaction starts then stops after a short time
Reason: This is due to the formation of insoluble lead chloride which forms a coating on the oxide hence preventing any further action of the acid

Preparation by reaction between hydrochloric acid with a metal Carbonates

i. Sodium carbonate forms a colourless solution of sodium chloride when react with dilute hydrochloric acid
$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + C0_2(g) + H_20(l)$

ii. Copper (II) carbonate, which is **green in colour**, reacts to give a *green solution of copper (II) chloride*
$CuCO_3(s) + 2HCl(aq) \rightarrow CuCl_2(aq) + C0_2(g) + H_20(l)$
The solution forms **green crystals** when boiled to saturation then cooled

iii. Calcium carbonate reacts with dilute hydrochloric acid to give a *colourless solution of calcium chloride*
$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl(aq) + C0_2(g) + H_20(l)$
The solution crystallizes to form white crystals of calcium chloride on heating to saturation

Nb:
Lead (II) carbonate cannot be used with hydrochloric acid to prepare lead (II) chloride
Reason: Lead (II) chloride is insoluble and would form a coating on the carbonate, preventing any further contact of the oxide with the acid

Preparation by reaction between hydrochloric acid with a metal

i. When zinc granules are put into dilute hydrochloric acid, metal chloride is formed and hydrogen gas is liberated.
$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
The saturated solutions of zinc chloride crystallize to form white crystals

ii. When magnesium granules are put into dilute hydrochloric acid, metal chloride is formed and hydrogen gas is liberated.
$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
The saturated solutions of magnesium chloride crystallize to form white crystals

Nb:

i. There is no reaction when copper is used
Reason: *Copper is below hydrogen in the reactivity series* and cannot displace hydrogen from the hydrochloric acid to produce hydrogen gas

ii. Sodium cannot be used
Reason:
(a) Reaction would be too vigorous to control
(b) Possibility of an explosion if hydrogen gas catches fire

Chemical properties of metal chlorides

i. All chlorides do not decompose on heat except ammonium chlorides

$NH_4Cl(s) \rightarrow NH_3(g) + HCl(g)$

Nb:

(a) Hydrated chlorides Undergo hydrolysis when heated strongly

(b) **By defn**: *hydrolysis is chemical breakdown of a compound due to reaction with water*

ii. Hydrated magnesium chloride gives up its water of crystallization when it is gently heated

$MgCl_2.6H_20 \rightarrow MgCl_2 + 6H_20$

iii. The liquid turns cobalt chloride paper **pink** due hydrolysis

iv. anhydrous copper (II) sulphate from **white to blue** confirming that the liquid is **water** due hydrolysis

v. When strongly heated, the magnesium chloride decomposes to give a ***greenish-yellow*** gas (chlorine), magnesium oxide and water

$2MgCl_2.6H_20(s) + 0_2(g) \rightarrow 2MgO(s) +2Cl_2(g) +12H_20\ (l)$

Nb:

1. Chlorine gas turns a wet blue litmus paper red, and then bleaches it
2. When magnesium oxide mixed with water, the white residue of magnesium oxide forms a white suspension of magnesium hydroxide

   $MgO(s) + H_20\ (l) \rightarrow Mg(OH)_2\ (s)$
3. The suspension of magnesium hydroxide turns the phenolphthalein indicator from colourless to red or pink

Test for chlorides

The following is the simple chemical reaction used to test metal chlorides

When concentrated sulphuric acid is added to a metal chloride, hydrogen chloride gas is given off

$NaCl_{(s)} + H_2S0_{4\ (l)} \rightarrow NaHSO_{4\ (aq)} + HCl_{(g)}$

The presence of the hydrogen chloride gas can be confirmed by testing using

1. Ammonia gas (concentrated aqueous ammonia)
2. Acidified silver nitrate solution
3. Moist blue litmus paper

By using ammonia gas

Hydrogen chloride gas forms dense white fumes with ammonia gas due to the formation of ammonium chloride

$NH_{3\ (g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$

By using acidified silver nitrate solution

Hydrogen chloride gas also forms a white precipitate with acidified silver nitrate due to the formation of silver chloride

$HCl_{(g)} + AgNO_{3(aq)} \rightarrow HNO_{3(aq)} + AgCl_{(s)}$

By using moist blue litmus paper

The gas is acidic and turns wet blue litmus paper red

Nb:

i. When test presence of hydrogen chloride gas, a few drops of *dilute nitric acid* are added first to a test solution followed by *silver nitrate solution*, a white precipitate of silver chloride is formed if the test solution is a chloride

$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$

Silver chloride does not dissolve even when dilute nitric acid is added to it

ii. Dilute nitric acid is added to prevent precipitation of other silver salts such as a carbonate, otherwise it will be mistaken for a chloride

$2Ag^+_{(aq)} + C0_3^{2-}{}_{(aq)} \rightarrow Ag_2CO_{3(s)}$

iii. If a carbonate is present, it will react with the *nitric acid* to give carbon dioxide and water

$H^+_{(aq)} + C0_3^{2-}{}_{(aq)} \rightarrow C0_{2(g)} + H_20_{(l)}$

iv. Chlorides are not affected by the dilute nitric acid

Uses of metal chlorides

The following are some of the areas where metal chlorides are used.

1. **Manufacture of dry batteries**: Zinc chloride mixed with ammonium chloride is used in dry batteries
2. **Household use**: Common salt (*sodium chloride*) is added to food to give it taste
3. **Food preservation**: Canned foods contain *sodium chloride* which in this case is used as a preservative to prevent the growth of bacteria.

iv. **Petroleum industry**: Aluminium chloride acts as a catalyst in many organic reactions whose reactants are derived from petroleum

v. Aluminium chloride used in the manufacture of synthetic lubricating oils

vi. **Spinning industry**: Magnesium chloride is used to lubricate cotton threads in the spinning industry

vii. **Dentistry**: Magnesium chloride is a constituent of the cement used to fill cavities in teeth.

Metal Sulphates

By defn: *Metal Sulphates are salts that are derived from sulphuric acid*

Preparation of sulphates

The method used for preparing any metal sulphate depends on whether the sulphate is **soluble** or **insoluble**

Nb:

All metal sulphates are soluble in water except the sulphates of barium and lead. Calcium sulphate is sparingly soluble

Preparation of soluble sulphates

Soluble sulphates can be prepared by reacting a *metal*, a *metal carbonate*, a *metal hydroxide* or a *metal oxide* with dilute sulphuric acid.

i. Dilute sulphuric acid reacts with granulated zinc to give a colourless solution of zinc sulphate and hydrogen gas

$Zn(s) + H_2S0_4\ (aq) \rightarrow ZnSO_4\ (aq) + H_2\ (g)$

White crystals of zinc sulphate are formed when the solution is heated to saturation and then cooled.

Nb:

(a) Granulated zinc contains impurities which act as a catalyst
(b) The impurities make the gas produced to have a choking smell. With pure zinc, the reaction would be very slow
(c) metal sulphates such as magnesium, copper and iron (III) sulphates can also be prepared using this method

ii. Zinc carbonate reacts with dilute sulphuric acid to give a colourless solution of zinc sulphate, carbon dioxide gas and water.

$ZnCO_{3(s)}+H_2SO_{4(aq)}\rightarrow ZnSO_{4(aq)}+C0_{2(g)} + H_20_{(l)}$

Nb:

Other metal sulphates that can be prepared in the same way are copper sulphate (using copper carbonate) and magnesium sulphate (using magnesium carbonate)

iii. Zinc hydroxide reacts with dilute sulphuric acid in a neutralization reaction to form zinc sulphate and water
$Zn(OH)_{2(s)} + H_2S0_{4(aq)} \rightarrow ZnSO_{4(aq)} + 2H_20_{(l)}$

Nb:
(a) Zinc sulphate solution is **colourless** but forms **white crystals** of zinc sulphate when heated to saturation then cooled
(b) Other sulphates that can be prepared using the same method are copper sulphate, magnesium sulphate and aluminium sulphate

iv. Copper (II) oxide, which is **black in colour**, reacts with dilute sulphuric acid to form a **blue solution** of copper (II) sulphate
$CuO\ (s) + H2S04\ (aq)\ CuSO4\ (aq) + H20\ (l)$

Nb:
(a) The reaction between copper (II) oxide and dilute sulphuric acid is a neutralization reaction
(b) The blue solution crystallizes to form blue crystals when heated to saturation then cooled

Preparation of insoluble sulphates

Barium and lead sulphates are the two common metal sulphates which are not soluble in water. Insoluble metal sulphates are prepared by precipitation reactions

i. lead sulphates prepared by reacting with dilute sulphuric acid to form precipitation of Lead (II) sulphate
$Pb(N0_3)_{2(aq)} + H_2S0_{4(aq)} \rightarrow PbSO_{4(s)} + 2HN0_{3(aq)}$

ii. A similar reaction would take place if lead chloride used
$PbCl_{2\ (aq)} + H_2S0_{4(aq)} \rightarrow PbSO_{4(s)} + 2HCl_{(aq)}$

iii. A white precipitate of barium sulphate is formed when dilute sulphuric acid is added to barium chloride solution
$BaCl_{2\ (aq)} + H_2S0_{4(aq)} \rightarrow BaSO_{4(s)} + 2HCl_{(aq)}$

iv. similar reaction would take place if barium nitrate used
$Ba(N0_3)_2(aq) + H_2S0_4(aq) \rightarrow BaSO_4(s) + 2HN0_3(aq)$

Chemical properties of sulphates

Effect of heat on metal sulphates

Sulphates are more stable to heat than the corresponding nitrates. Even sulphates of metals low in the reactivity series must be strongly heated to decompose

i. When crystals of hydrated copper sulphate are heated, the colour changes from **blue to white** due to the formation of anhydrous copper (II) sulphate
$CuSO_4.5H_20(s) \rightarrow CuSO_4(s) + 5H_20(l)$

On strong heating, the anhydrous copper (II) sulphate decomposes to copper (II) oxide and sulphur trioxide gas
$CuSO_4(s) \rightarrow CuO(s) + S0_3\ (g)$

Nb:
The gas turns a wet blue litmus paper red

ii. Zinc sulphate decomposes in the same way on strong heating
$ZnSO_4(s) \rightarrow ZnO(s) + S0_3\ (g)$

iii. When hydrated iron (II) sulphate is gently heated, it gives up its water of crystallization to give anhydrous iron (II) sulphate
$FeSO_4.7H_2O(s) \rightarrow FeSO_4(s) + 7H_20(l)$
(Light green) (White)

iv. On strong heating, the anhydrous iron (II) sulphate decomposes to form a reddish-brown iron (III) oxide, Sulphur trioxide and sulphur dioxide
$2FeSO_4(s) \rightarrow Fe_20_3(s) + S0_3\ (g) + S0_2\ (g)$

Nb:
Sulphur dioxide turns the filter paper dipped in acidified potassium dichromate solution to green

v. When hydrated iron (III) sulphate is gently heated, it releases its water of crystallization to form a **reddish brown** solid which is anhydrous iron (III) sulphate
$Fe_2(S0_4)_3.9H_20(s) \rightarrow Fe_2(SO)_3(s) + 9H_20(l)$

vi. On strong heating, the anhydrous iron (III) sulphate decomposes to a **reddish-brown** iron (III) oxide and sulphur trioxide
$Fe_2(S0_4)_3(s) \rightarrow 4Fe_2O_3(s) + 3S0_3(g)$

Nb:

Sulphur trioxide turns a wet blue litmus paper red

Test for sulphates

Barium ions (Ba^{2+}) and lead ions (Pb^{2+}) are used to test for the presence of sulphate ions

Reason: they form insoluble sulphates

How tested

Hydrochloric acid is added to a test solution which is a sulphate, if no effervescence is observed it indicate that the solution is a sulphate. If on adding barium chloride a precipitate is formed, then the test solution is a sulphate.

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

$Pb^{2+}(aq) + SO_4^{2-}(aq) \rightarrow PbSO_4(s)$

Nb:

1. The acid is added to eliminate any sulphites and carbonates, which if present would also form precipitates with barium ions.
   $Ba^{2+}(aq) + SO_3^{2-}(aq) \rightarrow BaSO_3(s)$
   $Ba^{2+}(aq) + CO_3^{2-}(aq) \rightarrow BaCO_3(s)$
2. The acid reacts with any sulphates and carbonates present where by eliminating them from the solution.
3. Similar results would also be obtained if *nitric acid* and *barium nitrate* were used.
4. Soluble salts of lead such as lead nitrate can also be used in place of barium salts

Uses of metal sulphates

The following are uses of some metal sulphates:

Calcium sulphate

Plaster of Paris (POP) which is a form of calcium sulphate is used in the following ways:

i. in making moulds
ii. as plaster
iii. to give an accurate reproduction of a shape
iv. In hospitals to immobilize broken limbs

Iron (II) sulphate

v. To make tablets prescribed to patients who have iron deficiency
vi. To form a reddish-brown iron (III) oxide. The oxide commonly referred to as '**red oxide'** is used as a pigment
vii. To make potassium hexacyanoferrate which reacts with iron (III) ions to form a **dark blue insoluble crystalline** solid called **Prussian** blue which is used extensively as a dye for blue print paper ink
viii. As a weed killer
ix. For treating sewage and water
x. To coagulate (bind together) blood in slaughterhouses
xi. In tanning leather (iron-tanning)
xii. As a fungicide

Barium sulphate

xiii. As a white pigment in white paints.
xiv. When taking X-ray pictures of the digestive tract. Barium ions (Ba^{2+}) have a high ability to scatter X-rays which helps to detect the illnesses and disorders in the digestive tract

Aluminium sulphate

xv. As a mordant in dyeing. A mordant is a substance that to fix a pigment into a fabric during the dyeing process.
xvi. As a size in paper making. A size is a substance that is added to the paper pulp to reduce the tendency of the paper to absorb liquids

Potassium aluminium sulphate

xvii. Alum (potassium aluminium sulphate) is used in the dyeing industry, as a source of aluminium ions (Al^{3+}) which are uncontaminated by iron (III) ions
xviii. It is also used in water treatment plants as a **coagulant**. As a coagulant, it binds together very fine suspended particles into large particles that can be removed by settling and filtration.
xix. Alum is also used in the tanning of leather

Other metal sulphates

xx. Hydrated sodium sulphate ($Na_2SO_4 \cdot 10H_2O$), commonly known as **Glauber's salt**, is used as a mild laxative.
xxi. Copper (II) sulphate is used as a catalyst in the preparation of ethanol.

xxii. Hydrated zinc sulphate (ZnSO4.7H20) is used in the dyeing industry as an antiseptic and in preserving wood
xxiii. Hydrated zinc sulphate (ZnSO4.7H20) is used in zinc-plating by electrolysis

FORM FOUR NOTES

Non-metals and their compounds

Non-metals can be described as elements that lack the general properties of metals

Different Between Metals and Non Metals

Metal	Non Metal
good conductors	Non/poor conductors
forms basic and Amphoteric oxides	forms acidic oxides
ductile and malleable	Brittle
Shine/glow/luster	Little/no luster
High melting point and boiling point	Low melting point and boiling point
Lose electrons	Gain electrons

Nb:

Most non-metal exist in gaseous or liquid

Some non-metal exist in solid form like carbon

General Chemical Properties of Non Metals

Oxidizing properties

Non-metal are oxidizing agent since it gain electrons. Electronegativity (tendency to gain electron) decrease down the group, Hence oxidizing power decrease down the group

Displacement reactions involving halogens

Most non-metal replaces less non-metal during chemical reaction

Fluorine displace chlorine or bromine

$2KCl(aq) + F_2(g) \longrightarrow 2KF(aq) + Br_2(l)$

$PbBr_2(aq) + F_2(g) \longrightarrow PbF_2(aq) + Br_2(g)$

Chlorine displace iodine or bromine

$2KBr(aq) + Cl_2(g) \longrightarrow 2KFCl_{(aq)} + Cl_{2(g)}$

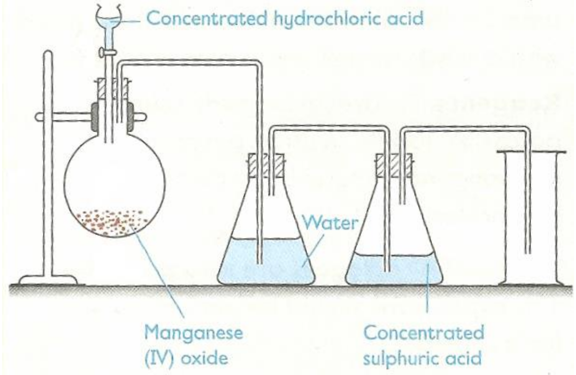
$NaI\ (aq) + Cl_2(g) \longrightarrow NaCl\ _{(aq)} + Cl_{2(g)}$

Chlorine

Chlorine exists as a diatomic molecule with an atomic number of 17. Chlorine is a very reactive element. It is the second strongest oxidizing agent among the halogens, after fluorine. Sodium chloride is the source main of chlorine in most industrial processes

Preparation of Chlorine by Using HCl

It prepared by oxidation of HCl by using oxidizing agent like potassium permanganate, manganese (IV) oxide and lead (IV) oxide. No heating is required.



$MnO_2\ (s) + 4HCl\ (g) \longrightarrow Cl_2\ (g) + MnCl_2\ (aq) + 2H_2O\ (l)$

Nb:

i. Water in the first conical flask is to remove any acid spray and hydrogen chloride gas
ii. Conc. Sulphuric acid in the second conical flask for dry chlorine gas
iii. It collected down ward delivery because it is denser than air
iv. When we use potassium permanganate no need to use heat because is more reactive (very strong oxidizing agent)

Preparation of Chlorine by Using H_2so_4

Consider the diagram above exchange HCL for H_2SO_4. Then mix sodium chloride with manganese (IV) oxide. Heat is required. The mixture forms hydrogen chloride and then hydrochloric acid during the reaction. The chloride ions (Cl^-) are then oxidized by manganese (IV) oxide to chlorine. The overall equation for the reaction is

$2NaCl\ (s) + 3H_2S0_4\ (l) + MnO_2(s) \longrightarrow 2NaHSO_4(s) + MnSO_4\ (s) + 2H_2O\ (l) + Cl_2\ (g)$

Preparation of Chlorine by Using Mineral Acid

Chlorine can also be prepared by the action of any dilute mineral acid on calcium

hypochlorite bleaching powder, ($CaOCl_2$). No heating is required.
$CaOCl_2 (s) + 2HCl (aq) \longrightarrow CaCl_2 (aq) + H_2O (l) + Cl_2 (g)$

Physical Properties of Chlorine

i. Chlorine gas is greenish-yellow in colour with pungent irritating smell. It is poisonous
ii. It is denser than air
iii. It is soluble in water to form pale yellow solution known as chlorine water

Chemical Properties of Chlorine

i. It is soluble in water to form pale yellow solution known as chlorine water
$C1_{2\,(g)} + H_2O_{\,(l)} \longrightarrow HCl_{\,(aq)} + HOCl_{\,(aq)}$

Chlorine water is a mixture of chlorine as in water, chloric (I) acid (HOCl), and hydrochloric acid (HCl). When hypochlorous (chloric (I) acid) acid comes into contact with a dye, it oxidizes the dye to a colourless compound. This process called **bleaching**
$HOCl(aq)$ + dye $\longrightarrow$ $HCl(aq)$ + dye - oxygen complex (colourless)

ii. When hydrogen sulphide gas is passed through chlorine water, it turns colourless and a yellow precipitate is formed. Chlorine oxidizes the hydrogen sulphide gas to sulphur and is itself reduced to hydrogen chloride gas.
$H_2S (g) + Cl_2 (g) \longrightarrow S(s) + 2HCl (g)$
The sulphur produced in the reaction forms a yellow precipitate.

iii. Hydrogen chloride gas forms white fumes of ammonium chloride, with ammonia gas.
$NH_3 (g) + HCl (g) \longrightarrow NH_4Cl(s)$

iv. Chlorine is a strong oxidizing agent. It oxidizes the iron (II) chloride to iron (III) chloride.
$C1_2 (g) + 2FeCl_2(s) \longrightarrow 2FeC1_3(s)$
The green iron (II) chloride turns brown, the colour of iron (III) chloride.

v. Chlorine reacts with hydrogen gas to form hydrogen chloride gas.
$Cl_2 (g) + H_2(g) \longrightarrow 2HC1(g)$

vi. Chlorine oxidizes sulphites such as sodium sulphide, to sulphates
$Na_2SO_3(aq)+C1_2(g) + H_2O(1) \longrightarrow Na_2SO_4(aq) + 2HC1(aq)$

vii. Chlorine reacts with cold sodium hydroxide solution to form a mixture of chlorides and hypochlorite which are bleaching agents.
$2NaOH(aq) + Cl_2(g) \longrightarrow NaCl(aq) + NaOCl(aq) + H_2O(l)$

viii. The gas reacts with a hot solution of sodium or potassium hydroxide to give a mixture of sodium chloride and sodium chlorate.
$3C1_2(g) + 6NaOH(aq) \longrightarrow 5NaCl(aq) + NaC1O_3(aq) + 3H_20(1)$
Chlorine reacts with potassium hydroxide in the same way.

With cold potassium hydroxide solution
$2KOH(aq) + C1_2(g)$ — $KCl(aq) + KOCl(aq) + H_2o(l)$

With hot potassium hydroxide solution
$3C1_2(g) \div 6KOH(aq)$ — $5KC1(aq) + KClO_3 +3H_2o$

ix. Chlorine oxidizes Sulphur dioxide gas to form Sulphur chloride.
$Cl_2(g) + S0_2(g) \longrightarrow S0_2C1_2(g)$

Uses of Chlorine

The following are some of the uses of chlorine.

i. Chlorine is used as a bleaching agent in textile industries. It is also used to bleach wood pulp in the paper industry. Liquid household bleach is a solution of sodium hypochlorite (NaOCl).
ii. Chlorine can be used both as a germicide and a disinfectant. It is also used to treat drinking water, water in swimming pools and sewage.
iii. Chlorine is used to manufacture tetrachloromethane which is used as a solvent. It is also used to manufacture trichloroethane which is used as a solvent to remove grease from clothes.
iv. Chlorine is used to prepare hydrogen chloride gas, which is dissolved in water to form hydrochloric acid. The acid is

used as a reagent in many industrial processes and as a rust remover.

v. Chlorine is used to manufacture plastics such as polychloroethene which is commonly known as **polyvinylchloride** (PVC). PVC is used in making insulators for wires and cables.

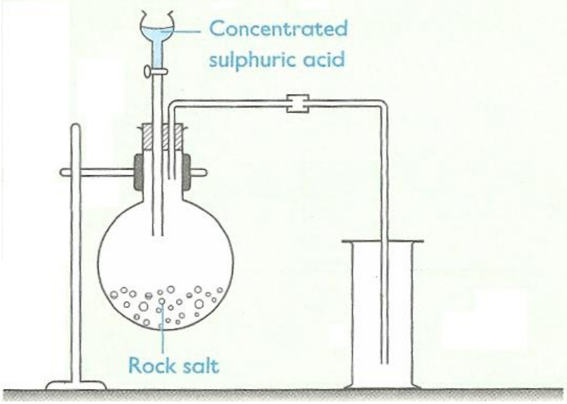
Hydrogen Chloride Gas

Hydrogen chloride gas is a compound of chlorine and hydrogen. Its formula is HCl.

Preparation of Hydrogen Chloride Gas

Hydrogen chloride gas can be prepared in the laboratory by reacting rock salt (sodium chloride) with concentrated Sulphuric acid to give sodium hydrogensulphate and hydrogen chloride gas.

