CHEMISTRY

FORM FOUR

❖***PREPARED BY:***

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TOPIC 1

NONMETALS AND THEIR COMPOUNDS

1.1 GENERAL CHEMICAL PRPERTIES OF NON - METALS

- ***Non-metals*** are the elements which ionize by gaining electron.
- They are said to be oxidizing agents due to their property of gaining electron from other elements.

❖ Example of non-metals are; Chlorine, fluorine, oxygen, nitrogen, bromine.

Physical properties of non-metals

i) Poor conductors of heat and electricity.
ii) Low boiling and melting point.
iii) Most of them exists in gaseous or liquid state at room temperature.
iv) They are brittle(for solid non-metals).

Chemical properties of non-metals

i) They form acidic oxides when react with oxygen

$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

ii) They have oxidizing properties, since they gain electron.

$$2FeCl_{2(aq)} + Cl_{2(g)} \longrightarrow 2FeCl_{3(aq)}$$

iii