$NaCl\ (s) + H_2S0_4\ (l) \rightarrow NaHSO_4\ (aq) + HCl\ (g)$



Physical Properties of Hydrogen Chloride Gas

i. Hydrogen chloride is a colourless gas.
ii. It has a pungent choking smell and the sharp taste of acids.
iii. Dry hydrogen chloride gas does not affect dry blue litmus paper.
iv. Hydrogen chloride gas does not burn and it extinguishes a burning wooden splint.
v. It is about $1\frac{1}{4}$ times denser than air, thus it is collected by downward delivery or upward displacement of air.

Chemical Properties of Hydrogen Chloride Gas

Hydrogen chloride gas dissolves in water to form hydrochloric acid.

$HCl\ (g) + \text{water} \longrightarrow HCl\ (aq)$

Hydrogen chloride gas reacts with ammonia gas to form ammonium chloride (dense white fumes).

$HCl\ (g) + NH_3\ (g) \longrightarrow NH_4Cl(s)$

Chemical Properties of Hydrochloric Acid

i. It reacts with metal to produce metal chloride and hydrogen gas. Example Dilute hydrochloric acid reacts with zinc, Calcium, magnesium and iron metal to form metal chloride and hydrogen gas.

$Zn(s) + 2HCl\ (aq) \longrightarrow ZnCl_2\ (aq) + H_2\ (g)$

$Ca(s) + 2HCl_{(aq)} \longrightarrow CaCl_{2\,(aq)} + H_{2\,(g)}$
$Mg(s) + 2HCl\ (aq) \longrightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$
$Fe(s) + 2HCl\ (aq) \longrightarrow FeCl\ (aq) + H_2\ (g)$

Nb:
(a) The copper (II) sulphate used as crystals
(b) If no catalyst is used, warm the mixture
(c) Cold dilute hydrochloric acid has no effect on copper metal

ii. It reacts with carbonates of more reactive metals to give a salt (chloride), carbon dioxide gas and water. Example carbonates of calcium and magnesium reacts with dilute hydrochloric acid to give carbonates of calcium and magnesium respectively, water and carbon dioxide gas.
$CaCO_{3(s)}+2HCl_{(aq)} \rightarrow CaC1_{2(aq)}+C0_{2(g)}+H_20_{(l)}$
$MgCO_{3(s)}+2HCl_{(aq)} \rightarrow MgCl_2 +C0_{2(g)}+H_20_{(l)}$

iii. Dilute hydrochloric acid reacts with some metal oxides in neutralization reactions to give a salt and water as the only products. For example:
$CaO_{(s)} + 2HCl_{(aq)} \longrightarrow CaC1_{2\,(aq)} + H_20_{(l)}$
$MgO_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2\,(aq)} + H_20_{(l)}$

iv. The reaction of dilute hydrochloric acid with metal hydroxides is a neutralization reaction.
$NaOH_{(aq)} + HC1_{(aq)} \longrightarrow NaC1_{(aq)} + H_20_{(l)}$

Uses of Hydrogen Chloride Gas/ Hydrochloric Acid

1. **Controlling pH in chemical processes**
In industries where high purity is required such as in the manufacture of food, medicines and drinking water, high quality hydrochloric acid is used to control the pH of the water used.

2. **Cleaning metals**
Hydrochloric acid is used to remove rust (oxide) from iron. The acid dissolves the oxide (the rust) to form a chloride.
$Fe_20_3(s) + Fe(s) + 6HC1(aq) \longrightarrow 3FeC1_2(aq) + 3H_20(l)$
Hydrochloric acid is also used in removing limescale from boilers. **Limescale** is the precipitation of calcium salts in water, causing a hard scale to form in pipes, taps, washing machines, shower heads and boilers.

3. **Production of inorganic compounds**
Many useful inorganic compounds can be produced using hydrochloric acid in normal acid-base reactions. These include chemicals such as iron (III) chloride and polyaluminium chloride (PAC). Both iron (III) chloride and PAC are used as flocculation and coagulation agents in the treatment of both waste and drinking water. They are also used in paper production.

4. **Qualitative analysis**
Hydrochloric acid is used to analyze substances in laboratories. For example, iron (II) oxide (FeO) is insoluble in water but it can dissolve in hydrochloric acid to form iron (II) chloride solution. Hydrochloric acid is also used in volumetric analysis.

5. **Production of organic compounds**
Most of the hydrochloric acid manufactured in industries is used in the production of organic compounds such as polyvinylchloride (PVC)

6. The production of fertilizers, dyes, artificial silk and paint pigments.
7. The refining of edible oils and fats.
8. The concentration of metal ores.

Sulphur

Sulphur is a yellow, crystalline non-metallic element that occupies the 16th position in the Periodic Table. Its atomic number is 16. It is a member of Group VI elements.

Nb:

i. Sulphur exists in nature as a free element and in compounds, mainly in sulphides and sulphates.
ii. In hot springs and volcanic areas sulphur exists as free element

Extraction of Sulphur

Sulphur extracted by Frasch process

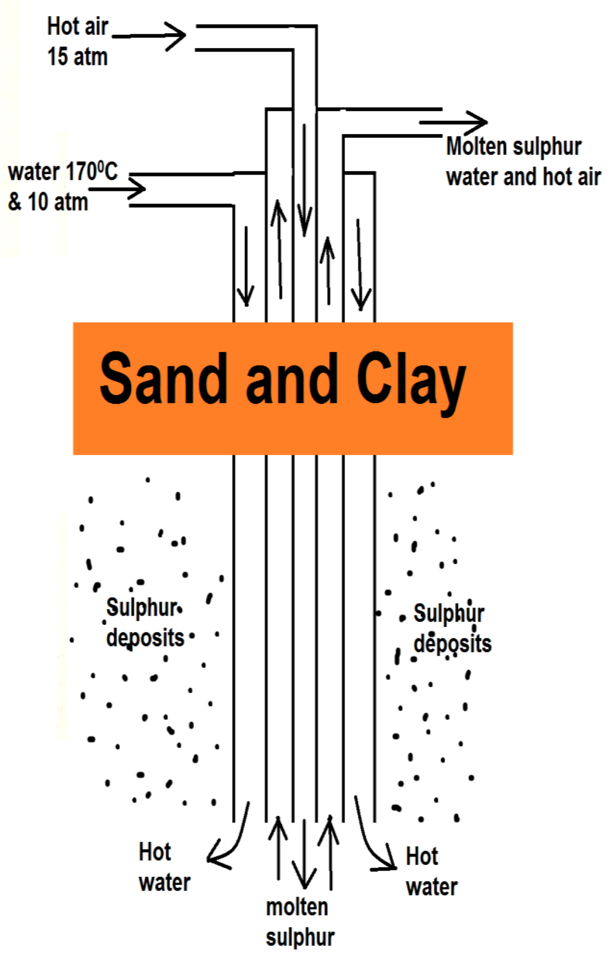
Position of Sulphur

Solid Sulphur are found at over 200 meters or more beneath the rocks and quicksand

Frasch Process

The Frasch process makes use of the relative low melting point (119°C) of sulphur. In this process, three concentric pipes (pipes with a common center) are used

Diagram:



Stages Involved In the Frasch Process

i. Super-heated water (at 170°C) is forced down through the outer pipe to melt the sulphur.
ii. Hot compressed air is forced down through the inner pipe. The combination of the hot water and the hot air melts the sulphur. The molten sulphur, hot air and hot water form froth.
iii. The froth is forced to the earth's surface through the middle pipe by the compressed air. It is then collected in vats, where the water drains off and the sulphur solidifies.

Allotropes of Sulphur

By Defn: Allotropy is the existence of an element in two or more different physical forms in the same physical state. There are two main allotropes of sulphur include.

i. Monoclinic sulphur
ii. Rhombic sulphur

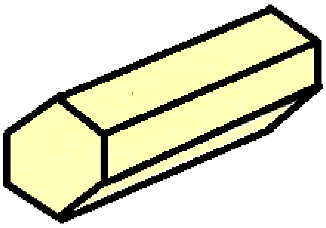
Nb: other allotropes of

iii. Plastic sulphur
iv. Amorphous sulphur
v. Colloidal sulphur

Monoclinic Sulphur

The name is derived from the shapes of the crystals, it containing eight sulphur atoms. Monoclinic sulphur is obtained by allowing molten sulphur to solidify

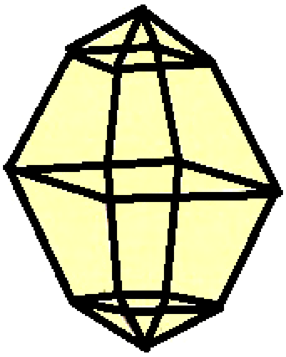
The crystals of monoclinic sulphur are **needle-shaped**. Monoclinic sulphur is also known as **prismatic sulphur or beta sulphur** (β-sulphur). It is stable above 96°C.



Rhombic Sulphur

The name is derived from the shapes of the crystals, it containing eight sulphur atoms. Rhombic sulphur is obtained when sulphur crystallizes from solution in carbon disulphide. The crystals of rhombic sulphur have an **octahedral shape**. Rhombic sulphur changes to monoclinic sulphur when heated above 96°C and vice versa. Rhombic sulphur is also known as **alpha**

sulphur (a-sulphur). Rhombic sulphur is stable below 96°C.



Plastic Sulphur

Plastic sulphur, which is a tough plastic substance formed when molten sulphur is poured into cold water.

Amorphous Sulphur

Amorphous sulphur which is an insoluble white solid that remains when flowers of sulphur are reacted with carbon disulphide. Flowers of sulphur are a fine powder of pure sulphur.

Colloidal Sulphur

Colloidal sulphur, which is a yellow crystalline solid

Physical Properties of Sulphur

i. Sulphur is a yellow solid.
ii. It is a non-metal.
iii. It is insoluble in water but soluble in non-polar solvents such as carbon disulphide and methylbenzene.
iv. If rhombic sulphur is melted and partly allowed to crystallize slowly, needle like crystals of monoclinic sulphur are formed.
v. Rhombic sulphur is stable below 96°C.
vi. Rhombic sulphur has a density of 2.06 gcm^{-3}
vii. Monoclinic sulphur has a density of 1.96 gcm^{-3}
viii. When left standing at room temperature, monoclinic sulphur gradually changes to rhombic sulphur.
ix. Plastic sulphur is insoluble in carbon disulphide

Chemical Properties of Sulphur

In chemical reactions, sulphur exhibits both reducing and oxidizing properties.

i. **Reaction with metals**

Heated sulphur reacts with metals such as iron, copper, zinc and tin, to give metal sulphides.

$Fe(s) + S(s) \longrightarrow FeS(s)$ - (Black)
$2Cu(s) + S(s) \longrightarrow Cu_2S(s)$

ii. **Reaction with acids**

Sulphur is oxidized by strong concentrated acids such as concentrated sulphuric acid and nitric acid. In such reactions, sulphur acts as reducing agent.

$S(s) + 2H_2S0_4\ (1) \longrightarrow 3S0_2\ (g) + 2H_20(l)$
$S_{(s)} + 6HN0_{3\ (l)} \rightarrow H_2S0_{4\ (g)} + 6N0_{2\ (g)} + 2H_20_{(l)}$
(brown fumes)

iii. **Reaction with hydrogen**

When hydrogen gas is bubbled through molten sulphur, hydrogen sulphide is formed.

$H_2\ (g) + S\ (l) \longrightarrow H_2S\ (g)$

Nb: This is not a convenient method of preparing hydrogen sulphide

iv. **Reaction with strong alkalis**

Sulphur dissolves in sodium and potassium hydroxides to form a mixture of a sulphite, (SO_3^{2-}) and a sulphide, S^{2-}

$3S(s) + 6NaOH\ (aq) \longrightarrow 2Na_2S(aq) + Na_2SO_3(aq) + 3H_20(l)$

v. **Reaction with other non-metals**

Sulphur directly combines with fluorine, chlorine and carbon.

$S(s) + 3F_2\ (g) \longrightarrow SF_6(l)$
$2S(s) + C1_2\ (g) \longrightarrow S_2C1_2\ (l)$
$2S(s) + C(s) \longrightarrow CS_2\ (l)$

Uses of Sulphur

i. Most of the sulphur produced in the world is used to make sulphuric acid.
ii. Sulphur is used in the manufacture of sulphur dioxide and sodium sulphite, which are used for bleaching straw and wood fibres. They are also used in removing lignin from wood pulp in the paper industry.
iii. Gunpowder is a mixture of potassium nitrate, carbon and sulphur.
iv. Sulphur is used in the vulcanization of natural rubber. **Vulcanization** is the process of making naturally soft rubber harder by reacting it with sulphur.

v. Sulphur is used in the manufacture of various organic compounds such as plastics and medicines.
vi. It is used to dust vines to prevent the growth of fungus.

Sulphuric Acid

Sulphuric acid is the compound involves combination of hydrogen, oxygen and sulphur (H_2SO_4).

Manufacture of Sulphuric Acid

Sulphuric acid is produced in large scale by using contact process. Contact process involves four major stages

Stages Involves In Contact Process

i. Production of sulphur dioxide
ii. Purification of sulphur dioxide
iii. Catalytic conversion of sulphur dioxide to sulphur trioxide
iv. Conversion of sulphur trioxide to sulphuric acid

Production of Sulphur Dioxide

i. The sulphur dioxide may be obtained by Burning sulphur in air.

$S(s) + 0_2(g) \longrightarrow S0_2\,(g)$

NB: This is the most convenient method of producing sulphur dioxide.

ii. Burning sulphide ores such as iron pyrite (FeS2) and zinc blende (ZnS)

$4FeS_{2(s)} + 110_{2(g)} \longrightarrow 8SO_{2\,(g)} + 2Fe_2O_{3(s)}$

$2ZnS(s) + 3O_2\,(g) \longrightarrow 2S0_2\,(g) + 2ZnO(s)$

Sulphur dioxide gas is produced as a by-product (secondary product)

Purification of Sulphur Dioxide

Sulphur dioxide obtained in the first stage is purified by remove impurities, such as dust and arsenic (III) oxide, which may poison catalyst in the next stage. Also is passed through conc. H_2SO_4 for drying sulphur dioxide.

Catalytic Conversion of Sulphur Dioxide to Sulphur Trioxide

Dry sulphur dioxide is heated at 4500C at normal atmospheric pressure in presence of catalyst, may be **vanadium pentaoxide** or **platinum**. Since vanadium pentaoxide is cheapest it preferred. Reaction is reversible

$2SO_2\,(g) + 0_2(g)\ 2 \longrightarrow 2SO_3(s) + \text{heat}$

Conversion of Sulphur Trioxide to Sulphuric Acid

The sulphur trioxide from the conversion chamber is passed through a heat exchanger to remove excess heat. It is then taken to an absorption tower where it is dissolved in concentrated sulphuric acid to form **oleum** or **fuming sulphuric acid**.

$H_2S0_4\,(l) + S0_3\,(g) \longrightarrow H_2S_20_7\,(l)$

Oleum is then diluted to give concentrated sulphuric acid.

$H_2S_20_7\,(l) + H_20\,(l) \longrightarrow 2H_2S0_4\,(l)$

Nb: Sulphur trioxide cannot be dissolved directly in water to form sulphuric acid, the reaction is highly exothermic and the heat produced vaporizes the sulphuric acid formed. This makes it difficult to collect the acid

Physical Properties of Conc. H_2s0_4

i. It is a dense oily liquid. It is sometimes referred to as oil of vitriol.
ii. It is a colourless liquid with a specific gravity of 1.84 g/cm^3.
iii. It has a boiling point of 333°C. It decomposes at this temperature to give sulphur dioxide gas and water.
Conc. $H_2S0_4\,(l) \longrightarrow S0_3\,(g) + H_20\,(g)$
iv. Concentrated sulphuric acid has no effect on litmus paper
v. It does not conduct electricity
vi. It does not give hydrogen when reacted with metals. This is because the acid is a covalent compound and it is not ionized.

Nb: The properties of concentrated and dilute sulphuric acid are not the same

Chemical Properties of Dil. H_2s0_4

i. **Reaction with metals**

Dilute sulphuric acid reacts with common metals such as magnesium, zinc and iron to form a sulphate of the metal and hydrogen gas

$Mg(s) + H_2S0_{4\,(aq)} \longrightarrow MgSO_4\,(aq) + H_{2\,(g)}$

$Cu(s) + H_2S0_{4\,(aq)} \longrightarrow CuSO_4\,(aq) + H_{2\,(g)}$

$Fe(s) + H_2S0_{4\,(aq)} \longrightarrow FeSO_4\,(aq) + H_{2\,(g)}$

ii. **Reaction with metal hydroxides**

The reactions between dilute sulphuric acid and metal hydroxides are neutralization reactions.

$2NaOH\ (aq) + H_2S0_4\ (aq) \longrightarrow Na_2SO_4\ (aq) + 2H_20(l)$

iii. **Reaction with metal carbonates**

Dilute sulphuric acid reacts with metal carbonates to give a metal sulphate, carbon dioxide and water.

$Na_2CO_3\ (aq) + H_2S0_4\ (aq) \longrightarrow Na_2SO_4\ (aq) + C0_2\ (g) + H_20\ (1)$

$PbCO_3(s) + H_2S0_4\ (aq) \longrightarrow PbSO_4(s) + C0_2\ (g) + H_20\ (l)$

Chemical Properties of Conc. H_2S0_4

In chemical reactions, concentrated sulphuric acid can act as a dehydrating agent, a drying agent or an oxidizing agent.

i. **Sulphuric acid as a dehydrating agent**

As a dehydrating agent, sulphuric acid removes the elements of water (oxygen and hydrogen) from a compound to form a new compound.

$C_{12}H_{22}0_{11}(s) + H_2S0_4 \longrightarrow 12C(s) + 11H_20(g)$

(Sugar) (Black)

The reaction is highly exothermic.

$CuSO_4.5H_20(s)+H_2S0_4 \longrightarrow CuSO_4(s)+5H_20(l)$

(Blue) (White)

ii. **Sulphuric acid as a drying agent**

As a drying agent, concentrated sulphuric acid absorbs traces of water from substances. It is especially used as a drying agent during the laboratory preparation of gases, with the exception of ammonia and carbon dioxide

iii. **Sulphuric acid as an oxidizing agent**

Hot concentrated sulphuric acid is a strong oxidizing agent. It oxidizes both metals and non-metals while it is reduced to sulphur dioxide.

$C(s) + 2H_2S0_4(l) \longrightarrow C0_2(g) + 2S0_2(g) + 2H_20(1)$

$S(s) + 2H_2S0_4(l) \longrightarrow 3S0_2(g)\ t\ 2H_20(l)$

NB: The orange colour of the dichromate (VI) paper changes to green. This confirms the presence of sulphur dioxide gas

Uses of Sulphuric Acid

i. **Extraction of metals**

Sulphuric acid is used in large quantities in the iron and steel-making industry to remove rust and scale from rolled iron sheets

ii. **Manufacture of fertilizers**

Ammonium sulphate, an important nitrogenous as fertilizer, is commonly produced as a by-product in the production of coke from coal. The ammonia produced in the thermal decomposition of coal is reacted with waste sulphuric acid to produce ammonium sulphate

iii. **Manufacture of aluminium sulphate**

Sulphuric acid is used in the manufacture of aluminium sulphate, which is used in water treatment plants to filter impurities and to improve the taste of the water. Aluminium sulphate is made by reacting 'bauxite with sulphuric acid

iv. **Refining crude oil**

A large quantity of sulphuric acid is used in refining petroleum. The acid is used as a catalyst for the reaction of isobutane with isobutylene to give isooctane, a compound that raises the octane rating of petrol

v. Sulphuric acid is used in lead-acid (car) batteries

vi. Sulphuric acid is used as a dehydrating agent in its concentrated form

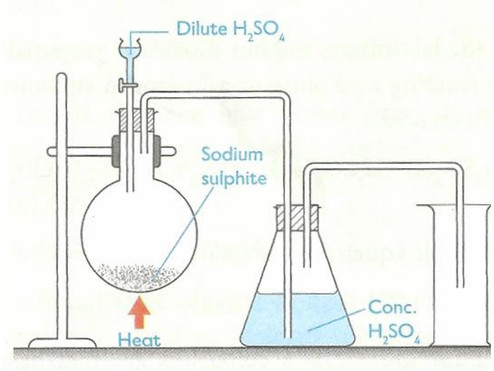
vii. Sulphuric acid is used in the manufacture of a wide range of pigments

Sulphur Dioxide

By Defn: Sulphur dioxide is a binary compound of sulphur with oxygen.

Preparation of Sulphur Dioxide

1. When sulphur burns in air (oxygen) it gives sulphur dioxide.
   $S(s) + 0_2(g) \longrightarrow S0_2\ (g)$
2. In the laboratory, sulphur dioxide is prepared by reacting a sulphite or a hydrogen sulphite with an acid.



   $Na_2SO_3(s) + H_2S0_4\ (aq) \longrightarrow Na_2SO_4\ (aq) + H_20\ (l) + S02\ (g)$

Nb:

- i. Conc. Sulphuric acid in the conical flask for dry chlorine gas
- ii. It collected down ward delivery because it is denser than air

3. In the laboratory, sulphur dioxide is prepared by the reaction between copper turnings and concentrated sulphuric acid can be represented by the following equation.
   $Cu(s) + 2H_2S0_4\ (l) \longrightarrow CuSO_4\ (s) + S0_2\ (g) + 2H_20(l)$

Physical Properties of Sulphur Dioxide

- i. It is a colourless gas with an irritating chocking smell.
- ii. It is poisonous and should therefore be prepared in the fume chamber.
- iii. It is two and a half times denser than air.
- iv. It is readily liquefied. Liquid sulphur dioxide boils at about -10°C.

Chemical Properties of Sulphur Dioxide

- i. Sulphur dioxide is an acidic gas. Dissolve in water to form acidic solution of sulphuric acid which is commonly known as **sulphurous acid**.
  $S0_2(g) + H_20(l) \longrightarrow H_2S0_3(aq)$
- ii. **Solubility of sulphur dioxide**
  Sulphur dioxide has a high solubility in water. It dissolves to form sulphurous acid. 1 cm^3 of water dissolves about 700 cm^3 of sulphur dioxide
- iii. **Reducing property of sulphur dioxide**
  Sulphur dioxide is a strong reducing agent. It reduces potassium permanganate and potassium dichromate (VI) solutions to manganese sulphate and chromic sulphate respectively. In moist conditions, sulphur dioxide is a **bleaching agent**.
  $2KMnO_4\ (aq) + 5S0_2\ (g) + 2H_2O\ (l) \longrightarrow K_2SO_4\ (aq) + 2MnSO_4\ (aq) + 2H_2S0_4\ (aq)$
  Where:
  $2KMnO_4$ = purple
  $2MnSO_4$ =colourless

  $K_2Cr_2O_7\ (aq) + H_2S0_4\ (aq) + 3S0_2\ (g) \longrightarrow K_2S0_4\ (aq) + Cr_2(S0_4)_3(aq) + H_20(l)$
  Where:
  $K_2Cr_2O_7$ = orange
  $Cr_2(S0_4)_3$ = green
- iv. **Oxidizing property of sulphur dioxide**
  In the presence of moisture Sulphur dioxide is also an oxidizing agent. Consider the chemical reaction below.
  $FeS(s) + 2HCl(aq) \longrightarrow HS(g) + FeCl_2(aq)$
  $2H_2S(g) + S0_2(g) \longrightarrow 3S(s) + 2H_20(l)$
- v. **Reaction of sulphur dioxide with oxygen**
  Sulphur dioxide does not burn. However, it combines with oxygen in the presence of a heated catalyst (platinized asbestos) to give sulphur trioxide.
  $2S0_2\ (g) + 0_2(g) \longrightarrow 2S0_3\ (g)$

Test for Sulphur Dioxide

- i. The presence of sulphur dioxide can be tested using a filter paper that has been soaked in acidified potassium dichromate (VI). If sulphur dioxide is present, the colour of the paper changes from orange to green due to the reduction of dichromate (VI) to chromate (III).
- ii. Sulphur dioxide also decolorizes acidified potassium permanganate solution.

Pollution Effects of Sulphur Dioxide

i. Soil erosion because the major sources of sulphur dioxide in the air are power plants that use fossil fuels such as coal and diesel, industrial boilers, and exhaust emissions from motor vehicles.
ii. It causes acidic rain.
iii. It can cause impairment of respiratory function and heart diseases

Uses of Sulphur Dioxide

i. The main use of sulphur dioxide is in the manufacture of sulphuric acid through the contact process.
ii. It is used as a bleaching agent for fibres, mainly of animal origin, for example wool, silk, straw and sponges.
iii. It is used in the manufacture of calcium and sodium hydrogensulphites. Calcium hydrogensulphite ($CaHSO_3$) is used for bleaching wood-pulp in the manufacture of paper and artificial silk. Sodium hydrogensulphite, $NaHSO_3$, is used in the manufacture of sodium sulphinate, which is a reducing agent used in dyeing.
iv. It is used for fumigating houses and clothing to kill micro-organisms. It is also used to kill insects such as white ants because it is poisonous.
v. Sulphur dioxide is used in small doses as a preservative of some liquids such as lemon and orange juices. This is because even a small concentration of the gas prevents fermentation of the liquids as it reacts with oxygen. This prevents oxidation of the liquids.
vi. Liquid sulphur dioxide is used in refrigerators because it liquefies at three atmospheres at room temperature.

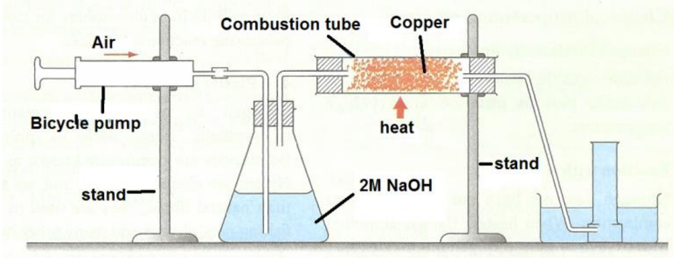
Nitrogen

Nitrogen exists in gaseous state as a diatomic molecule (N_2). Nitrogen gas is odourless and colourless. Nitrogen also occurs in combined state in the form of nitrates and oxides. It is also found in plants and animals as a constituent of proteins.

Preparation of Nitrogen Gas

Nitrogen prepared in the laboratory by isolation from atmospheric air.

Diagram:



When air is passed through a solution of sodium hydroxide, carbon dioxide from the air dissolves in the alkali which removes carbon dioxide from the air.

$NaOH\ (aq) + C0_2\ (g) \longrightarrow NaHCO_3\ (aq)$

In the combustion tube, the hot copper turnings (brown) react with oxygen to form copper (II) oxide (black) where oxygen is removed from the air

$2Cu(s) + 0_2(g) \longrightarrow 2CuO(s)$

Nb:

i. The nitrogen obtained is impure which contains inert gases such as **neon** and **argon** makes the gas impure
ii. Dry nitrogen gas can be obtained by passing it through concentrated sulphuric acid instead of collecting it over water

Physical Properties of Nitrogen

i. Nitrogen is a colourless, odourless and tasteless gas.
ii. It is almost insoluble in water.
iii. It has a boiling point of -196°C.
iv. It can be liquefied to form liquid nitrogen.
v. Nitrogen prepared from air is denser than pure nitrogen since it contains the noble gases
vi. It occupies about 78% by volume in the atmosphere

Chemical Properties of Nitrogen

Nitrogen is relatively Unreactive

Nitrogen gas is stable below 3000°C. It only takes part in reactions at very high temperatures.

Reaction with oxygen

Nitrogen does not burn nor does it support combustion. When heated, the gas combines with oxygen to form nitrogen monoxide gas.

N_2 (g) + 0_2(g) $\longrightarrow$ 2N0 (g)

Reaction with hydrogen

Nitrogen reacts with hydrogen when heated to form ammonia.

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

Reaction with metals

When heated together with metals, nitrogen forms **metal nitrides**. For example, with magnesium it forms magnesium nitride.

3Mg(s) + N_2 (g) heat $\longrightarrow$ Mg_3N_2 (g)

Uses of Nitrogen

The following are some uses of nitrogen gas.

1. Manufacture of fertilizers

Nitrogen is used to manufacture nitrogenous fertilizers. These include Diammonium phosphate (DAP), calcium ammonium nitrate (CAN), ammonium superphosphate (ASP), ammonium nitrate (AN), ammonium phosphate sulphate (APS), ammonium sulphate nitrate (ASN), and ammonium sulphate (AS) and urea.

2. Refrigeration

Nitrogen gas is used as a refrigerant because of its low boiling point (inert atmosphere 196°C).

3. Processing reactive substances

Because of its low reactivity; nitrogen is used to provide an inert atmosphere for storing and processing reactive substances.

4. Plastic industries

Nitrogen is used in the manufacture of synthetic fibres such as polyamides. Polyamides are commonly known as nylons. Nylons are chemically inert and are stronger than natural fibres. They are used in making fishing nets, clothes and many other items.

5. Manufacture of ammonia

Nitrogen is used in the manufacture of ammonia through the Haber process. Reaction is reversible

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

6. Manufacture of nitric acid

The ammonia gas manufactured in the Haber process is used in the manufacture of nitric acid by catalytic oxidation.

This Process Involves Three Main Stages.

i. Catalytic oxidation of ammonia. platinum gauze used as catalyst at 700°C

   $4NH_{3(g)} + 50_{2(g)} \longrightarrow 4N0_{(g)} + 6H_20_{(g)} + Heat$

ii. Oxidation of nitrogen monoxide to nitrogen dioxide at 30°C. Reaction is reversible

   $2N0_{\,(g)} + 0_{2(g)} \longrightarrow 2N0_{2\,(g)}$

iii. Reaction of nitrogen dioxide with water to form nitric acid.

   $4N0_{2\,(g)} + 2H_2O_{\,(l)} + O_{2\,(g)} \longrightarrow 4HN0_{3\,(aq)}$

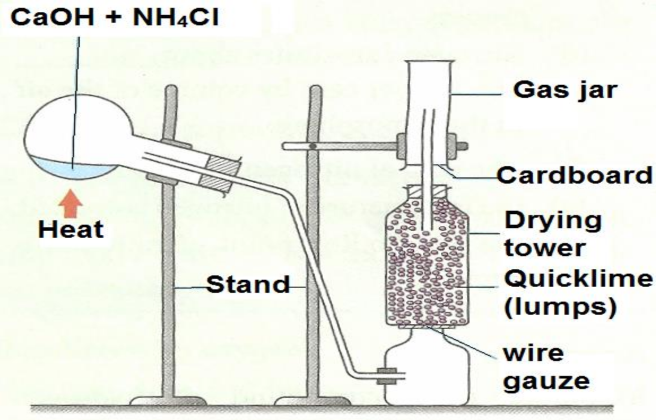
Ammonia

Ammonia is a compound of hydrogen and nitrogen. Its chemical formula is NH_3. It exists in nitrogenous organic materials such as hoofs and horns of animals.

Preparation of Ammonia

Ammonia can be prepared in the laboratory by heating any ammonium salt together with an alkali. The most commonly used alkalis are potassium hydroxide with ammonium chloride.

Diagram:



Calcium hydroxide reacts with ammonium chloride to produce ammonia gas, calcium chloride and water

$2NH_4Cl(s) + Ca(OH)_2(s) \longrightarrow CaCl_2(aq) + 2H_2O(l) + 2NH_3(g)$

Ammonia gas is dried by passing it over quicklime

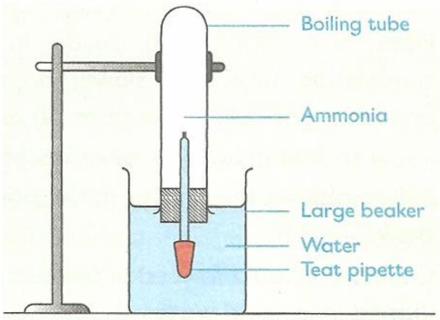
Nb:

i. The round-bottomed flask is tilted to prevent any condensed water from running back into the hot flask, which would make the flask crack.
ii. The common drying agents such as concentrated sulphuric acid and calcium chloride are not used because they react with the gas. Reactions is reversible
  $2NH_3\ (g) + H_2S0_4\ (l) \longrightarrow (NH_4)_2S0_4\ (l)$
  $8NH_3\ (g) + CaCl_2(s) \longrightarrow CaCl_2.8NH_3(s)$
iii. Ammonia is collected by upward delivery or downward displacement of air. This is because it is less dense than air.
iv. Ammonia is an alkaline gas and turns wet red litmus paper blue.
v. When sodium hydroxide or potassium hydroxide is used, they are used in solution form because they are very reactive in solid form

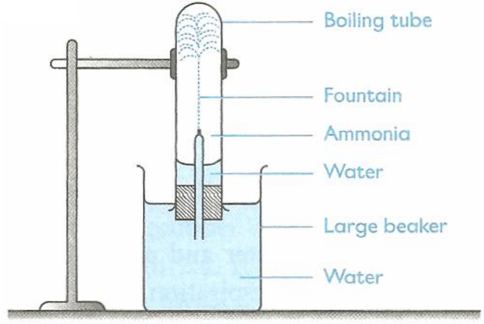
Physical Properties of Ammonia

i. Ammonia is a colourless gas with a pungent choking smell
ii. It is less dense than air
iii. Ammonia is highly soluble in water

Fountain Experiment



When a drop of water is released into the boiling tube containing ammonia, the water dissolves most of the ammonia gas, thus leaving a partial vacuum. This lowers the pressure inside the boiling tube. The rubber remains pressed inside because of atmospheric pressure.



When the teat is removed, the water in the beaker rushes into the boiling tube, thus dissolving the remaining ammonia gas. The water forms a fountain, thus the name of the experiment.

Nb:

i. The solution of ammonia which is a base is called aqueous ammonia.
ii. In aqueous ammonia, the molecules of ammonia continuously interact with water molecules to produce ammonium ions ($NH4^+$) and hydroxyl ions (OH^-). Reaction is reversible
  $NH_3\ (g) + H_20\ (l) \longrightarrow NH_4^+\ (aq) + OH^-(aq)$
iii. Ammonium hydroxide does not exist as a molecule. Instead it exists as NH_4^+ and $0H^-$ ions.
iv. The presence of the hydroxyl ions in aqueous ammonia, OH^-, makes the solution alkaline.

Chemical Properties of Ammonia

Reaction with concentrated hydrochloric acid

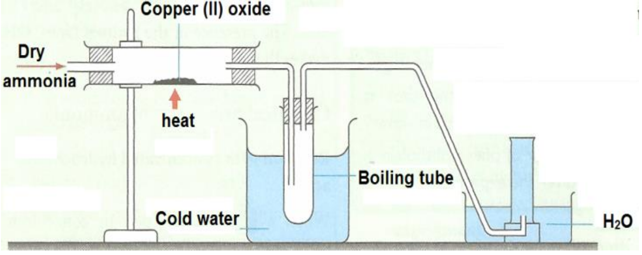
When a glass rod dipped in concentrated hydrochloric acid is placed at the mouth of a gas jar containing ammonia, dense white fumes of ammonium chloride are formed.

$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$

This is used as a test for ammonia gas.

Oxidation of ammonia

Oxidizing agents, such as copper (II) oxide, oxidize ammonia gas to nitrogen.



When ammonia gas is passed over heated copper (II) oxide, the gas is oxidized to nitrogen while the copper (II) oxide is reduced to copper.

$3CuO(s) + 2NH_3(g) \longrightarrow 3Cu(s) + 3H_20(l) + N_2(g)$

The liquid collected in the test tube is water. The liquid changes white anhydrous copper (II) Sulphate to blue or blue cobalt (II) chloride paper to pink.

Uses of Ammonia

The following are some of the uses of ammonia

1. Manufacture of fertilizers

Ammonia is used in the manufacture of nitrogenous fertilizers such as ammonium sulphate nitrate (ASN), ammonium sulphate (AS), di-ammonium phosphate (DAP), calcium ammonium nitrate (CAN) and ammonium nitrate (AN).

2. Cleaning

Ammonia softens water and neutralizes acid stains caused by perspiration, thus making washing easier.

3. Refrigeration

Liquid ammonia can be used as a refrigerant because it is highly volatile.

4. Manufacture of nitric acid

Nitric acid is manufactured by the catalytic oxidation of ammonia

Carbon

Carbon is a Group IV and Period 2 element. It usually forms covalent bonds when combining with other elements. Carbon is found in a variety of natural substances. These include shells, coal, diamond, and graphite. It is also found in compounds of carbonates such as chalk ($CaCO_3$).

Allotropes of Carbon

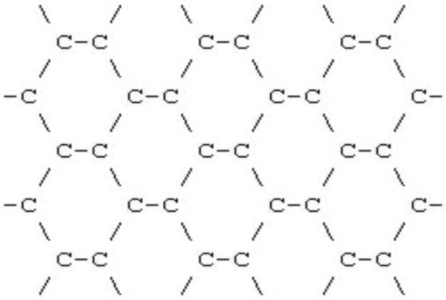
Carbon exists in three main forms include

i. Graphite Carbon
ii. Diamond Carbon
iii. Amorphous Carbon

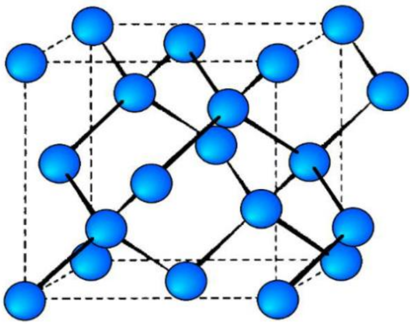
Graphite Carbon

Each carbon atom is bonded to three other carbon atoms, giving it a **trigonal structure**. Three out of the four valence electrons of each carbon atom are used in bond formation. The fourth electron is referred to as a delocalized electron, and is free to move in the graphite structure. The trigonal units come together to form a hexagonal ring. These rings form flat parallel layers, one over the other. The layers can slide over one another. This makes graphite soft and slippery.

Diagram:



Bond formation in a graphite carbon



Graphite structure

Physical Properties of Graphite Carbon

i. It has a low density
ii. It is soft and greasy.
iii. Good conduct of heat and electricity due to the delocalized of electrons.

iv. It has relatively low melting and boiling points (compared to diamond).

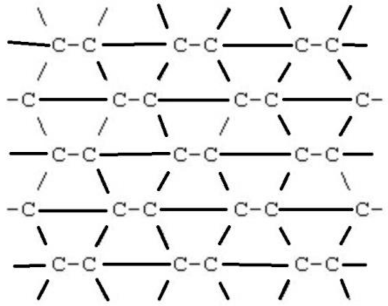
Uses of Graphite Carbon

i. It is used as a lubricant in high temperature processes because of its slippery nature and high boiling point.
ii. It is used to make electrodes due to its good electrical conductivity
iii. It is mixed with clay to make the lead in pencils.

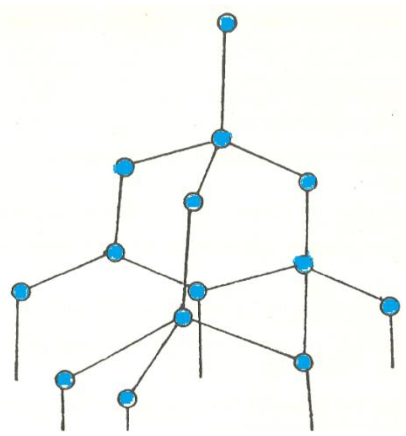
Diamond Carbon

In diamond, all the four valence electrons of a carbon atom are used in bonding, forming four strong covalent bonds in each carbon atom. The electrons form a tetrahedral shape.

Diagram:



Bond formation in a diamond carbon



Diamond structure

Physical Properties of Diamond Carbon

i. It has a high density compared to graphite.
ii. It is the hardest natural substance known.
iii. It is a bad conductor of electricity and heat.
iv. It has a high melting point of 3,550°C and a high boiling point of 4,289°C.
v. It has a high refractive index of 2.45. The high refractive index results in high dispersion of light, making it suitable for use in jewellery

Uses of Diamond Carbon

i. It is used in making jewellery
ii. It is used to make glass cutters and rock borers because of its hardness.

Amorphous Carbon

Amorphous carbon is carbon that does not have any clear shape, form or crystalline structure. Amorphous carbon is made up of tiny bits of graphite with varying amounts of other elements considered as impurities. It is formed when a material containing carbon is burned in limited supply of oxygen, resulting in incomplete combustion.

Example of Amorphous Carbon

i. Sugar charcoal -made by dehydrating sugar
ii. Wood charcoal - made by heating wood in a limited supply of air
iii. Coal

Uses of Amorphous Carbon

i. it used to make ink, paint and rubber products.
ii. It is also pressed into shapes and used to form cores of dry batteries.
iii. Used as fuel for cooking example wood charcoal and coal

Chemical Properties of Carbon

The following are some chemical properties of carbon.

1. **Carbon burns in excess oxygen to form carbon dioxide gas.**

   2. $C(s) + 0_2(g) \longrightarrow C0_2\ (g)$

   In insufficient oxygen, carbon monoxide gas is formed.

   $2C(s) + 0_2(g) \longrightarrow 2C0\ (g)$

2. **Carbon has a high affinity for oxygen and thus acts as a reducing agent.**

   Carbon reduces oxides of less reactive metals to their respective metals.

   $ZnO(s) + C(s) \longrightarrow Zn(s) + CO\ (g)$

   $PbO(s) + C(s) \longrightarrow Pb(s) + CO\ (g)$

   Carbon reduces hot concentrated nitric acid and concentrated sulphuric acid.

   $4HN0_3\ (l) + C(s) \longrightarrow 4N0_2\ (g) + C0_2\ (g) + 2H_20(l)$

$2H_2S0_4 (l) + C(s) \longrightarrow 2S0_2 (g) + C0_2 (g) + 2H_20(l)$

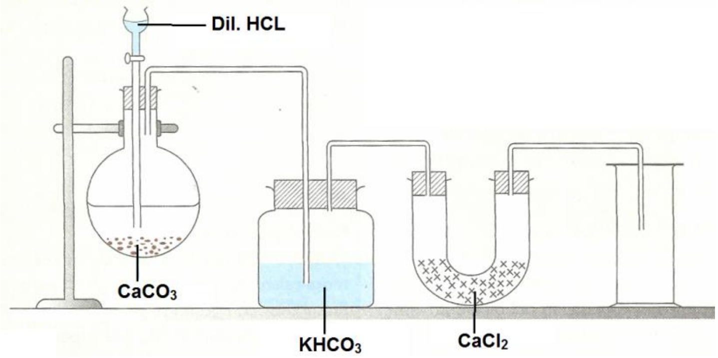
Carbon Dioxide

Carbon dioxide is the covalent compound formed between carbon and oxygen

Preparation of Carbon Dioxide

Carbon dioxide can be prepared in the laboratory by the action of dilute hydrochloric acid on marble chips (calcium carbonate).

Diagram:



Dilute hydrochloric acid reacts with marble chips to give calcium chloride, water and carbon dioxide.

$CaCO_3(s) + 2HCl (aq) \longrightarrow CaCl_2 (aq) + H_20 (l) + C0_2 (g)$

The potassium hydrogen carbonate solution absorbs any traces of hydrochloric acid from the carbon dioxide. The gas is then dried by passing it through anhydrous calcium chloride. Carbon dioxide is collected by downward delivery because it is denser than air.

Nb:

Other carbonates, such as magnesium carbonate can also be used to prepare carbon dioxide gas.

Physical Properties of Carbon Dioxide Gas

i. Carbon dioxide is a colourless and odourless gas.
ii. It has a melting point of -199°C and a boiling point of -91.5°C.
iii. The gas is denser than air.
iv. Solid carbon dioxide is referred to as dry ice. Dry ice sublimes means changing directly to gas at atmospheric pressure.

Chemical Properties

Carbon dioxide does not support combustion. The gas is slightly acidic. As a result, it may not have any observable effect on a litmus paper.

Reaction of carbon dioxide with lime water

Carbon dioxide react with Lime water (calcium hydroxide) a white precipitate of calcium carbonate is formed.

$Ca(OH)_2(aq) + C0_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$

When excess carbon dioxide is bubbled into the lime water, the white precipitate dissolves due to the formation of soluble calcium hydrogen carbonate.

$CaCO_3(s) + H_20 (l) + CO_2 (g) \longrightarrow Ca(HCO_3)_2(aq)$

Reaction of carbon dioxide with barium hydroxide

Carbon dioxide react with Barium hydroxide to forms a precipitate of barium carbonate.

$Ba(OH)(aq) + C0_2(g) \longrightarrow BaCO_3(s) + H_20(l)$

Reaction of carbon dioxide with metals

Generally, carbon dioxide does not react with metals, except under special conditions.

When a burning magnesium ribbon is lowered into a gas jar containing carbon dioxide, it continues to burn for a short time with a **spluttering flame**. A white ash of magnesium oxide and black specks of carbon are formed.

$2Mg(s) + C0_2 (g) \longrightarrow 2MgO(s) + C(s)$

Reaction with water

Carbon dioxide reacts with water to form weak carbonic acid. The reaction is reversible.

$H_20(l) + C0_2(g) \longrightarrow H_2C0_3(aq)$

Test for Carbon Dioxide

By using lime water

When a little carbon dioxide is bubbled into lime water a white precipitate of calcium carbonate is formed.

By using Barium hydroxide

When a little carbon dioxide is bubbled into Barium hydroxide a white precipitate of barium carbonate is formed.

Uses of Carbon Dioxide

The following are some of the uses of carbon dioxide.

1. Fire extinguisher

Carbon dioxide gas is used as a fire extinguishing agent because it does not support combustion and is denser than air. This means it displaces oxygen from the burning site, thus stopping the fire.

2. Manufacture of fizzy drinks

Carbon dioxide is used in making fizzy drinks and mineral salts. A solution of the gas in water has a pleasant taste.

3. Refrigeration

Carbon dioxide is used as a refrigerant. The gas sublimes at -78°C to form dry ice. Dry ice is a good refrigerant because it leaves no residue after sublimation

4. Manufacture of sodium carbonate

Carbon dioxide is used in the manufacture of anhydrous sodium carbonate in the **Solvay process.** Sodium carbonate is used in the manufacture of glass.

5. Manufacture of baking soda

Carbon dioxide is used in making baking powder (sodium hydrogen carbonate). Baking soda is prepared by passing carbon dioxide into cold concentrated sodium carbonate

6. Photosynthesis

Plants make use of carbon dioxide to manufacture food through the process of photosynthesis

7. Cloud seeding

Carbon dioxide is used in cloud seeding. **Cloud seeding** is a method of increasing the amount of rainfall received in an area by dispersing substances that help in cloud formation into the air

Introduction to Organic Chemistry

By Defn: *Organic chemistry is the study of the preparation, structure, properties, composition and reactions of organic compounds*

Nb:
Organic compound because most of them are found in animal and plant matter, both living and dead

Importance of Organic Chemistry

Organic chemistry is important both in industrial and in life processes

Life
All living organisms are made of millions of organic compounds.

Medicine
Organic compounds are also used in making medicines for treating various illnesses.

Textile industries
Clothes are made from organic compounds called fibres.

Energy
All fossils fuels such as coal, petroleum and natural gas are derived from organic compounds.

Plastic products
Organic compounds are used to manufacture plastic items.

Harmful Effects of Organic Compounds

These include the following

1. Some **insecticides** such as dichlorodiphenyltrichloroethane (DDT) have harmful effects on life processes in animals, especially birds
2. **Chlorofluorocarbons** (CFCs) contribute to global warming
3. Plastic materials such as polythenes do not decompose easily

Origin of Organic Compounds

Organic compounds are derived from three major sources, include the follows

1. Prehistoric sources
2. Living organisms
3. Synthetic compounds

Prehistoric sources
Prehistoric sources of organic compounds include **coal**, **petroleum** and **natural gas**.

Living organisms
Living organisms include plants and animals.

Synthetic compounds
Synthetic organic compounds are prepared in factories and laboratories through various processes.

Synthetic Organic With Its Uses

Substance	Uses
Polyester	Making cloth items
Polyvinyl cyanide	Making clothing, blankets and carpets
Perspex	Used as a substitute for glass in aircraft and in buildings
Polythene	Making packaging materials, baskets, cups, bowls and a wide range of kitchenware.
Polychloroethene	Commonly referred to as polyvinyl chloride (PVC), used to make water pipes, crates, electrical appliances and as a substitute for leather
Neoprene	Used as a substitute for natural rubber

Fractional Distillation of Crude Oil

By Defn: *fractional distillation of crude oil is the process of separating a mixture of component of crude oil by using their difference in boiling point*

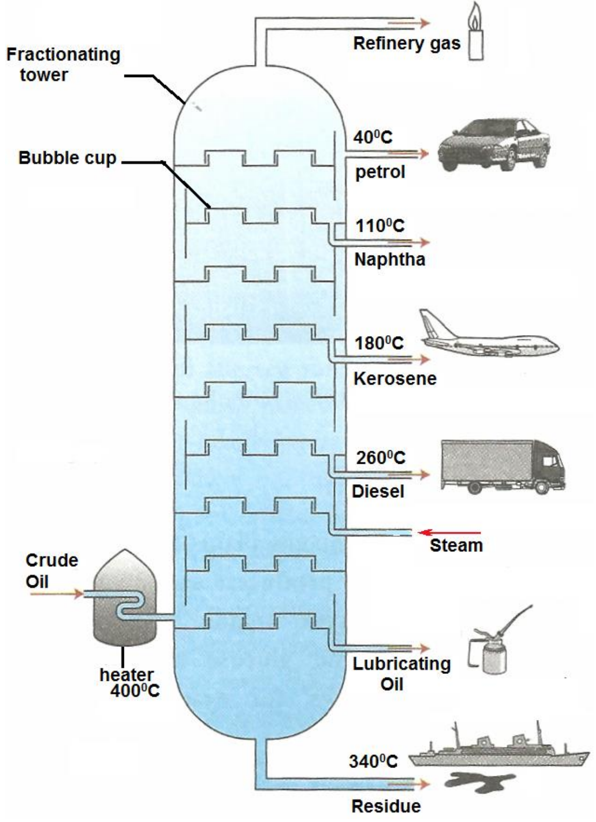
Nb:
The crude oil contains a mixture of different types of organic compounds.

Fractional Process

1. In primary fractional distillation, the crude oil is heated to about 400°C and vapours are passed into fractionating column. The column contains trays and bubble caps. The more volatile components go up the tower. Those with highest boiling points condense in trays

ii. This separation is followed by secondary fractional distillation. Secondary fractional distillation may be used to obtain individual hydrocarbons by further distillation

Diagram:



Components of Crude Oil

Fraction	**Boiling Point**	**Carbon Number**
Fuel gas	-160°C - 20°C	1 - 4
Petrol	20°C - 70°C	5 - 10
Naphtha or gasoline	70°C - 120°C	8 - 12
Paraffin (kerosene)	120°C - 240°C	10 - 16
Diesel oil	240°C - 350°C	15 - 70
Lubricating oil	240°C - 350°C	15 - 70
Bitumen or residual	above 350°C	More than 70

Uses of Major Components of Crude Oil

Fraction	Derivative/Uses
Fuel gas	Cooking lighting chemicals etc
Petrol	Vehicles and solvent
Naphtha	chemicals
Paraffin	Jet engine and kerosene lamp
Diesel oil	Diesel engine
Lubricating oil	Lubricating oil
Bitumen	Make bitumen Fuel in ships Lubricant oil Making waxes etc

Cracking

By Defn: Cracking is the conversion of large molecule organic compounds into compounds with smaller molecules.

Methods of Crack Organic Compound

i. Thermal cracking
ii. Catalytic cracking

Thermal cracking

Heat energy used to cracking large molecule of organic compound to smaller molecules of organic compound

Catalytic cracking

Catalyst used to speed up the crack large molecule of organic compound to smaller molecules of organic compound

Terms Commonly Used

i. **Molecular Formula:** *molecular formula is a chemical formula indicating the types and number of atoms in a molecule*

ii. **Structural Formula:** *structural formula is a chemical formula which shows the arrangement of atoms in a molecule*. The structural formula can be shown in **condensed/closed formula** (without shows bond) or in **opened formula** (with bond)

iii. **Isomers:** *Isomers are organic compounds with the same molecular formula but different structural formulae*

iv. **General Formula:** *general formula is a general rule that can be used to calculate the number of each type of atom in a molecule*

v. **Homologous Series:** *homologous series is an arrangement of the members of a family of organic compounds in order of increasing molecular masses*

Characteristics Of A Homologous Series

i. All the members of a particular series can be represented by the same general formula

ii. The molecular formula of each member of a particular series differs from the member above or below it by one **structural unit**

By Defn: *structural unit is made up of one carbon atom and two hydrogen atoms that is CH_2*. The molecular mass of two adjacent members therefore differs by 14 since the mass of CH_2 is 12 + (2x1) = 14

iii. Compounds that are members of a homologous series prepared by using the same general methods

iv. The physical properties such as melting point, boiling point and density show a gradual change with the increase of the formula or molecular mass

v. Members of a given series have similar chemical properties

vi. **Functional Group:** *functional group is an atom or group of atoms attached to an organic molecule which enable the molecule to react in specific ways*. The functional group determines the chemical properties of the organic compound

Examples of functional groups include

(a) $-C-CH_3$ (alkanes)

(b) $-CH=CH_3$ (alkenes

(c) $-C\equiv CH_3$ (alkynes)

(d) -OH (alcohols)

(e) -COOH (carboxylic acids)

Hydrocarbons

By Defn: *Hydrocarbons are organic compounds made up of carbon and hydrogen only*

Types/Groups of Hydrocarbon

There are two main groups of hydrocarbons.

i. Saturated hydrocarbons

ii. unsaturated hydrocarbons

Saturated Hydrocarbons

Saturated hydrocarbons are formed if all the four bonds of every carbon atom are joined using a single bond to another carbon atom or a hydrogen atom

Unsaturated Hydrocarbons

Unsaturated hydrocarbons have a double bond (C=C) or a triple bond (C≡C) between any of the carbon atoms

Families/Groups Of Hydrocarbons

There are three main groups of hydrocarbons.

i. Alkanes

ii. Alkenes

iii. Alkynes

Nb: Each family has unique physical and chemical properties

Naming of Hydrocarbons

The IUPAC system works for naming organic. The names given to a hydrocarbon have two parts. These are the **root name** and the **primary suffix**.

Root Name

A root word/name indicates the nature of the basic carbon chain making up the hydrocarbon.

Root Names for Hydrocarbons

Number Of Carbon Atoms	Root Name
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-
7	Hept-
8	Oct-
9	Non-
10	Dec-

Primary Suffixes

Primary suffixes are added to the root name to show whether the hydrocarbon is saturated or not and the degree of unsaturation

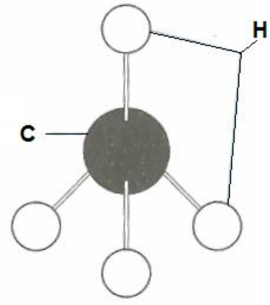
Primary Suffixes for Hydrocarbons

Family	Type Of Bond	Suffix
alkanes	Single(C-C)	-ane
alkenes	Double(C=C)	-ene
alkynes	Triple (C≡C)	-yne

Alkanes

By Defn: *Alkanes is the saturated hydrocarbons that contain only single* covalent bonds between the carbon atoms. It has single bond

Diagram:



General Formulae

It has a general formula of $C_nH_{(2n + 2)}$

Where:

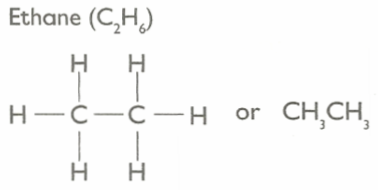
n = number of carbon atoms

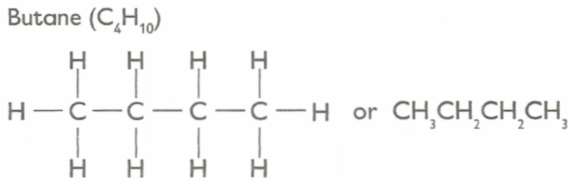
Homologous Series of Alkanes

n	Name	Molecular Formula
1	Methane	CH_4
2	Ethane	C_2H_6
3	Propane	C_3H_8
4	Butane	C_4H_{10}
5	Pentane	C_5H_{12}
6	Hexane	C_6H_{14}
7	Heptane	C_7H_{16}
8	Octane	C_8H_{18}
9	Nonane	C_9H_{20}
10	Decane	$C_{10}H_{22}$

Structural Formulae

Consider the open and condensed formulae of ethane and Butane





The condensed structural formulae can be simplified further. Example CH3 CH_2 CH_2 CH_3 become CH_3 $(CH_2)_2CH_3$

Branched-Chain Alkanes

By Defn: *Branch of alkane is any atom or group of atoms, except hydrogen, which is bonded/attached to the longest continuous carbon chain*

Nb:

i. The branches or side groups are called **substituents**
ii. The most common substituents are **alkyl groups**

Alkyl Group

Alkyl group is the alkane which lost one hydrogen atom. They have a general formula of $C_2H_{2n+l.}$ The name of the alkyl group is obtained by replacing the suffix -**ane** in a corresponding alkane with -**yl**.

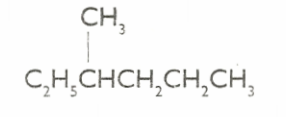
Names and Formulae of Some Alkyl

Number Of Carbon	Name Of Substituent	Molecular Formula
1	Methyl	CH_{43}
2	Ethyl	C_2H_5
3	Propyl	C_3H_7
4	Butyl	C_4H_{19}
5	Pentyl	C_5H_{11}
6	Hexyl	C_6H_{10}
7	Heptyl	C_7H_{15}
8	Octyl	C_8H_{17}
9	Nonyl	C_9H_{19}
10	Decyl	$C_{10}H_{21}$

Rules for Naming Alkane

The following rules must be followed when naming alkanes.

i. Identify the longest continuous carbon chain. This becomes the parent chain.



$$C_2H_5\overset{\overset{CH_3}{|}}{C}HCH_2CH_2CH_3$$

The longest continuous carbon chain has six carbon atoms. The parent name of the alkane is **hexane**.

Note: the ethyl group (C_2H_5-) can be expanded to CH_3CH_2-

ii. Identify the position and the name of the substituent attached to the longest continuous carbon chain if present and read to the smallest possible number of carbon attached. Consider the example above, from left methyl bonded to third carbon and from right methyl is attached to forth carbon. Therefore is **3-methyl**

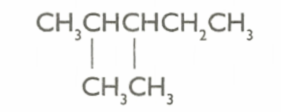
Nb: the carbon that the loCation of substituent is called **locant**

iii. Write down the name of the alkane, starting with the locant, followed by the name of the substituent and then the name of the parent chain
Name of the alkane is **3-methyihexane**

Nb:
- i. Use a hyphen (-) to separate the locant from the name of the substituent
- ii. The name should be continuous with no spaces between
- iii. The name which follows after the locant should start with a small letter

When more than one substituent is attached

Consider the alkane below contain more than one substituent is attached to the parent chain.

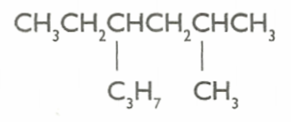


$CH_3\underset{\overset{|}{CH_3}}{CH}\underset{\overset{|}{CH_3}}{CH}CH_2CH_3$

- i. The parent chain is therefore pentane
- ii. First branch is 2-methyl
- iii. Second branch is 3-methyl
  Nb: the prefix like **di**, **tri**, **tetra** etc may be used
- iv. Arrange with alphabetical order
- v. A comma is used to separate the locants
- *vi.* Therefore The name of the alkane is **2,3-dimethylpentane**

When two or more different substituents are attached to the parent chain

The name of the substituents is written in an alphabetical order



$CH_3CH_2\underset{\overset{|}{C_3H_7}}{CH}CH_2\underset{\overset{|}{CH_3}}{CH}CH_3$

- i. The parent chain is therefore **heptane**
- ii. First branch is **2-methyl**
- iii. Second branch is **4-ethyl**
- *iv.* Therefore The name of the alkane is **4-ethyl-2-methyl** heptane

Isomerism in Alkanes

By Defn: *Isomerism is the property of two or more compounds having the same molecular formula but different structural formulae*

Types of Isomerism
- i. structural isomerism
- ii. stereoisomerism

Structural Isomerism

It divided into three types include,
- i. chain or branched isomerism
- ii. functional group isomerism
- iii. positional isomerism

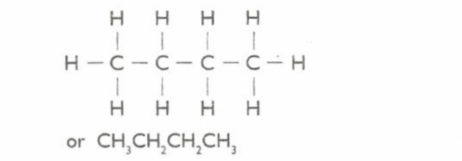
Stereoisomerism

It divided into two types include,
- i. geometric isomerism
- ii. optical isomerism

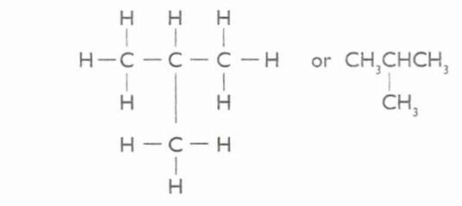
Nb:
- i. Methane, ethane and propane do not have isomers
- ii. Butane has two isomers
- iii. As the number of carbon atoms increases, the number of possible isomers also increases

Isomers of Butane

(a) Butane

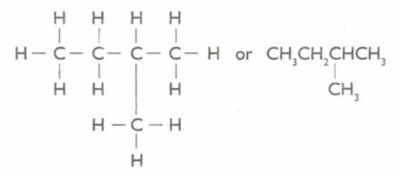


(b) 2-methylbutane

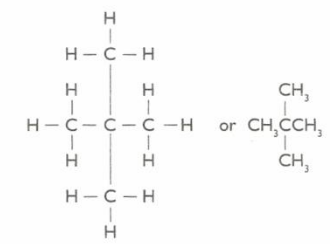


Isomers of Pentane

(a) 2-methylpropane



(b) 2, 2-dimethylpropane



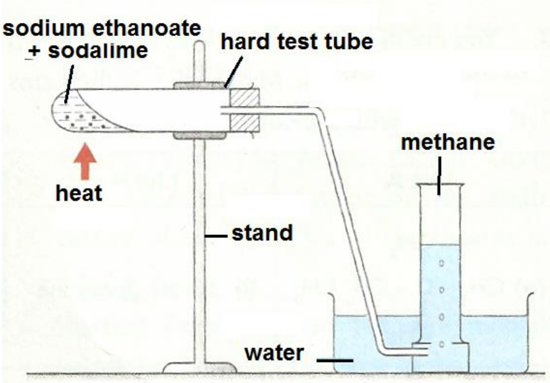
Preparation of Alkanes

All alkane is prepared in the same way but let us see the preparation of methane and ethane

Preparation of Methane

Methane gas can be prepared in the laboratory by reacting sodium Ethanoate with soda lime

Diagram:



Soda lime is a mixture of sodium and calcium hydroxide. The sodium hydroxide in the mixture reacts with sodium Ethanoate to produce methane gas.

$CH_3COONa_{(s)} + NaOH_{(s)} \longrightarrow CH_{4(g)} + Na_2CO_{3(g)}$

Nb:

i. Methane gas is colourless and odourless
ii. It is insoluble in water. This is the reason why it is collected over water

Preparation of Ethane

It prepared like methane, sodium propanoate react with soda lime to produce Ethane

$CH_3CH_2COONa_{(s)} + NaOH \longrightarrow C_2H_{6\ (g)} + Na_2CO_{3(s)}$

Nb:

i. Ethane is a constituent of natural gas but it is of a lower percentage compared to methane
ii. It is a colourless and odourless gas
iii. It is insoluble in water and this is why it is collected over water

Physical Properties of Alkanes

The trend in physical properties of the straight-chain alkanes changes gradually from methane to decane.

i. The first four alkanes, that is *methane, ethane, propane and butane*, are gases at room temperature and pressure.
ii. Alkanes with five to ten carbon atoms (pentane to decane) are liquids at room temperature and pressure
NB: The change in physical state is due to increase in molecular mass. This in turn increases intermolecular attractions
iii. boiling points of alkanes increase methane to decane
iv. melting points of alkanes increase methane to decane
v. density of alkanes increase methane to decane

Physical Properties of the Alkanes

Alkane	B.P (°C)	M.P (°C)	Density (g/cm³)
Methane	-162	-183	0.466
Ethane	-89	-772	0.572
Propane	-42	-188	0.585
Butane	-0.5	-135	0.601
Pentane	36	-130	0.626
Hexane	69	-95	0.659
Heptane	98	-91	0.684
Octane	126	-57	0.703
Nonane	151	-54	0.718
Decane	174	-30	0.730

Chemical Properties of Alkanes

Reactions with air (oxygen)

Alkane burn in air to give carbon dioxide and water

For example, Methane burns in air as shown in the following equation.

$CH_4\ (g) + 2O_2\ (g) \longrightarrow CO_2\ (g) + 2H_20(l)$

Nb:

The combustion of alkanes is a highly exothermic reaction; most alkanes are actually used as fuels.

Alkanes undergo Substitution reaction

Alkanes are saturated hydrocarbons. They only take part in substitution reactions.

By Defn: *A substitution reaction is one in which an atom or a group of atoms is replaced by another atom or group of atoms.*

NB:

i. Substitution reactions of alkanes mainly involve halogens such as bromine and chlorine.

ii. Substitution reaction can be used to test whether the hydrocarbon is saturated

iii. In the presence of sunlight alkane decolorized potassium permanganate and bromide water, this two reagent is used to test for saturated hydrocarbon

Bromine reacts with methane in the presence of sunlight in a substitution reaction to form tetrabromoethane

$CH_4\,(g) + 4Br_2\,(g) \longrightarrow CBr_4\,(g) + 4HBr\,(g)$

Chlorine also reacts with methane in the same way

$CH_4\,(g) + 4Cl_2\,(g) \longrightarrow CCl_4\,(g) + 4HCl\,(g)$

The reaction takes place in stages, with one chlorine atom replacing a hydrogen atom in methane at each stage.

(i) **Formation of chloromethane**

$CH_4\,(g) + Cl_2\,(g) \longrightarrow CH_3C1\,(g) + HC1\,(g)$

(ii) **Formation of dichloromethane**

$CH_3Cl\,(g) + Cl_2\,(g) \longrightarrow CH_2Cl_2(g) + HCl(g)$

(iii) **Formation trichloromethane**

$CH_2Cl_2\,(g) + Cl_2\,(g) \longrightarrow CHCl_3\,(g) + HCl\,(g)$

(iv) **Formation of tetrachloromethane**

$CHCl_3\,(g) + Cl_2\,(g) \longrightarrow CCl_4\,(g) + HCl\,(g)$

Nb:

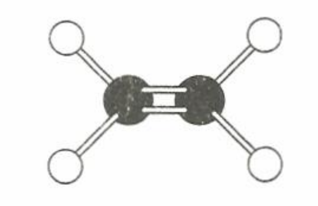
i. The reaction between methane and bromine also takes place in a similar way.

ii. Substitution reactions are characteristic of saturated hydrocarbons

Alkenes

By Defn: Alkenes are hydrocarbons which contain at least one double bond (-C=C-) between two carbon atoms.

Diagram:



General Formula

Alkenes have the general formula $\mathbf{C_2H_{2n}}$

Homologous Series of Alkenes

n	Name	Molecular Formula	Structure Formula
2	Ethene	C_2H_4	$CH_2{=}CH_2$
3	Propene	C_3H_6	$CH_3CH{=}CH_2$
4	Butene	C_4H_8	$CH_3CH_2CH{=}CH_2$
5	Pentene	C_5H_{10}	$CH_3(CH_2)_2CH{=}CH_2$
6	Hexene	C_6H_{12}	$CH_3(CH_2)_3CH{=}CH_2$
7	Heptene	C_7H_{14}	$CH_3(CH_2)_4CH{=}CH_2$
8	Octene	C_8H_{16}	$CH_3(CH_2)_5CH{=}CH_2$
9	Nonene	C_9H_{18}	$CH_3(CH_2)_6CH{=}CH_2$
10	Decene	$C_{10}H_{20}$	$CH_3(CH_2)_7CH{=}CH_2$

NB: methane not exist

Naming Alkenes

The rules used in naming alkenes are applied the same way as those for naming alkanes. In alkene the position of double bond added to the root word followed by the suffix **-p-ene**

Where:

p is the position of double bond of smallest number

Example

Name the compound below

$CH_3CH_2CH{=}CH_2$

Answer

Parent chain is butene

Smallest number Position of double bond is 1

The name of compound is **but-1-ene**

Example: NECTA 2006 Qn 08 (c) roman B

Name the systematic IUPAC name of the compound $CH_2=CH_2$

Answer

Parent chain is ethene

Smallest number Position of double bond is 1

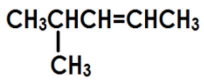
The name of compound is **eth-1-ene**

Example:

Name the systematic IUPAC name of the compound A, B, C and D

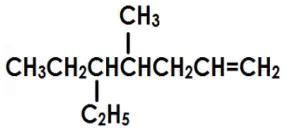
A. $CH_3CH=CHCH_2CH_3$

B.



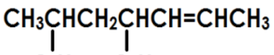
$CH_3\underset{CH_3}{CH}CH=CHCH_3$

C.



$CH_3CH_2\underset{C_2H_5}{CH}\overset{CH_3}{C}HCH_2CH=CH_2$

D.



$CH_3\underset{C_2H_5}{CH}CH_2\underset{C_3H_7}{CH}CH=CHCH_3$

Answer for Compound A

Parent chain is pentene

Smallest number Position of double bond is 2

The name of compound is **pent-2-ene**

Answer for Compound B

Parent chain is pentene

Branch chain is 4-methyl

Smallest number Position of double bond is 2

The name of compound is **4-methylpent-2-ene**

Answer for Compound C

Parent chain is hexene

Branch chain is 4-methyl and 5-ethyl

Smallest number Position of double bond is 1

The name of compound is 5-ethyl,4-methylhex-1-ene

Answer for Compound D

Parent chain is octene

Branch chain is 6-methyl and 4-propyl

Smallest number Position of double bond is 2

The name of compound is 6-methyl,4-propyloct-2-ene

Isomerism in Alkenes

Alkenes form different isomers due to the changing position of the double bond as well as the presence and position of substituents.

NB: Ethene and propene have not isomers.

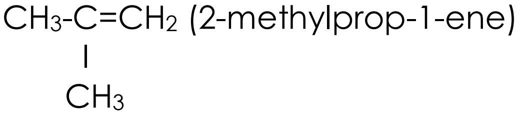
Example

Write the possible isomers of butene

Answer:

$CH_3CH_2CH=CH_2$ (but-1-ene)

$CH_3CH=CHCH_3$ (but-2-ene)



$CH_3\text{-}\underset{CH_3}{C}=CH_2$ (2-methylprop-1-ene)

Nb:

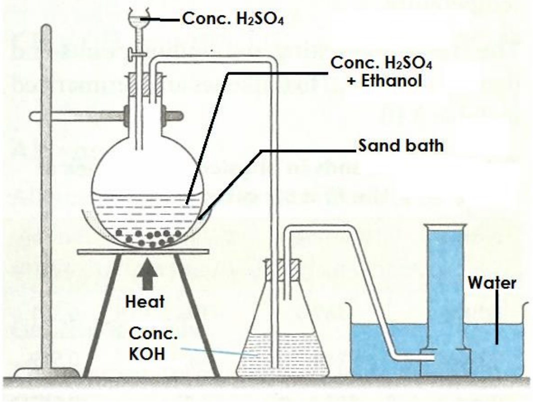
i. Isomers due to the position of the double bond. They are usually referred to as **positional isomers**

ii. Isomer due to the presence of a substituent. It is usually referred to as a **branch isomer**

Preparation of Ethene

Ethene can be prepared in the laboratory by heating a mixture of ethanol and concentrated sulphuric acid

Diagram:



Concentrated sulphuric acid dehydrates ethanol at 160 - 180°C to give ethene.

$$CH_3CH_2OH\ (l) \xrightarrow[170^0C]{Conc.\ H_2SO_4} CH_2CH_2\ (g) + H_20\ (l)$$

Ethene can also be prepared in the laboratory by dehydrating ethanol using aluminium oxide.

$$CH_3CH_2OH\ (l) \xrightarrow{Al_2O_3} CH_2CH_2\ (g) + H_20\ (l)$$

NB:

i. Ethene is a colourless gas with a faint smell

ii. It is slightly soluble in water

Physical Properties of Alkenes

i. The first three alkenes, that *ethene, propene and butene*, are gases at room temperature and pressure.

ii. The four ten alkenes are liquids at room temperature and pressure

NB: *The change in physical state is due to increase in molecular mass. This in turn increases intermolecular attractions*

iii. boiling points of alkenes increase ethene to decene
iv. melting points of alkenes increase ethene to decene
v. density of alkenes increase ethene to decene

Physical properties of the alkenes

Alkene	B.P (°C)	M.P (°C)	Density (g/cm³)
Ethene	-169.0	-104.0	0.501
Propene	-185.0	-48.0	0.519
But-1-ene	185.0	-6.5	0.595
Pent-1-ene	138.0	30.0	0.641
Hex-1-ene	140	63.0	0.673

Chemical Properties of Alkenes

Chemical reactions involving alkenes are **addition reactions**.

By Defn: an addition reaction is one in which one molecule is added to another.

Reaction with oxygen

Alkenes burn in air to give water and carbon dioxide

C_2H_4 (g) + $3O_2$ (g) $\longrightarrow$ $2C0_2$ (g) + $2H_20$(l)

Halogenation of ethene

By Defn: Halogenation of alkenes is the process through which halogen groups such as bromine and chlorine are added across the carbon-carbon double bond.

The bromine decolorized by alkenes, for example eth-1-ene react with bromine in absence/presence of light to produce 1, 2-dibromoethane (colourless)

$CH_2 = CH_2$ (g) + Br_2 (g) $\longrightarrow$ CH_2BrCH_2Br (g)

NB:

i. Light is not necessary for the reaction between bromine and ethene,
ii. The reaction between bromine and ethene is an addition reaction, in which bromine takes the place of the double bond in ethene.
iii. Addition reactions are characteristic of unsaturated hydrocarbons.
iv. Bromine is used to test for unsaturation in hydrocarbons.

Chlorine will react in a similar way with ethene in presence of silica ($Si0_2$) to form 1,2-dichloroethane (colourless)

CH_2CH_2 (g) + Cl_2 (g) $\longrightarrow$ CH_2ClCH_2Cl (g)

Hydrogenation of alkenes

The reaction takes place in the presence of **nickel** which acts as a catalyst.

$CH_2{=}CH_2$ (g) + H_2 (g) $\longrightarrow$ CH_3CH_3 (g

NB:

i. Hydrogenation is an addition reaction.
ii. Hydrogenation is an important industrial process in the manufacture of margarine from vegetable oils such as corn oil and sunflower oil. These oils are unsaturated and contain one or more double bonds.
iii. Hydrogenation converts the oils into solid fats such as margarine. Margarines are left partially unsaturated because unsaturated fats are healthier than completely saturated ones.

Reaction with hydrogen halides

Halides are binary compounds that contain halogens. Alkenes react with hydrogen halides such as hydrogen bromide and hydrogen iodide, in addition reactions.

$CH_2{=}CH_2$ (g) + HBr (g) $\longrightarrow$ CH_3CH_2Br (l)
(Bromoethane)

$CH_2{=}CH_2$ (g) + HI (g) $\longrightarrow$ CH_3CH_2I (l)
(Iodoethane)

NB:

i. During these reactions the alkenes become saturated.
ii. Hydrogen chloride does not react with alkenes at room temperature
iii. The reaction with ethene requires heat and a catalyst.

Reaction with sulphuric acid

Ethene takes part in an addition reaction with concentrated sulphuric acid to form ethyl hydrogensulphate

CH_2CH_2 (g) + H_2S0_4 (l) $\longrightarrow$ $CH_3CH_2OSO_3H$

Alkynes

Alkynes are unsaturated hydrocarbons which contain at least one triple bond (**$-C\equiv C-$**)

General Formula

The general formula of alkynes is **C_nH_{2n-2}**

Homologous Series of Alkynes

n	Name	Molecular Formula	Structure Formula
2	Ethyne	C_2H_2	$CH\equiv CH$
3	Propyne	C_3H_4	$CHC\equiv CH$
4	But-1-y ne	C_4H_6	$CH_3CH_2C\equiv CH$
5	Pent-1-yne	C_5H_8	$CH_3(CH_2)_2C\equiv CH$
6	Hex-1-yne	C_6H_{10}	$CH_3(CH_2)_3C\equiv CH$
7	Hept-1-yne	C_7H_{12}	$CH_3(CH_2)_4C\equiv CH$
8	Oct-1-yne	C_8H_{14}	$CH_3(CH_2)_5C\equiv CH$
9	Non-1-yne	C_9H_{16}	$CH_3(CH_2)_6C\equiv CH$
10	Dec-1-yne	$C_{10}H_{18}$	$CH_3(CH_2)_7C\equiv CH$

Naming Alkynes

The rules used in naming alkynes are applied the same way as those for naming alkenes.

In alkene the position of triple bond added to the root word followed by the suffix **-p-yne**.

Where:

p is the position of triple bond of smallest number of alkyne

Nb:

i. The position of the triple bond in the first two alkynes, that is ethyne and propyne, cannot change.
ii. methyne not exist

Isomerism in Alkynes

Alkynes form different isomers due to the changing position of the triple bond as well as the presence and position of substituents.

Nb:

i. Ethyne and propyne have not isomers.
ii. The number of possible isomers of alkynes increases with the increase in molecular mass

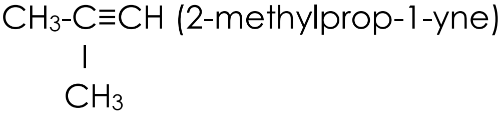
Example

Write the possible isomers of butyne (C_4H_6)

Answer:

$CH_3CH_2C\equiv CH$ (but-1-yne)

$CH_3CHC\equiv CH_3$ (but-2-yne)

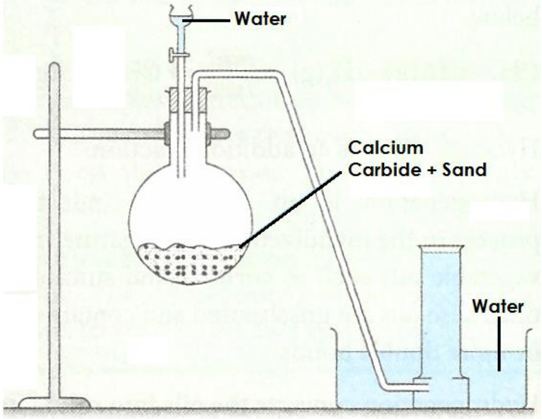


$CH_3-\underset{\displaystyle CH_3}{\underset{|}{C}}\equiv CH$ (2-methylprop-1-yne)

Preparation of Alkynes

Ethyne can be prepared in the laboratory by the action of water on calcium carbide (CaC_2).

Diagram:



Calcium carbide is hydrolysed by water to give ethyne and calcium hydroxide.

$CaC_{2(s)} + 2H_2O_{(l)} \longrightarrow C_2H_{2(g)} + Ca(OH)_{2(s)}$

NB:

The reaction is exothermic and this is why sand is put into the round-bottomed flask to prevent it from cracking.

Physical Properties of Alkynes

i. The first three alkynes are all gases at room temperature.
ii. Melting points of alkynes increase with the increase in molecular mass.
iii. Boiling points of alkynes increase with the increase in molecular mass.
iv. Density of alkynes increase with the increase in molecular mass.

Physical Properties of the Alkynes

Alkyne	B.P (°C)	M.P (°C)	Density (g/cm^3)
Ethyne	-75	-82	0.62
Propyne	-23	-102	0.67
But-1-y ne	9	-122	0.69

Pent-1-yne	40	-98	0.72
Hex-1-yne	72	-124	0.712
Hept-1-yne	100	-80	0.73
Oct-1-yne	126	-70	0.75
Non-1-yne	151	-65	0.76
Dec-1-yne	182	-36	0.77

Chemical Properties of Alkynes

Just like alkenes, alkynes take part in addition reactions. However, alkynes are less reactive than corresponding alkenes.

Reaction with oxygen

The Alkynes burn in air with a luminous smoky flame (due to the high proportion of carbon compared with hydrogen in alkynes) to produce carbon dioxide and water

$2C_2H_2\ (g) + 50_2(g) \longrightarrow 4C0_2\ (g) + 2H_2O\ (g)$

In limited supply of air carbon monoxide is formed due to incomplete combustion.

$2C_2H_2\ (g) + 30_2(g) \longrightarrow 4C0\ (g) + 2H_20(g)$

Halogenation of alkynes

Bromine is decolourized by ethyne as we see from Halogenation of alkene. For example when ethyne react with bromine form 1,1,2,2-tetrabromoethane which is colourless

$HC \equiv CH + 2Br_2 \longrightarrow CHBr_2\text{-}CHBr_2$

Nb:

i. Alkynes react with halogens in the same way as alkenes.
ii. The reaction between alkynes and bromine is used as a test for unsaturation of alkynes.

Hydrogenation of alkynes

Like in alkynes, this reaction takes place in presence of a nickel catalyst at 150^0C. The hydrogenation of alkynes first gives alkenes.

$CH \equiv CH\ (g) + H_2\ (g) \longrightarrow H_2C{=}CH_2\ (g)$

Further hydrogenation gives alkanes.

$H_2C{=}CH_2\ (g) + H_2\ (g) \longrightarrow CH_3CH_3\ (g)$

Reaction with hydrogen halides

Alkynes react with hydrogen halides at room temperature in stages as shown below.

Stage I:

$HC \equiv CH\ (g) + HBr\ (aq) \longrightarrow H_2C{=}CHBr\ (g)$

Stage II:

$H2C{=}CHBr\ (g) + HBr\ (aq) \longrightarrow H_3CCHBr_2\ (g)$

The overall equation is:

$HC \equiv CH\ (g) + 2HBr\ (aq) \longrightarrow H_3CCHBr_2\ (g)$

Alcohols/ Alkanols

Alcohols are organic compounds with an -OH (hydroxyl) as a functional group which is attached to a saturated carbon. The systematic name for alcohols is alkanols.

General Formulae

Alcohols can be represented as R-OH.

Where:
R is the alkyl group (C_nH_{2n+1})

Therefore the general formula of alcohols **$C_nH_{2n+1}OH$**

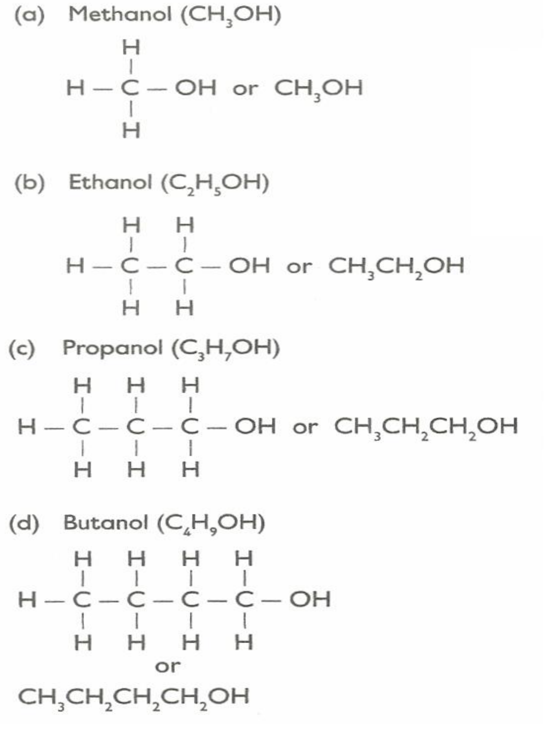
Where:
n = number of carbon atoms

Homologous Series of Alkanes

N	Name	Molecular Formula
1	Methanol	CH_3OH
2	Ethanol	C_2H_5OH
3	Propan-1-ol	C_3H_7OH
4	Butan-1-ol	C_4H_9OH
5	Pentan-1-ol	$C_5H_{11}OH$
6	Hexan-1-ol	$C_6H_{13}OH$
7	Heptan-1-ol	$C_7H_{15}OH$
8	Octan-1-ol	$C_8H_{17}OH$
9	Nonan-1-ol	$C_9H_{19}OH$
10	Decan-1-ol	$C_{10}H_{21}OH$

Structural Formulae

The figure below shows the structural formulae of some alcohols.



Nb: The condensed structural formula of butanol ($CH_3CH_2CH_2CH_2OH$) can be simplified further to be $CH_3(CH_2)_2CH_2OH$.

Naming of Alcohols

The rules used in naming Alcohols are applied the same way as those for naming hydrocarbons. In Alcohols the position of -OH (hydroxyl) added to the root word followed by the suffix **-p-ol**.

Where:
P is the position of -OH (hydroxyl) of smallest number of alkyne

Example

Write the IUPAC name of the follows compounds

i. CH_3OH
ii. CH_3CH_2OH
iii. $CH_3CH_2CH_2OH$
iv. $CH_3CH_2CH_2CH_2OH$
v. $CH_3CH_2CH_2CH_2CH_2OH$

Answer:

i. CH_3OH - Methanol
ii. CH_3CH_2OH - Ethanol
iii. $CH_3CH_2CH_2OH$ - Propan-1-ol
iv. $CH_3CH_2CH_2CH_2OH$ - Butan-1-ol
v. $CH_3CH_2CH_2CH_2CH_2OH$ - Pentan-1-ol

Isomerism in Alcohols

Like alkenes, alcohols form positional isomers by changing the position of the -OH functional groups

Nb:

i. As the number of carbon atoms increases the number of possible isomers of the alcohols also increases.
ii. methanol and ethanol have no isomers
iii. Propanol have two isomers
iv. butanol have three isomers

Example

Write the possible isomers of Propanol and butanol

Answer:

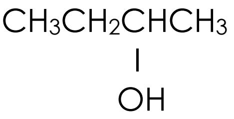
For Propanol

$CH_3CH_2CH_2OH$ – propan-1-ol

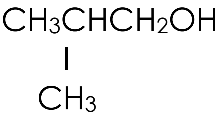
CH_3CHCH_3 – propan-2-ol
I
OH

For butanol

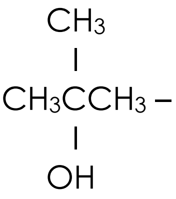
$CH_3CH_2CH_2CH_2OH$ – Butan-1-ol



$CH_3CH_2\underset{OH}{CH}CH_3$ – Butan-2-ol



$CH_3\underset{CH_3}{CH}CH_2OH$ – 2-methylpropan-1-ol



$CH_3\overset{CH_3}{\underset{OH}{C}}CH_3$ – 2-methylpropan-2-ol

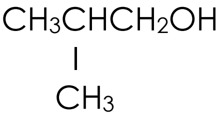
Classification of Alcohols

Alcohols are classified into three main groups depending on the position of the -OH group in the main carbon chain include;

i. Primary alcohols
ii. secondary alcohols
iii. Tertiary alcohols

Primary Alcohols

In primary alcohols, the carbon atom carrying the -OH group is attached to only one other carbon atom. Examples

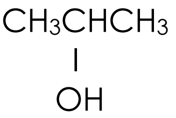


$CH_3\underset{CH_3}{CH}CH_2OH$ – 2-methylpropan-1-ol

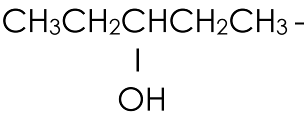
$CH_3CH_2CH_2OH$ – propan-1-ol

Secondary Alcohols

In secondary alcohols, the carbon atom carrying the -OH group is attached to two other carbon atoms.



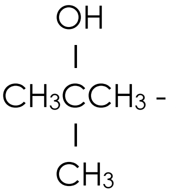
$CH_3\underset{OH}{CH}CH_3$ - propan-2-ol



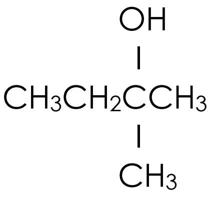
$CH_3CH_2\underset{OH}{CH}CH_2CH_3$ - pentan-3-ol

Tertiary Alcohols

In tertiary alcohols, the carbon atom carrying the -OH group is attached to three other carbon atoms. Example



$CH_3\overset{OH}{\underset{CH_3}{C}}CH_3$ - 2-methylpropan-2-ol



$CH_3CH_2\overset{OH}{\underset{CH_3}{C}}CH_3$ - 2-methylbutan-2-ol

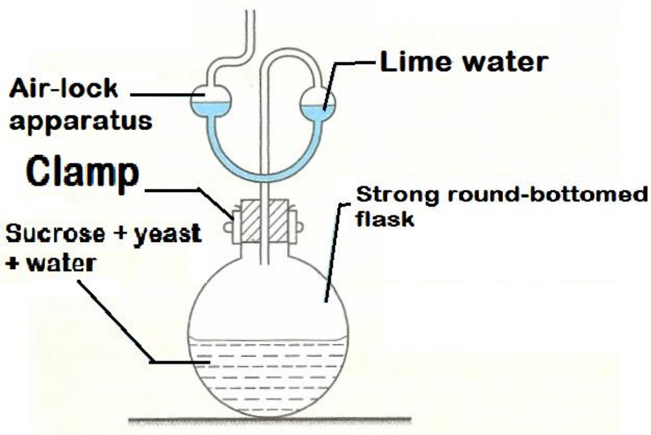
Preparation of Ethanol

Ethanol is produced through the fermentation of carbohydrates

Fermentation of carbohydrates

By Defn: *Fermentation is the process in which carbohydrates, are broken down into alcohol with the help of living organisms (bacteria, yeasts, moulds and fungi)*

Diagram:



The following reactions take place during the fermentation of sucrose. First, the sucrose ($C_{12}H_{22}O_{11}$) is converted to glucose ($C_6H_{12}0_6$) and fructose ($C_6H_{12}0_6$):

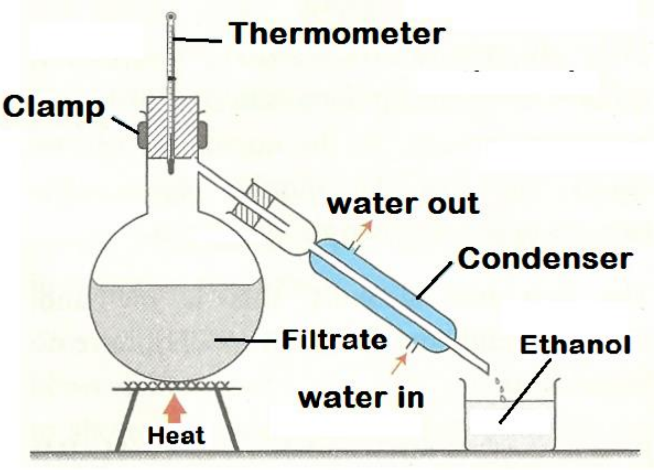
i. $C_{12}H_{22}O_{11}(s) + H_20(1) \longrightarrow C_6H_{12}0_6(aq) + C_6H_{12}0_6(aq)$
ii. The glucose and fructose produced are then converted to ethanol and carbon dioxide.
iii. $C_6H_{12}0_6\ (aq) + C_6H_{12}0_6\ (aq) \longrightarrow 4C_2H_50H\ (aq) + 4C0_2\ (g)$

Nb:

i. Lime water turn milky due to the carbon dioxide produced
ii. Fructose is an isomer of glucose. The two compounds therefore have the same molecular formula.
iii. The optimum temperature for yeast to catalyze the process is 37°C.
iv. Ethanol can also be prepared by the hydrolysis of ethene using concentrated sulphuric acid.
$CH_2{=}CH_2\ (g) + H_20\ (l) \longrightarrow CH_3CH_2OH\ (aq)$

A solution of ethanol in water is produced. This solution contains only a small amount of ethanol. A more concentrated solution is obtained by distillation.

Diagram:



Chemical Properties of Alcohols

Combustion of alcohols

Alcohols burn in air to give carbon dioxide and water

$CH_3CH_2OH\ (aq) + 3O_2\ (g) \longrightarrow 2C0_2\ (g) + 3H_20(l)$

Nb:

1. Chemical reactions Takes part due to the presence of the -OH functional group.
2. It burns in air with a blue flame

Reaction with sodium metal

Sodium reacts with ethanol to give sodium ethoxide and hydrogen gas.

$2Na(s) + 2C_2H_50H\ (aq) \longrightarrow 2C_2H_5ONa\ (aq) + H_2\ (g)$

Nb:

The reaction between sodium and ethanol is similar to that between sodium and water. However, the reaction with water is faster and more vigorous

Reaction with concentrated sulphuric acid

When concentrated sulphuric acid is heated together with ethanol at temperatures between 169° and 180°C, it dehydrates ethanol to give ethene and water.

$C_2H_5OH\ (aq) \longrightarrow CH_2{=}CH_2\ (g) + H_20\ (1)$

Oxidation of alcohols

Acidified potassium dichromate (VI) oxidizes primary alcohols to carboxylic acids. The oxidation takes place in stages.

i. The alcohols are first partially oxidized to a group of compounds known as **aldehydes**. For example, ethanol is first oxidized to ethanal, which is an aldehyde.

   $CH_3CH_2OH\ (aq) + [0] \longrightarrow CH_3CHO + H_20(l)$

   Nb:

   Aldehydes are named by replacing the -ol in the alcohol with **-al**

ii. The aldehydes (ethanal) are then oxidized to carboxylic acids (Ethanoic acid).

   $CH_3CHO + [0] \longrightarrow CH_3COOH$

Nb:

The full equation for the complete oxidation is:

$CH_3CH_2OH\ (aq) + 2\ [O] \longrightarrow CH_3COOH + H_2O(l)$

The [0] represents the oxygen from the oxidizing agent

Esterification Reactions

By Defn: *Esterification reactions(Reaction between alcohol and carboxylic acid)are neutralization reactions in which a salt (alkanoate) and water are formed*

Alcohols react with carboxylic acids to form sweet-smelling compounds known as **esters**. For example, ethanol reacts with Ethanoic acid to form **ethylethanoate**, which is an ester.

$CH_3CH_2OH\ (aq) + CH_3COOH \longrightarrow CH_3COOCH_2CH_3 + H_20\ (l)$

Nb:

i. The first part of the name of an ester is derived by replacing the **-ol** in alcohol with **-yl**
ii. The second part is derived by replacing the **-oic** in the carboxylic acid with **-oate**

   In general:

   Alkanol + alkanoic acid ⟶ alkylalkanoate + water

For example

Ethanol + propanoic acid ⟶ ethylpropanoate + water

$C_2H_5OH\ (aq) + C_2H_5COOH \longrightarrow C_2H_5COOC_2H_5 + H_20(l)$

Harmful Effects of Alcohol

Excessive consumption of alcohol leads to addiction. A person who is addicted to alcohol is known as an **alcoholic**

Negative Effects in the Society

i. Neglecting families and other relationships.
ii. Children from neglected families can also get involved in criminal activities.
iii. Alcoholics are sometimes violent and may cause injuries to other people.

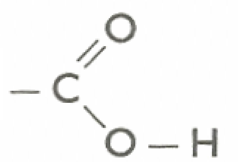
Harmful Effects on the Human Body

i. Damage of the liver
ii. Damage of the brain cells
iii. Damage to the heart
iv. The alcoholic may develop anaemia
v. Alcohol interferes with the production of testosterone and may lead to impotence and male **feminization**
By Defn: *Feminisation is a situation in which males develop female characteristics and behaviour*
vi. Excessive consumption of alcohol by pregnant women may lead to defects in an unborn baby
vii. Alcohol is a diuretic, that is, it stimulates production of urine

Carboxylic Acids

Carboxylic acids are organic acids derived by replacing one or two hydrogen atoms of the alkanes with a carboxyl group (-COOH). Its functional group is **–COOH** with structure formula shown below

Diagram



Carboxylic acids occur naturally but can also be manufactured

Natural Sources of Organic Acids

Natural sources of organic acids are;

i. Methanoic (formic) acid is found in bees and ants which use it as a defence against the enemy. It is also found in the stinging nettle plant.
ii. Ethanoic (acetic) acid is found in rotting fruits.
iii. Octadecanoic (stearic) acid is found in many natural fats and oils.
iv. 2-hydroxypropanoic (lactic) acid is found in sour milk and in animal muscles.
v. 2-hydroxypropan-1,2,3-tricarboxylic (citric) acid is found in citrus fruits such as **lemons**, **oranges** and **lime fruits**.
vi. Ascorbic acid (vitamin C) is found in citrus fruits and tomatoes.

General Formula

Carboxylic acids can be represented by a general formula of $\mathbf{C_nH_{2n}0_2}$ or $\mathbf{C_nH_{2n+1}COOH}$

Nb:

The formulae of carboxylic acids with more than one carbon atom can be represented as **R-COOH**, where R represents an **alkyl group**.

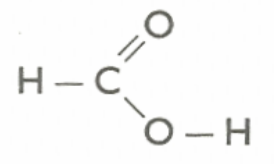
Homologous Series of Carboxylic Acids

Name	Molecular Formula
Methanoic acid	CH_20_2 or HCOOH
Ethanoic acid	$C_2H_40_2$ or CH_3COOH
Propanoic acid	$C_3H_60_2$ or C_2H_5COOH
Butanoic acid	$C_4H_80_2$ or C_3H_7COOH
Pentanoic acid	$C_5H_{10}0_2$ or C_4H_9COOH

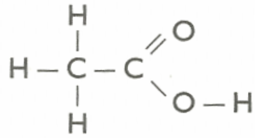
Structural formulae

The following are the structural formulae of the first four carboxylic acids

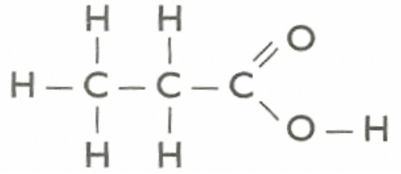
Methanoic acid



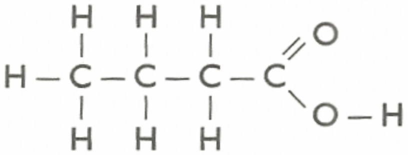
Ethanoic acid



Propanoic acid



Butanoic acid



Naming Of Carboxylic Acids

The rules used in naming carboxylic acids are applied the same way as those for naming alkanes

Nb:

1. Carboxylic acids are named by replacing the suffix **-ane** in a corresponding alkane, with **-anoic**
2. The functional group can only be at the end of the carbon chain
3. The position of the carboxylic group (R-COOH) is therefore not indicated in the name

Names of First Five Carboxylic Acids

Old Name	Iupac Name
Formic acid	Methanoic acid
Acetic acid	Ethanoic acid
Propionoic acid	Propanoic acid
Butyric acid	Butanoic acid
valeric acid	Pentatonic acid

Nb:

The use of old names is discouraged because they do not aid in the drawing of structural formulae.

Isomerism of Carboxylic Acids

Like many organic compounds, carboxylic acids also have isomers.

Nb:

1. The first three carboxylic acids that is, methanoic acid, ethanoic acid and propanoic acid, have no isomers.
2. Butanoic acid has two isomers which is butanoic acid and 2-methylbutonoic acid

Physical Properties

Physical state

The first four members of the homologous series are liquids.

pH value

They have a pH value of 4 and above, therefore its weak acid

Smell

Methanoic, ethanoic and propanoic acids have sharp smells similar to that of vinegar.

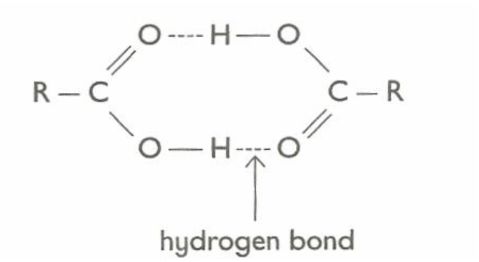
Carboxylic acids with four or more carbon atoms have unpleasant smells. An example is butanoic acid found in human sweat.

Solubility

In vapour form, alkanoic acids dissolve in organic solvents and form **dimers**.

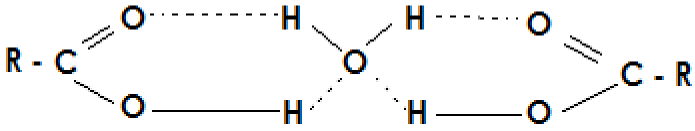
By Defn: dimers are pairs of molecules bridged by hydrogen bonds

Diagram:



Carboxylic acids of lower molecular mass dissolve completely in water. The dimers dissociate to form single molecules which form hydrogen bonds with water molecules.

Diagram:



Boiling and melting points

Carboxylic acids have higher melting and boiling points compared to the corresponding alcohols due to dimer. The dimers have double the mass of the individual molecule.

Anhydrous ethanoic acid freezes at 17°C, which is also its melting point, and is often called **glacial acetic acid**

Boiling and Melting Points

Alkanoic Acid	B.P (°C)	M.P (°C)
Methanoic acid	101	08
Ethanoic acid	118	17
Propanoic acid	141	21

Chemical Properties

Reaction with sodium hydroxide

Carboxylic acids react with sodium hydroxide in a neutralization reaction to form a salt and water.

Example Ethanoic acid reacts with sodium hydroxide to form sodium ethanoate, which is a white crystalline salt.

$$CH_3COOH\ (aq) + NaOH\ (aq) \longrightarrow CH_3COONa\ (aq) + H_20\ (l)$$

Reaction with sodium carbonate

Ethanoic acid reacts with sodium carbonate and sodium hydrogen carbonate to give a salt (sodium ethanoate), water and carbon dioxide.

$2CH_3COOH\ (aq) + Na_2CO3(s) \longrightarrow$
$2CH_3COONa\ (aq) + H_20\ (l) + C0_2\ (g)$

$CH_3COOH\ (aq) + NaHCO3(s) \longrightarrow$
$CH_3COONa\ (aq) + H_20\ (l) + C0_2\ (g)$

The reaction between ethanoic acid and sodium hydroxide is a neutralization reaction in which a salt and water are formed.

$CH_3COOH_{(aq)} + NaOH_{(aq)} \longrightarrow$
$CH_3COONa_{(aq)} + H_20_{(l)}$

Oxidation of ethanol to ethanoic acid

During fermentation, ethanol is formed. When fermentation goes beyond 14%, it stops and the ethanol formed is oxidized to ethanoic acid.

Preparation of soap from animal fats or vegetable oils

Soaps are sodium or potassium salts of long-chain alkanoic acids (fatty acids) such as **octadecanoic** acid (stearic acid), $C_{17}H_{35}COOH$

Soap making

Liquid Soaps are made from natural fats and oils, e.g. lard animal fat, castor oil, palm oil, etc which boiled with sodium or potassium hydroxide

Fat + sodium hydroxide → soap + glycerol

Solid soap made from reaction between liquid soap and brine (salt solution)

Liquid soap + Brine → solid soap

Procedure to make soap

Apparatus

i. 250 cm^3
ii. Beaker
iii. 50 cm^3 measuring cylinder
iv. Glass rod
v. Bunsen burner
vi. Wash bottle
vii. Tripod stand
viii. Spatula
ix. Stop watch
x. Filter paper

Material required

i. Fat oil
ii. 4M Sodium hydroxide
iii. Brine (NaCl)
iv. Distilled water

Procedure

i. Put 25 cm^3 of fat oil into 250 cm3 beaker
ii. Add 100 cm^3 of 4m NaOH solution
iii. Heat the mixture gently over a Bunsen burner for 30 minutes
iv. Continue heating and stirring continuously. Keep adding distilled water from time to time until no more solid separates out
v. Allow the mixture to cool and then add brine to precipitate solution. Stir the mixture continuous for 5 minutes
vi. Dry liquid soap to form solid soap by cool

Nb:

i. Soap is a precipitated out of the mixture by adding (brine) salt solution
ii. The process of making soap is called **saponification**
iii. Do not put any soap you made on skin or in eye if it still contain sodium hydroxide

Soil Chemistry

By defn: *Soil chemistry is the study of various chemical nutrients present in the soil and their influence on the properties of the soil such as acidity and alkalinity*

Nb:

Chemical reactions in the soil determine the availability of important nutrients in the soil required for growth of healthy crops

Soil

By defn: *soil is the top layer of the land covering the earth's surface*

Or

By defn: *soil is the medium/layer in which plants grow and derive moisture and nutrients*

Composition of soil

It made from ***broken down rock particles***, ***rotten plant material***, ***water*** and ***air***

Soil formation

Soil is formed by **weathering process**

Weathering

By defn: *Weathering is the physical and chemical breakdown of the rock material near the earth's surface*

Or

By defn: *Weathering is a combination of disintegration (breaking down) and synthesis (building up) process*

Nb:

i. Weathering involves series of complex changes that alter the form, colour, texture and composition of the rock particles
ii. The rock is first broken down into smaller fragments and eventually into individual constituent minerals
iii. The weathered rock materials combine with decomposing organic matter to form soil layers
iv. The processes are continuous

Agents of weathering

Include the factors that facilitate the weathering process as

i. Water
ii. Gravity
iii. Air (oxygen and carbon dioxide)
iv. Plants and animal
v. Temperature changes
vi. Humans activities

Types of weathering

There are two main types of weathering **namely**

i. Physical weathering
ii. Chemical weathering

Physical weathering

By defn: *Physical weathering is disintegration of rock material without change its chemical composition*

Nb:

i. Physical weathering involves breakdown of big rocks to form small rocks
ii. Physical weathering is more effective in areas which have
   (a) little vegetation
   (b) large diurnal (each day) temperature range
   (c) temperature falling as low as 0 ℃

Ways physical weathering takes places

The follows ways are physical weathering takes places, includes

i. Pressure release
ii. Exfoliation
iii. Frost shattering
iv. Crystallization
v. Biological weathering

Pressure release

Pressure occurs over overlying rocks which removed by erosion which release pressure cause rock to expands, which result stress within the rock. Crack is formed parallel to the rock surface. Over a period of time, the outer layers of the rock break away in sheets

Exfoliation

Exfoliation occurs in hot deserts where a temperature rises to over 40℃ and night fall to below 10℃. Repeation of this cause expansion and contraction of rock, This create stress in the rock causing it to crack and final the outer layer of the rock peel off

Frost shattering

Frost shattering occurs in cold regions and mountain tops, where temperature is just above or below freezing point. Water fills the cracks or joints in the rock and freezes at night or during winter. Repeating of this cause expansion and contraction of rock, this create stress in the rock causing it to crack and final the broken materials collected at the foot of the slope

Crystallization
Crystallization is the weathering by growth of salt crystal. In hottest region (desert) evaporation draws ground water from dissolved water upward into the pores of the rock. When the water evaporates, the salts are left behind as crystal. Salts crystal creates stress in the rock, weakens it and breaks it down into grains

Biological weathering
Biological weathering involves

i. Roots growing into the cracks and joint in the rocks
ii. Burrowing animals such as a moles, earthworms and termites making hole/tunnel in the ground
iii. Human activities, such as building roads and cultivating land

Chemical weathering
By defn: *chemical weathering is disintegration of rock materials whereby chemical constituent of minerals changed*

Nb:

i. chemical weathering destroy (change) internal structure of minerals
ii. chemical weathering occur common in warm and wet areas

Agent of chemical weathering
There are two main agent of chemical weathering includes

i. Water
ii. Weak acids (Carbonic acid)
   Rain + carbon dioxide ⟶ Carbonic acid
   $H_2O_{(l)} + CO_{2(g)} \longrightarrow H_2CO_{3(aq)}$
   $H_2CO_{3(aq)} \longrightarrow H^+_{(aq)} + CO_3{}^{2-}{}_{(aq)}$
   H^+ can easily enter crystals structure results release other ions into the water

Ways chemical weathering takes places
The follows ways are chemical weathering takes places, includes

i. Dissolution
ii. Hydrolysis
iii. oxidation

Dissolution
The mineral (rocks) is dissolved in water. For example calcite rock ($CaCO_3$) dissolved in acidic rain to form calcium bicarbonate ($CA(HCO_3)_2$)

$CaCO_{3(s)} + H_2O_{(l)} + CO_{2(g)} \longrightarrow CA(HCO_3)_{2(aq)}$

$CA(HCO_3)_{2(aq)} \longrightarrow Ca^{2+}_{(aq)} + 2HCO_3{}^-{}_{(aq)}$

The dissolved rocks are washed down through the soil

Hydrolysis
Hydrogen ions (H^+) and hydroxyl ions (OH^-) replace other ions in a mineral. Hydrolysis takes place in the presence of water. For example orthoclase ($KAlSi_3O_8$) react with hydrogen ions in presence of water to form potassium ion clay mineral ($Al_4Si_4O_{10}(OH)_8$) and silica (SiO_2)

$KAlSi_3O_{8(s)} + 4H^+_{(aq)} + 2H_2O_{(l)} \rightarrow 4K^+_{(aq)} + Al_4Si_4O_{10}(OH)_{8(s)} + 8SiO_{2((s)}$

Oxidation
Oxygen reacts with other minerals, changing the oxidation state of ions. For example pyroxene ($FeSiO_3$) reacts with oxygen to form magnetite (Fe_3O_4) and silica (SiO_2)

$6FeSiO_{3(s)} + O_{2(g)} \rightarrow 2Fe_3O_{4(aq)} + 6SiO_{2(s)}$

Nb:

i. Oxidation is common in iron-bearing mineral
ii. Oxidation state of iron is +2 and +3 in Fe_3O_4

Factors Influencing Soil Formation
Follows are Factors determine the kind of soil which is formed in a particular area, include

i. Parent rock material
ii. Climate change
iii. Living organisms
iv. Topography of the area
v. Time

Parent rock material
The following factors that parent rock determine the type of soil formed

i. Basic rocks such as limestone are easily weathered unlick acidic rock which contain silicate

ii. Rock contain Porous provide large surface area for chemicals to act on it which easily weathered by chemical weathered

Nb:
(a) Parent rock also affect the soil texture
(b) Soil texture is the relative proportions of the different size in the soil
(c) Soil texture influence the water permeability of the soil

Climate change

Climate change such as rainfall, temperature, sunshine, relative humidity and wind influence soil formation

i. Rainfall provides water, which is the main agent of weathering
ii. Temperature change cause alternate expansion and contraction of rock which result the breakdown of rock into smaller particles
iii. High temperature speed up the rate of chemical reactions , rate of weathering and activity of micro-organism and vice versa
iv. Wind acts as a transportation agent and carries weathered materials from one to another

Living organisms

Living organisms such as plant and animals contribute towards the organic matter present in the soil

i. Soil formatted in area of a lot of vegetation cover
ii. Plants root and burrowing animal help in breaking the rock into smaller particle

Topography of the area

The appearance of the landscape influence soil formation

i. Soil on the top of hilly area are heavily leached
ii. Soil found in flat land and low lying area tend to be more fertile and deep mainly because of deposition of materials
iii. Lower and flatter areas tend to be darker in colour because they have more organic matter

Time

The deep soils are found in place whereby process of soil formation has been going on for a long time and vice versa

Soil Nutrients

By defn: *Soil Nutrient is the dilute solution released into soil from parent rock during weathering needed by the growing plants*

Nb:
i. Essential plant nutrients include elements such as carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, zinc, chloride and cobalt
ii. A soil contain all essential element required by plant in their proportion is called **complete culture solution**
iii. A solution contain all essential element required by plant in their proportion is called **complete culture soil**
iv. A water contain all essential element required by plant in their proportion is called **water culture**

Essential nutrients

Element	Chemical symbol	Form taken up by plant
Carbon	C	CO_2
Hydrogen	H	H_2O
Oxygen	O	H_2O

Classification of essential plant nutrients

It categorised into two, includes
i. Macronutrients (Major nutrients)
ii. Micronutrients (Trace elements)

Macronutrients

By defn: *Macronutrients is the nutrient required by plant in large quantity*

Classification of Macronutrients

It categorised into two, includes
i. Primary Macronutrients
ii. Secondary Macronutrients

Primary Macronutrients

By defn: *Primary Macronutrients is the nutrient required by plant in relatively large quantity*. They are **Nitrogen**, **Phosphorous** and **Potassium**

Essential Primary Macronutrients

Element	Chemical symbol	Form taken up by plant

Nitrogen	N	NH_4^+ , NO_3^-
Phosphorous	P	H_2PO_4 , HPO_4^{2-}
Potassium	K	K^+

Function of primary macronutrient

The following are the function of macronutrients in plant growth

Function of Nitrogen

i. It is constituent element of protoplasm of all plant cell
ii. It is constituent element of protein
iii. It forms part of the chlorophyll molecule which gives plants the green colour
   Nb: Chlorophyll is necessary for photosynthesis
iv. Nitrogen promote vegetative growth in crops it important in crops whereby leaves are harvested e.g. cabbages
v. Essential element in cell division
   Nb: Need for plant growth
vi. Control the availability of phosphorous and potassium in plant
vii. Increase grain size and protein content in cereals
viii. Helps in manufacture of enzymes and plant hormones
ix. Promote root growth

Effects of nitrogen deficiency

i. Plant leaves turn yellow and fall prematurely
ii. Stunted growth in plants
iii. Plant become chlorosis
   Nb: Chlorosis is situation whereby leaves lose chlorophyll and turn yellow or yellowish green
iv. Cause production of pigment such as anthocyanin (purplish colouration) Instead of chlorophyll
   Nb: This lowers the efficiency of plant to photosynthesize

Function of Potassium

It the second most essential element after nitrogen, the following is the function of potassium

i. Important in carbohydrate formation and translocation of food
ii. Useful in neutralization organic acids in plants
iii. Regulate nitrogen and phosphorous uptake
iv. Component of chlorophyll molecule
v. Regulate osmosis in cells
vi. Improve tissue formation
vii. Assists in protein synthesis
viii. Strengthens plant stall, hence prevent lodging and microbial attack

Effects of potassium deficiency

i. Leaf curling
ii. Leaf surface lose chlorophyll and become yellow
iii. Premature leaf fall
iv. Leaf margins become scorched while central part remains green
v. Stunted growth

Function of Phosphorous

i. Helps in root nodule formation in leguminous plants such as beans and groundnuts
ii. Strengthens plant stem, thus prevent lodging
iii. It is a constituent of nucleoproteins, which are required during cell division
iv. Essential in flowering and fruit and seed formation
v. Important in protein, fat and carbohydrate synthesis
vi. Promote resistance to the disease in plants
vii. Increase grain yield in cereals
viii. Hastens plant maturity

Nb:

Micro-organism in the soil convert inorganic/organic phosphorous into phosphates which insoluble in water and there are not easily leached

Effects of Phosphorous deficiency

i. Stunted growth
ii. Increase production of anthocyanin

Poor development of roots, barks, flower and seeds

Secondary Macronutrients

By defn: *Secondary Macronutrients is the nutrient required by plant in small quantity*. They include **Calcium**, **Magnesium** and **Sulphur**

Essential Secondary Macronutrients

Element	Chemical symbol	Form taken up by plant
Calcium	Ca	Ca^{2+}

Magnesium	Mg	Mg^{2+}
Sulphur	S	SO_4^{2-}

Micronutrients

By defn: *Micronutrients is the nutrient required by plant in small quantity*. They include Manganese, Molybdenum, Iron, Cobalt, Zinc, Boron, Copper and Chlorine

Essential Micronutrients

Element	Chemical symbol	Form taken up by plant
Iron	Fe	Fe^{2+} , Fe^{3+}
Manganese	Mn	Mn^{2+}
Boron	B	H_3BO_3
Chlorine	Cl	Cl^-
Zinc	Zn	Zn^{2+}
Copper	Cu	Cu^{2+}
Molybdenum	Mo	MoO_4^{2-}

Loss of plant nutrients from the soil

Unmanaged soil loses their fertility (ability to provide crops). If nutrients are not supplied in the correct quantity, the plants and their yields are affected

How soil loses nutrients

Soil may lose its nutrients in any of the following ways

i. Soil erosion
ii. Monocropping
iii. Overgrazing
iv. Overstocking
v. Deforestation
vi. Burning of vegetation
vii. Leaching
viii. Poor farming methods

Soil erosion

Removal and carrying away of top fertile soil (organic matter and plant nutrients) leading to the loss of soil nutrients

Monocropping

Growing one type of crop repeatedly one the same piece of land, exhausts the soil nutrients and leaves it bare after harvest. This make easy for the top soil be carried away by agent of erosion, leading to loss of soil nutrients

Overgrazing

Practice of grazing animals on the same piece of land repeatedly to the point of leaving the land bare cause exposition the top soil of agents of erosion

Overstocking

Keeping too many animals on the piece of land than it can support, animals eat most vegetation, leaving the land bare cause exposes the top soil of agents of erosion

Deforestation

Cutting down trees without planting other leaves soil unprotected against agent of soil

Burning of vegetation

Burning vegetation exposes the top soil of agents of erosion

Leaching

When soluble plant nutrients are washed into the lower layer of soil and beyond the root zone makes the nutrients unavailable to plants

Poor farming methods

Destroy or exhaust plant nutrients in the soil like monoculture, overgrazing, overstock and burning of vegetation lose soil nutrients

Managing of soil nutrients

Soil can be managing by the following methods

i. Prevention of soil erosion
ii. Crop rotation
iii. Good harvesting practices
iv. Controlled grazing
v. Intercropping (Mixed cropping)
vi. Uses of manures
vii. Minimum tillage
viii. Agroforestry
ix. Mulching

Prevention of soil erosion

The soil erosion can be prevented by the following ways

i. Terracing
ii. Contour farming
iii. Strip cropping
iv. Planting windbreakers

Terracing

By defn: *Terracing is the levelled section of cultivated hilly area designed to check the* *speed of water flowing on the surface*. They are constructed to follow the contour of the land to keep rain water on the land rather than run down the slope

Types of terracing

There are two main types, include

i. Level terracing
ii. Drain terracing

Level terracing

By defn: *Level terracing is the kind of terracing whereby soil removed from both sided of the terrace line to control water run-off*

Drain terracing

By defn: *Drain terracing is the kind of terracing whereby channels are made across the slope to control water run-off*

Contour farming

By defn: *Contour farming Is the cultivation across the slope by slows down the speed of surface run-off and traps any eroded soil*

Strip cropping

Alternative strips of crops can be planted on the contour to protect the soil erosion

Planting windbreakers

When trees and tall grasses planted in strip, it reduce the speed and intensity of wind so reduce soil erosion

Crop rotation

Growing different crops on the same field at different times in an orderly sequence, involves a leguminous crop. It helps to manage soil

Important of Crop rotation

i. it improve nitrogen content of the soil
ii. balance utilizing of the soil nutrients
iii. helps to control pests and diseases

Good harvesting practices

Leaving plant remains to rot in the soil instead of removing them help to restore soil fertility by returning the nutrients back into the soil

Controlled grazing

Keeping right number of animals on a piece of land and rotational grazing does not leaves the land bare

Intercropping (Mixed cropping)

Growing different crops on the same land at same times with legumes, it prevent soil erosion and legumes fix nitrogen into soil

Uses of manures

Manure (decomposing organic water such as plant remains and animal waste) can manage soil by the follows way

i. Manure bind the soil particles which help to prevent soil erosion
ii. Manure increase water holding capacity of the soil
iii. Manure Regulate pH
iv. Manure Improve soil structure
v. Manure Release nutrients into soil
vi. Manure Prevents leaching of essential nutrients

Minimum tillage

Prepare and cultivate for crops at minimum level avoid over cultivation which destroy soil structure and lead to soil erosion and leaching. Minimum tillage achieved by using alternative methods such as fallowing, uprooting and slashing of weed

Agroforestry

Planting trees together with agricultural crops protect the soil erosion

Mulching

Covering the bare soil with a layer of organic matter such as straw, grasses, leaves and rice husks protect the soil erosion

Advantage of mulching

i. Mulching help to conserve soil moisture and suppresses the growth of weeds
ii. Mulching keep the soil cool and adds to the organic matter in the soil

Manures

By defn: *Manure is decomposed organic substance derived from animal waste and plant residues contain one or more plant nutrients*

Types of manure

There are three main types of manures, includes

i. Farmyard manure
ii. Compost manure
iii. Green manure

Farmyard manure

Made from the waste of farm animals such as cattle, horse, sheep, pigs, rabbits and chicken

Nb:

i. Manure Contain varies nutrient due to food eaten and its storage before used
ii. Manure Stored in optimum air and water to prevent oxidation, which cause heat that loss nitrogen as a gas
iii. Too much water cause Manure leaching
iv. Manure Stored in a closed system to avoid any factors that can harm it

Green manure

Made from ploughing green plant material into the soil, most plants used are legumes which have nitrogen contents

Advantage of using green manure

i. It maintain and improve the organic matter of soil
ii. It conserve plants nutrients
iii. Compost manure

Compost manure

Made from different types of decayed organic matter such animal waste and plant residue or plant material only, it has high nutrient content

Preparation of compost manure

It involves two main stages, includes

i. Site selection
ii. Preparation methods

Site selection

The place compost can be prepared can be selected the following factors

i. Drainage
ii. Direction of the prevailing wind
iii. Size of the farm
iv. Accessibility

Drainage

It should be placed in drainage (cause the liquid to run out, leaving it empty or dry) which prevent leaching of nutrients and to ensure good aeration (introduce air into manure)

Direction of the prevailing wind

Compost manure preparation should not place in the place where wind blow from compost manure to the settlements

Reason: prevents bad odour to settlements

Size of the farm

Compost manure should located at centre of the farm where compost manure is to be used

Reason: easily in transport around the farm

Accessibility

The site should easily accessible for easy transportation on of the material used

Preparation methods

Compost manure can prepared by using two methods, includes

i. Preparation by using pit method
ii. Preparation by using stack method or heap method

Preparation by using pit method

The following procedure is used to prepare compost manure by using pit method

i. Dig the compost pit
   It should be about 1m deep, (1.5 – 2) m wide and of a suitable length

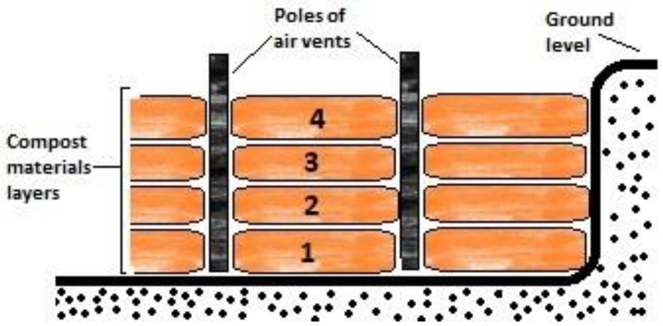
ii. Fill the pit with material
   Material filled in layers of (10 – 15) cm, always
   (a) Start with the fibrous material such as maize stalks to make foundation of compost
   (b) Pack the next layer with glass, leaves or any refuse material
   (c) Add some well decomposed manure to provide nutrients to micro organism
   (d) Add a layer of wood ash to improve the level of phosphorus and potassium in the resulting manure

(e) Add a layer of top soil to supply the micro-organism necessary for the organic decomposition of the manure

iii. Repeat step 2 until the pit is full

iv. Cover the pit with a layer of top soil

Diagram:

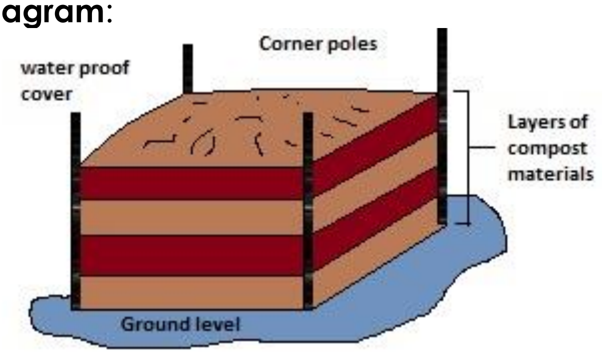


Preparation using heap method

The following procedure we used to prepare compost by using stack method

i. Scrape off surface vegetation and top soil from the selected site. Level the ground
ii. Fix pegs at a distance of 2m apart to form the four corners of the heap. The heap should be about 105m high
iii. Start the heap with a 20 cm layer of fibrous material such as leaves, hay, straw or any other refuse materials
iv. Cover the layer of fibrous material with a 10 cm layer of nitrogenous material such as fresh grass, weeds, fresh or dry manure or digested(disintegrate) sewage sludge
v. Repeat the pattern of 20cm of fibrous material and 10 cm nitrogenous material until hep height is achieved
vi. Wet the heap after each layer
vii. Cover the heap with soil or hay to retain heat
viii. Turn the heap at intervals of 6 and 12 weeks, until complete decomposition of the compost has occurred

Diagram:



Nb:

i. Turning help air circulation for proper decomposition
ii. Prepared during rainy season
iii. Material used are crop residue, animal waste, farmyard, compost manure, inorganic fertilizer and top soil
iv. Usually used after about six months

Advantage of manure

i. It improve soil structure
ii. Humus from manure bind soil particle together
iii. Humus (black) from manure absorb more heat which moderate soil temperature
iv. Humus from manure improve soil aeration and drainage
v. It not readily lashed out
   Reason: takes long time to be soluble
vi. It food and shelter for soil micro organism
vii. Do not change the pH soil
viii. Improve soil fertility by release wide range of nutrients over a long period

Disadvantage of manure

i. It have a low nutrient content, they used in large quantity to supply the required amount of nutrients
ii. Manure spreading pests, diseases or weed seeds when infested material used
iii. Manure release nutrients slowly over a long time
iv. Manure can easily lose nutrients if poorly stores
v. Manure have high moisture content which makes difficult to store and transport

Fertilizers

By defn: *Fertilizers is inorganic substance which added to soil to supply one or more plant nutrients*

Classification of Fertilizers

Fertilizers are classified on basis of

i. Nutrients content
ii. Time of application
iii. Effects on soil pH

Nutrients content

It the fertilizer contain two or more of primary macronutrients

Classification of Nutrients content

It divided into two categories, includes

i. Straight Fertilizers
ii. Compound Fertilizers

Straight Fertilizers

Straight fertilizers contains only one of the primary macronutrients

Classes of Straight fertilizers

There three classes of Straight fertilizers, includes

i. Nitrogenous fertilizers
ii. Phosphatic fertilizers
iii. potassic fertilizers

Nitrogenous fertilizers

It contains nitrogen as only primary macronutrients. Example

i. Calcium nitrate (CAN) $[NH_4NO_3 + CaCO_3]$
ii. Ammonium sulphate nitrate (ASN) $[NH_4NO_3 + (NH_4)_2SO_4]$
iii. Sulphate of Ammonia (SA) $(NH_4)_2SO_4]$
iv. Urea - $[CO(NH_2)_2]$

Properties of Nitrogenous fertilizers

i. Highly soluble in soil water
ii. Easily leached to lower soil horizons beyond the root zone of most crops
iii. They applied to growing crops
iv. Do not remain in the soil for the long time
v. Scorching the plant parts
vi. Highly volatile under hot weather condition
vii. They hygroscopic (absorb moisture from the atmosphere)
viii. Most have corrosive effect

Properties of Nitrogenous fertilizers

Fertilizer	Characteristics
CAN	i. Mixture of ammonium nitrate and calcium carbonate ii. Contain 21% of nitrogen iii. Neutral fertilizer iv. Improve soil structure v. High hygrospic and non-corrosive vi. Applied as atop dress vii. Greyish granules
ASN	i. Mixture of ammonia nitrate and ammonium sulphate ii. Contain 261% nitrogen iii. Less acidic compare to CAN iv. Brownish orange or yellows granules v. High corrosive
SA	i. Contain 20 to 21% nitrogen in ammonium form ii. Acid forming fertilizer iii. White crystals almost like sugar High volatile
Urea	i. Contain 45 to 46% nitrogen ii. Easily lost by evaporation and leaching iii. Prefer to high absorption capacity like sugar cane iv. Has scorching effect v. soluble

Phosphatic fertilizers

It contains Phosphorus as only primary macronutrients. Example

Single superphosphate (SSP)
$[Ca(H_2PO_4)CaSO_4]$
Double superphosphate (DSP)
Triple superphosphate (TSP)

Properties of Phosphatic fertilizers

i. Remain in the soil for a long time
ii. Sparingly soluble in water
iii. They are not easily leached and usual uses at planting time
iv. Slight scorching affect and usual mixed with other to minimize scorching effect

Properties of Phosphatic fertilizers

Fertilizer	Characteristics
SSP	i. Contain 20 to 21% of phosphorous pentaoxide (P_2O_5) ii. Do not induce acidity to soil

	iii. Supplies phosphorous, calcium and sulphur iv. Soluble in water v. White creamy granules
DSP	i. Contain 43 to 52% of (P_2O_5) ii. Greyish granules smaller than CAN iii. Slightly acidic
TSP	

Potassic fertilizers

It contains potassium as only primary macronutrients. They include

i. Potassium chloride (chloride of potash) (KCl)
ii. Potassium sulphate (K_2SO_4)

Nb:

Potassic fertilizer are not commonly used in Tanzania because the soil are rich in potassium

Properties of potassic fertilizers

i. Have moderate scorching effect
ii. Moderate soluble in water
iii. More soluble than phosphatic fertilizer and less soluble than nitrogenous fertilizer

Compound Fertilizers

A compound fertilizer contains two or more of primary macronutrients. They include

i. Diammonium phosphate (DAP) [$(NH_4)_2PO_4$]
ii. Nitrophos
iii. Monoammonium phosphate (MAP)

Nb:

i. They made by mixing two or more straight fertilizers
ii. Fertilizer contains all the three primary macronutrients called **Complete fertilizer**

Properties of Compound Fertilizers

Fertilizer	Characteristics
DAP	i. Has fertile grade of 18:46:0 ii. Moderate acidic iii. Contain both nitrogen and phosphorus iv. Applied at planting time v. Has fertile grade of 20:20:20
Nitrophos	i. Moderate acidic ii. Contain both nitrogen and phosphorus
MAP	i. Moderate acidic ii. It has same characteristics of DAP

Time of application

There are fertilizers that are applied during

i. During planting
ii. During crop is actively growing

During planting

Phosphate and compound fertilizers are usually applied. They called **planting fertilizer**

During crop is actively growing

Nitrogenous or potassic fertilizers are usually applied. They called **top-dressing fertilizers**

Effects on soil pH

Fertilizer can be acidic or neutral

i. Calcium ammonium nitrate (CAN) is a neutral to sparingly basic
ii. All others fertilizers are acidic

Fertilizer analysis (grade)

By defn: *Fertilizer analysis Is the percentage amount of each primary macronutrient*

Mathematically

$p = \frac{N}{Ft} \times 100\%$

$$\mathbf{p = \frac{\boldsymbol{N} \times 100\%}{\boldsymbol{Ft}}}$$

Where

Percentage of nutrients = P
Nutrient = N
Total weight of fertilizer= Ft

Nb:

i. Fertilizer grade usually indicated on the fertilizer bag
ii. Fertilizer Bag indicated as NPK, means P stand for P_2O and K stand for K_2O
iii. Usually Percentage given as a ratio. For example 100Kg of fertilizer of grade 20:20:20 contains 20 Kg of N, 20 Kg of P and 20 Kg of K

Fertilizer ratio

By defn: *Fertilizer ratio is the simple ratio of the nutrients relative to each other*

Nb:

i. For example a fertilizer of grade 20:20:20 has a 1:1:1 ration of N:P:K

ii. Fertilizer ratio is calculated by dividing smallest number in the fertilizer grade

Determining the amount of fertilizer to apply

The amount of fertilizer to apply per hectare depends on the amount of nutrient required and the fertilizer grade available

Example

Piece of land requires 120 kg of N, 60kg of P and 80kg of K to be applied per hectare. What amount of each fertilizer will need to be applied per hectare on a piece of land if following fertilizer is available?

(a) Sulphate of ammonia (21% N)
(b) Single superphosphate (18% P)
(c) Nitrate of potash (60% K)

(a) **Data**

N = 120 kg
p = 21%
Ft = ?

Solution

From: p = $\frac{N \text{ x } 100\%}{Ft}$ – make Ft subject

Ft = $\frac{N \text{ x } 100\%}{P}$ = $\frac{120 \text{ x } 100\%}{21}$

Ft = $\frac{120 \text{ x } 100\%}{21}$ = 571.43

Ft =571.43 Kg

(b) **Data**

N = 60 kg
p = 18%
Ft = ?

Solution

From: p = $\frac{N \text{ x } 100\%}{Ft}$ – make Ft subject

Ft = $\frac{N \text{ x } 100\%}{P}$ = $\frac{60 \text{ x } 100\%}{18}$

Ft = $\frac{60 \text{ x } 100\%}{18}$ = 333.33

Ft =333.3 Kg

(c) **Data**

N = 80 kg
p = 60%
Ft = ?

Solution

From: p = $\frac{N \text{ x } 100\%}{Ft}$ – make Ft subject

Ft = $\frac{N \text{ x } 100\%}{P}$ = $\frac{80 \text{ x } 100\%}{60}$

Ft = $\frac{80 \text{ x } 100\%}{60}$ = 133.33

Ft =133.3 Kg

Methods of fertilizer application

The following are some of the methods used in applying fertilizers

i. Broadcasting methods
ii. Placement methods
iii. Side dressing
iv. Foliar spraying
v. Drip application
vi. Banding

Broadcasting methods

Involves the random scattering of fertilizers on the farm either manually or fertilizer spreads

Nb:

i. It used with nitrogenous and potassium fertilizers
ii. It used when soil is moist

Placement methods

Fertilizer is put in the planting holes or drills, and then fertilizer mixed thoroughly with the soil before the placement of seeds

Nb:

Method used when applying phosphatic fertilizers

Side dressing

This is placement of Nitrogenous fertilizers at the side of the crop or around the growing crop

Nb:

It mainly used on perennial crops like coffee

Foliar spraying

Involves the putting of fertilizers solution on the leaves of crop which absorbed by leaves

Nb:

i. Applied when condition do not allow the use of soil-applied fertilizer
ii. It applied to avoid formation of complex compound which reduce the availability of plant nutrients

Drip application

Fertilizer is dissolved in water and applied to individual plants through pipes or bottles

Nb:

i. It is uneconomical method

ii. It is commonly used in horticultural (practice of garden cultivation and management) crop fields

Banding

Fertilizer placed either below or on the side of the seed or plant usual at a distance of (6-9) cm from the seed or plant

Advantage of inorganic (artificial) fertilizers

i. They are not bulky and can be transported easily
ii. They contain readily available nutrients for plant growth
iii. They are relatively easy to apply compared to manures
iv. They allows the regulation of specific nutrients to required level for the growth of specific crops

Disadvantage of inorganic fertilizers

i. They expensive to buy
ii. They cause rapid chemical changes in the soil, hence affect soil pH
iii. They not improve physical properties of soil, such as soil structure
iv. Nutrients from inorganic fertilizer are easily released, hence can be easily leached
v. They have scorching (burning) effect on some crop parts such as leaves and stems
vi. They do not promote the activities of micro organisms

Soil Reaction

By defn: *Soil reaction refers to the acidity or alkalinity of the soil*

Nb:

i. Soils that are acidic are said to have an acid reaction
ii. Soils that are alkaline are said to have an alkaline reaction
iii. Soil reaction are determined by concentration of hydrogen ion (H^+) and hydroxyl ions (OH^-)
iv. When concentration of OH^- is greater than concentration of H^+, the soil has an **alkaline reaction**
v. When concentration of H^+ is greater than concentration of OH^-, the soil has an **acidic reaction**
vi. When concentration of H^+ is equal to the concentration of OH^-, the soil reaction is **neutral**

Soil pH

By defn: *soil pH refers to the measure of acidic or alkalinity of the soil*. It expresses as the negative logarithm of the hydrogen ion concentration

Mathematically

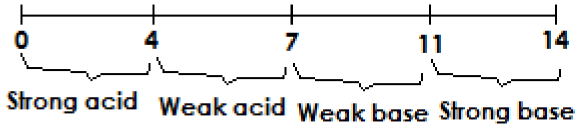
$$pH = -\log[H^+]$$

Where:

$[H^+]$ = concentration of hydrogen ions

Nb:

i. pH value ranges from 0 to 14



ii. pH value below 7 are acidic
iii. pH value above 7 are basic
iv. pH value of 7 are neutral
v. pH of most soil range from 3.5 to 11
vi. Most plants grow well in soil having a pH range of between 6 and 8
vii. Tolerance to acidity or alkalinity varies from plant to plant
viii. Some plant such as tea do well in acidic soil
ix. Nutrients such as Nitrogen, phosphorous, potassium and manganese available within the pH range of 6.5 to 7.5
x. Nutrients such as iron, Chorine, Copper, Manganese and Zinc favoured by acid soils
xi. Very acidic soil or very alkaline soil do not support micro-organism activities

Importance of soil pH

i. Enable us to select crop to plant associate with pH value
ii. Enable us to determine kind of some nutrients available in soil
iii. Enable us to determine the micro-organism activities

Factors affect soil pH

The pH of a soil is affected by the following factors, includes

i. Parent rock
ii. Rainfall
iii. Human activities

iv. Application of fertilizers

Parent rock

Soil formed from basic rocks has higher pH value than those formed from acidic rocks

Rainfall

Soils formed under high rainfall (acidic rain) conditions are more acidic than those formed under dry conditions

Human activities

Pollution alter the pH of the soil such as harmful gases releases by vehicles

Application of fertilizers

Fertilizers contain ammonium or urea lower the pH value of the soil by increase acidity of the soil. Manure also add acidity to the soil

Testing soil pH

Soil pH is measured in order to assess soil nutrients that may be lacking and crop suitable

Methods of testing soil pH

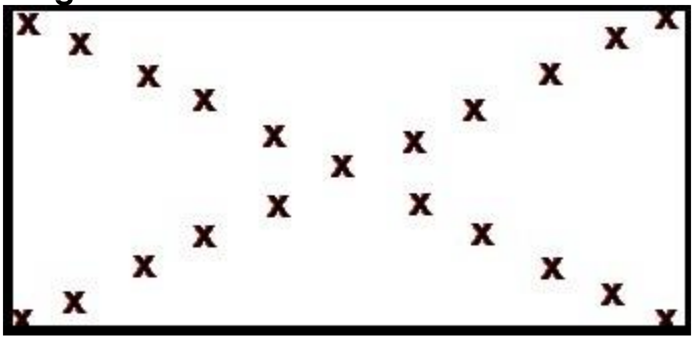
There two main methods used to obtain soil samples for pH test, include

i. Transverse method
ii. Zigzag method

Transverse method

It involves collecting samples diagonally within the farm

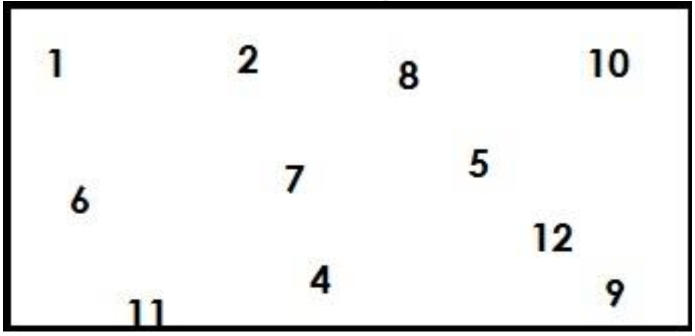
Diagram



Zigzag method

It involves collecting samples zigzag pattern within the farm

Diagram



Nb:

i. Avoid taking sample from old manure heaps and along paths
ii. Soil sample is measures using pH meter or colour indicator dyes

Managing soil pH

By defn: *Managing soil pH is the adjust/ modifying soil PH to a required range using an appropriate method*

Method of modifying soil pH

Common methods of modifying soil pH includes

i. Addition of amendment (liming) material
ii. Use of fertilizers
iii. Tillage practices
iv. Using organic matter
v. Improving drainage

Nb: method chosen depends on whether the soil is acidic or alkaline

Method of modifying soil pH of alkaline soils

i. A common amendment used to acidify alkaline soil is sulphur. Sulphur is oxidized by micro-organisms to produce sulphate ions (SO_4^{2-}) and hydrogen ion (H^+). The hydrogen ions lower the pH of the soil
ii. Iron (II) sulphate ($FeSO_4$) and aluminium sulphate [$Al_2(SO_4)_3$] used to lower the pH of the soil
   Reason: contain acidic Cations (Fe^{2+} and Al^{3+})
iii. Ammonium-based fertilizer such as urea(46-0-0) and ammonium phosphate(11-52-0) or (18-46-0), are oxidized by soil micro-organism producing hydrogen ions (H^+)
iv. Manure are used to lower soil pH are oxidized by soil micro-organism producing hydrogen ions (H^+)

Nb:

The amount of the amendment applied depend on properties of the product and soil conditions

Liming

By defn: *liming is application of calcium in various forms to soil in order to increase the soil pH value*

Liming material

By defn: *liming material is application of calcium compound to increase the soil pH value*. Includes

1. Calcium carbonate (Lime stone)–$CaCO_3$
2. Calcium oxide (Quicklime) - CaO
3. Calcium hydroxide (Slaked lime)–$Ca(OH)_2$

Method of modifying soil pH of Acidic soils

1. The most common methods of increase the soil pH is liming materials. It react with carbon dioxide and water in the soil to form hydrogen carbonate ion (HCO_3^-) which neutralize acid in the soil
2. Magnesium carbonate ($MgCO_3$) also used to raise the soil pH
3. Wood ash can also use as liming material

Soil fertility

By defn: *Soil fertility Is the ability of the soil to provide nutrients in proper quantity and in a balance way for the growth of plants*

Soil productivity

By defn: *Soil productivity is the capacity of the soil in its normal environment to support plant growth*

Factors affect Soil productivity

1. Presence of weeds lower Soil productivity
2. Farming method used lower Soil productivity

Nb:

1. Fertile soil have the correct proportion of plant nutrients and optimum PH
2. Fertile soil affect soil product
3. Fertile soil always leads to high soil productivity

Factors affect Soil fertility and productivity

The following are factors affect Soil fertility and productivity

1. Soil depth
2. Drainage
3. Water holding capacity
4. Soil pH
5. Pests and diseases

Soil depth

Soil depth gives plant roots greater volume to obtain plant nutrients and provide strong anchorage

Drainage

Good drainage is important for proper aeration of the soil, hence root healthy development

Water holding capacity

Water holding capacity keeps enough water for plant use

Soil pH

Correct soil pH is important since different crops grow well under different soil pH

Pests and diseases

Productive and fertile soils are free from pests and diseases

Causes of loss of soil fertility

The following are ways through which human activities and natural process which soil fertility may be lost

1. Leaching
2. Soil capping
3. Soil erosion
4. Monocropping
5. Continuous cropping without nutrient replacement
6. Accumulation of salts
7. Change in soil pH
8. Burning of vegetation

Leaching

Nutrient soluble such as nitrogen carried to lower levels far from soil makes soil infertile

Soil capping

When soil covered with materials not allowing water to pass through into soil makes soil infertile

Soil erosion

Soil erosion carries away fertile soil which makes soil infertile

Monocropping

Monocropping uses all nutrient and left unused nutrient which makes soil infertile

Cropping without nutrient replacement

If the nutrients are not replaced the soil become deficiency in the particular nutrients

Accumulation of salts

Salt cause deficiency of water in plants since salt have a tendency to absorb water so the soil become infertility

Change in soil pH

Change in pH affect micro-organism activities and availability of some nutrients so soil become infertility

Burning of vegetation

Burning of vegetation destroy organic matter which is the medium of micro-organism activities, also soil remain bare which soil erosion can happen

Pollution

By defn: *Pollution is the introduction of (pollutant) harmful substance into the environment*

Types of pollution

- i. Terrestrial (land) pollution
- ii. Water pollution
- iii. Air pollution

Land pollution

By defn: *land pollution is the degration of earth's land surface through human activities*

Causes of Land pollution

There are two causes of land pollution, include

- i. Solid waste
- ii. Soil pollution

Solid waste

The following are some sources of solid waste in the environment

- i. **Agriculture**
  Waste matter produced by crops, animal manure and farm residue and mismanagement they pollute land
- ii. **Mining**
  Mining waste in form of overburden, waste rock and tailing pollute land
- iii. **Industries**
  Solid chemical waste comes from industries they pollute land
- iv. **Sewage treatment plants**
  Waste in form of Biomass sludge and settled solid pollute land
- v. **Solid fuels**
  Waste from solid fuel like wood, coal etc produce ashes which pollute land
- vi. **Nuclear plants**
  Waste form nuclear reactors, nuclear research project and nuclear bomb production they pollute land
- vii. **Garbage disposal**
  Degradable Waste like food, cloth, wood etc and waste that not degradable like glass, plastic etc they pollute land

Soil pollution

The following are some sources of soil pollution in the environment

- i. Agricultural chemicals, such as fertilizers, pesticides and herbicides
- ii. Poor irrigation methods, which cause leaching of chemicals and minerals into soil
- iii. Collected manure which leaches into the nearby land areas
- iv. Oil spillages that seep into soil

Effect of land pollution

The follows is the effect of land pollution to our environment

- i. Biodegradable remain for long pose a health threat to people and other living organism
- ii. Radiation from Nuclear waste causes deformities and cancers
- iii. Land pollution Makes environment ugly
- iv. Decaying wastes makes environment unhealthy, dirty and unpleasant place to resin in
- v. Damage terrestrial life especially plants
- vi. Reduce the amount of land available for useful purpose, such as agriculture and settlement

Methods of preventing land pollution

Land pollution is preventing by

- i. **Recycling and re-use materials**
  Recycling: Waste material such as metals, glass and plastics should collected, sorted and reprocessed into usable raw material instead of discarding them as waste
  Re-use: packaging materials such as plastic bag can also be re-used

- ii. **Using biodegradable plastics materials**
  We should use biodegradable plastics which can be decomposed or decayed, for example
  - a. Biopolymers such as plastics used to make surgical sutures
  - b. Photodegradable plastics which break down when exposed to light
  - c. Soluble plastics which broken down by water

- iii. **Using designated dumping sites**
  Waste in Designated dumping sites are treated by **recycling** or **burning** until it is destroyed completely in an **incinerator**

- iv. **Formulation and enacting policies and laws**

Laws and regulation should put to prevent and control land pollution in all avenues that contribute land pollution

v. **Creating awareness**
Education should be provided to the public on keeping environment clean

Water pollution

By defn: *water pollution is the introduction of a substance that lowers the quality of water into the water bodies*

Sources of water pollution

There are two categories of sources of water pollution, includes

i. Point sources
ii. Non point sources

Point sources

Point sources are those that release harmful substance directly into a water body. For example

i. Oil spills directly into water body
ii. Release of industrial effluent (liquid waste or sewage discharged into water body)

Non point sources

Non point sources are those that release harmful substance indirectly into a water body. For example

i. Fertilizer from a field carried into stream by surface run-off
ii. pesticides applied to crops and certain animals drip into stream by surface run-off

Causes of water pollution

The following are some of the main causes of water pollution

i. Pesticides
ii. Fertilizers (Nutrients)
iii. Oil spills
iv. Mining
v. Sediment
vi. Industrial processes
vii. Sewage
viii. Marine debris
ix. Poisonous gases and metals
x. Heat
xi. Noise

Pesticides

Pesticides from animals drip into soil when carried into local stream and rivers by surface run-off or drain down into ground water

Nb:

i. Contaminates water affect living organism in the water
ii. Contaminates water is Unsafe for drink

Fertilizers

Fertilizer contain nutrients such as nitrate and phosphates when carried into local stream and rivers by surface run-off or drain down into ground water

Nb:

i. Excess level nutrient cause excessive growth of aquatic plants and algae. This situation called **Eutrophication**
ii. Eutrophication clogs waterways and blocks light in the deeper water
iii. When aquatic plants and algae die, they use up dissolved oxygen as they decomposed which lower the amount of oxygen for aquatic organism
iv. Area of died aquatic plants and algae is called **dead zones**
v. Nutrient pollution is a particular problem in estuaries and deltas where watersheds dumped at mouth of major rivers

Oil spills

Oil spills in the water bodies from land-based petroleum, vehicle etc cause major water pollution

Nb:

Spill for a thin layer of oil on surface water which prevent gas exchange between water and atmosphere

Mining

Mining cause water pollution in number ways, includes

i. Buried of heavy metals and sulphur in the earth which later leaches
ii. Action of rain water on piles of mining waste (tailing)
iii. Pile of cyanide from gold extraction
iv. If a dam of mining waste leaks or bursts
v. Dump mining waste directly into rivers

Sediment

When soil erosion happen the roots of dead plants are deposited in nearby stream, rivers and lakes

Nb:

i. Sediment affects aquatic life
ii. Poor farming practices contribute sediment pollution in water

Industrial processes

When water used for production process discharged into ware body, tend to cause water pollution since may contain chemical substance which harm aquatic life

Sewage

When swage contains waste water for treatment leaking septic tanks can cause ground ware and stream water contamination

Marine debris

Debrides comes from urban and garbage thrown from ships and boats they pollute ocean water

Poisonous gases and metals

Pollutants like mercury, sulphur dioxide, nitrogen oxide and ammonia can get into water bodies from air

Nb:

i. Most pollutants comes from coal-fired power plants, vehicle exhaust fumes and industrial emissions
ii. pollutants It cause Contamination in fish
iii. pollutants It cause Acidification of lakes
iv. pollutants It cause Eutrophication

Heat

Heat is caused by global warming and discharge of heat water by factories and power plants

Nb:

Increases water temperature result the death of many aquatic organism

Noise

Noise caused by ship and boats cause pollution in the water bodies

Nb:

i. It cause marine organism fail to communicate since they used sound to communicate
ii. Sonar may give wrong measurement
iii. Aquatic organism can fail to navigate properly

Effect of water pollution

The follows is the effect of water pollution to our environment

i. Waterborne diseases
ii. Nutrient pollution
iii. Industrial chemicals
iv. Oil spills
v. Mercury
vi. Marine debris
vii. Thermal pollution

Waterborne diseases

When micro-organism which contaminated with water can cause

i. Diseases like typhoid, cholera and dysentery
ii. Vacillate the spread of internal parasites such as roundworms and hookworms
iii. Around the beach cause rashes, respiratory infection, diarrhea, vomiting and stomach aches

Nutrient pollution

i. Waterweeds pollutant reduce water clarity(makes hard for water animals to find food)
ii. Waterweeds also block the sunlight needed by sea grasses which serve a nursery for many important fish species
iii. Decomposition of Waterweeds takes a lot of oxygen out of the water
iv. Nutrient pollution also trigger unusual outbreaks of fish diseases

Industrial chemicals

i. Chemical spills and leaks into water bodies kill aquatic life such as fish
ii. Presence of pesticides in drink water and in food chain can result in damage to the nervous, endocrine and reproductive systems and the liver
iii. It can cause cancerous diseases

Oil spills

Oil alter the ecology of aquatic habitats and the physiology of marine organisms

Mercury

i. Mercury when exposure to unborn babies result in delaying or incomplete mental development, autism and brain damage
ii. Mercury cause serious nervous system problems in adults, include Parkinson's disease, multiple sclerosis and Alzheimer's disease

Marine debris

i. When marine animal swallow marine debris cause them to death by blockage intestinal
ii. It can destroy sea grass beds and other aquatic habitats

Thermal pollution

i. Rise in temperature kill the aquatic life
ii. Warmer water temperature lower the amount of oxygen dissolved in the water

Methods of preventing water pollution

Water pollution is preventing by

i. Reducing nutrients and pesticides pollution
ii. Treating sewage and industrial waste
iii. Stopping deforestation
iv. Control coastal development
v. Reducing pollution from oil spills
vi. Reducing mercury emissions
vii. Cleaning up exist and abandoned mines
viii. Cleaning up chemical pollution

Air pollution

By defn: *Air pollution is the introduction of harmful substance into the earth's atmosphere*

Sources of air pollution

There are two categories of sources of air pollution, includes

i. Natural sources
ii. Human-made sources

Natural sources

Natural sources is the one occurs natural especial from **volcanic eruption**, **hot spring** and **fumaroles** (opening in or near a volcano, through which hot sulphurous gases emerge)

Human-made sources

Human-made sources is the one causes by human being such as pollutant from industries, combustion of fuels, deforestation and chemical substances

Causes of air pollution

The following are some of the main causes of air pollution

i. Carbon dioxide
ii. Oxides of nitrogen
iii. Compound of sulphur
iv. Chlorofluorocarbons (CFCs)
v. Smog

Carbon dioxide

Carbon dioxide is the greenhouse gas which the main sources of carbon dioxide are burning of fossil fuel and deforestation

Oxides of nitrogen

They include **nitrogen monoxide**, **nitrogen dioxide** and **Dinitrogen oxide**, which produced from burning of biomass and fossil fuels

Nb:

i. They form acidic rain
ii. They form photochemical smog (chemical reaction of sunlight with oxides of nitrogen and volatile organic matter in the atmosphere)
iii. The photochemical smog produce airborne particles and ground-level ozone
iv. Nitrogen monoxide and nitrogen dioxide play role in the thinning stratospheric ozone
v. Dinitrogen oxide is a natural component of the atmosphere
vi. The oxide of nitrogen produced from nitrogen-based fertilizers, deforestation and burning vegetation
vii. Dinitrogen oxide is the greenhouse gas

Compound of sulphur

Include sulphur dioxide, sulphur trioxide and hydrogen sulphide

Nb:

i. Sulphur dioxide is produced by combustion of sulphur-containing fuels such as coal and fuel oil
ii. Sulphur dioxide produced in the process of produce sulphuric acid and metallurgical process that involves ores that contain sulphur

iii. Sulphur oxide cause health problems in people and damage plants and materials
iv. At high concentration Sulphur dioxide
v. Irritates the upper respiratory tract of human beings making breathing difficult
vi. Sulphur dioxide Cause acid rain

Chlorofluorocarbons (CFCs)

It is greenhouse gasses made up of carbon, chlorine and fluorine atoms which used as solvent in cleaners, coolants in refrigeration and air condition systems, blowing agents in the production of foam and as propellant in aerosols

Nb:

i. It destruct the stratosphere (ozone layer)
ii. One CFC molecule cause loss of 1000,000 ozone molecules
iii. CFC have a lifetime of about 20 – 100 years

Smog

Smog made up of ground-level ozone and fine particles

Nb:

i. Ozone cause eye irritations
ii. Ozone cause Impaired lung function
iii. Ozone cause damage to trees and crops

Effect of air pollution

The follows is the effect of air pollution to our environment

i. Health problems
ii. Acidic rain
iii. Reduced visibility
iv. The green house
v. Global warning

Health problems

i. Air pollution cause difficulty in breathing, wheezing and coughing
ii. Air pollution cause chronic respiratory and heart conditions
iii. Air pollution causes illnesses such as asthma, bronchitis, emphysema and other lung and heart diseases and respiratory allergies

Acidic rain

Acid rain damages forest and corrodes many ancient building and sculptures made of marble

Reduced visibility

Smog reduces visibility, making activities such as driving very difficult

Greenhouse Effect

By Defn: *Greenhouse effect is the process whereby radiation reflected by the atmosphere to warms the earth's surface*

Or

By Defn: *greenhouse effect is the trapping back of Sun's energy by a planet from atmospheres*

Or

By Defn: *Greenhouse effect is the process whereby radiation reflected by the atmosphere to warms the planet's surface*

How Greenhouse Effect Occurs

When a planet's surface is heated by sunlight it emits thermal (heat) radiation which is absorbed by the greenhouse gases in the atmosphere. The atmosphere reflects (re-radiates) back thermal radiation in all directions to the earth's surface and lower atmosphere. Over time, this increases the planet's temperature due to presence of greenhouse gases

Sources of Greenhouse Effect

Greenhouse effect is caused by the greenhouse gases includes the follows

i. Water vapor
ii. Ozone layer
iii. Carbon dioxide
iv. Methane
v. Chlorofluorocarbons
vi. Dinitrogen oxide

Carbon Dioxide

Carbon dioxide is the main greenhouse gas. The gas contributes over 50% of the greenhouse effect. The following are some of the sources of carbon dioxide includes

i. Clearing and burning of vegetation (deforestation)
ii. Burning of fossil fuels (coal and petroleum)

Methane

The main source of methane is;

i. **Agricultural activities**. It is released from wetlands, such as rice fields and from animals, particularly cud-chewing animals like cows.
ii. mining of coal and oil
iii. When vegetation is burnt

Note: Methane molecules have a lifetime of 10 years in the atmosphere

Dinitrogen Oxide

Dinitrogen oxide is produced from both natural and human-made processes. Human activities includes

i. combustion of fossil fuels in vehicles and power stations
ii. Use of nitrogenous fertilizers
iii. burning of vegetation
iv. Animal waste

Chlorofluorocarbons

Chlorofluorocarbons (CFCs) are organic compounds made up of chlorine, fluorine and carbon. The sources of CFCs in the atmosphere include **fridges**, **air conditioners**, **sprays** and **aerosols**

Note: CFCs are extremely effective greenhouse gases. A CFC molecule is 10 000 times more effective in trapping heat than a carbon dioxide molecule

Global Warming

By Defn: *Global warming is the increase of the average temperatures near or on the earth's surface caused by greenhouse gases*

Or

By Defn: *Global warming is the increase in temperature near or on the surface of the earth resulting into greenhouse effect*

Causes of global warming

Global warming is mainly caused by greenhouse gases

Effects of Global Warming

The effects of global warming include:

i. Increase the temperature of the oceans
ii. Rise in sea level due to melting land ice. This may lead to flooding of the coastal land
iii. Change in world's climate patterns
iv. Acidification of the oceans CO_2 dissolves in water and forms a weak carbonic acid and hence lower of PH of ocean
v. Extreme weather events which include floods, drought, heat waves, hurricanes and tornadoes
vi. higher or lower agricultural yields
vii. Melting of Arctic ice and snowcaps. This causes landslides, flash floods and glacial lake overflow
viii. Extinction of some animal and plant species,
ix. Increase in the range of disease vectors

Solutions to Minimize Global Warming

The major solution is to reduce the greenhouse gases emission into the atmosphere by:

i. Reduce the use of fossil fuels by use of public transport which will minimize the number of vehicles in the roads
ii. Use of fuel-efficient cars
iii. Use of clearer alternative sources of energy such as solar and wind.
iv. Afforestation
v. Countries to make a policy of minimizing the emission of greenhouse gases. Example Kyoto protocol

Methods of controlling air pollution

Air pollution is controlled by

i. Reduce over-dependence on fossil fuels
ii. Using fuel-efficient system
iii. Modification and replacement of industrial systems
iv. Use of air pollution control devices
v. Enactment of laws

Safety measures to protect industrial worked from gaseous pollution

The follows is the Safety measures to protect industrial worked from gaseous pollution

i. Eliminate hazardous chemicals
ii. Substituting hazardous chemicals
iii. Highly hazardous chemicals should be carried out in sealed chambers
iv. Workers should be Use of protective equipment

Ways workers contaminate gas pollutant

Chemical can get into the workers bodies through the following

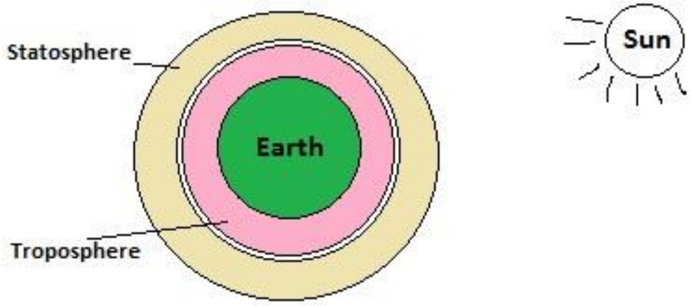
i. **Inhalation** – worker can contaminate through breathing
ii. **Skin contact** - worker can contaminate through contact with chemical

iii. **Ingestion** - worker can contaminate through swallow or smoking chemical

Ozone Layer

By defn: Ozone layer is a layer in the earth's atmosphere which contains relatively high concentration of ozone (O_3)

Diagram:



Main function of ozone layer

Ozone layer absorbs (97 – 99) % of the sun's high frequency ultraviolet light from the sun

Effect of sun's high frequency ultraviolet light

1. It causes skin cancer in human beings
2. It causes blindness in human beings
3. It causes skin ailment in human beings

Nb:

1. Over 90% of ozone(O_3) is within the ozone layer
2. Ozone layer is spread between (17 – 30) Km in the earth's atmosphere in the **Stratosphere**
3. Amount of ozone within the stratosphere varies according to altitude
4. Ozone concentration are highest between (19 – 23) Km but Significant amount up to 30 Km

Ozone Layer depletion

By defn: *Ozone Layer depletion is the destruction of ozone layer*

Ozone-depleting substances

This is the substances contribute to Ozone Layer depletion such as Chlorine and bromine atoms are main substance that deplete ozone. The main sources of bromine and chlorine atom in the atmosphere are Gases such as

1. Chlorofluorocarbons (CFCs)
2. Methyl bromide
3. Halons

Chlorofluorocarbons (CFCs)

These are used in refrigeration and air condition and in aerosols. When reach in stratosphere they broken up to form chlorine atoms

Methyl bromide

This used in agriculture as agricultural fumigant. When reach in stratosphere they broken up to form bromine atoms

Halons

These are compound delivered from hydrocarbons. All carbon atoms of halons replaced with halogen (chlorine atom, bromine atoms and fluorine atoms). Halons are mainly used in fire extinguishers

Ways of controlling ozone layer depletion

The most effective way of controlling the depletion of ozone layer is

1. To ban the production of all ozone-depleting substance
2. To ban the uses of all ozone-depleting substance
3. To use less harmful substance

Environmental conservation

By defn: *Environmental conservation is the protection and preservation of natural resources from destruction, wastage or loss.*

Natural resources includes

1. Minerals
2. Soil
3. Water
4. Aquatic life
5. Air
6. Forests
7. Animals (domestic and wild)

Important of Environmental conservation

The following is Important of Environmental conservation

1. To protect and preserve all resources which Sustain life on the earth
2. To protect and preserve ecological balance in an ecosystem
3. To keep continuous economic activities like fishing, hunting etc
4. To making natural resources available for Future generations
5. To keep Beauty of environment

Environmental conservation measures

The following are measure being put in place to conservation the environment

i. Implementations of organization and institutions responsible for protect and conserve the natural sources
ii. Formulation of laws which governing environmental conservation
iii. Provision of Environmental Education
iv. Research on the best way of protect and conserve the natural sources
v. Pollution should be prevented and controlled
vi. International agreement aim to protect and conserve the natural sources
vii. personal involvement to protect and conserve the natural sources

Ways personal involves in Environmental conservation

The following are some of the ways which can take part in environmental conservation

i. She/he should plant more trees at home and in school
ii. She/he should place rubbish and any other waste in designated areas or in disposal bins
iii. She/he should not start fires near forested areas
iv. She/he should not harm animal both domestic and wild
v. She/he should educate other people on the importance of environmental conservation
vi. She/he should take part in environmental conservation programs and tasks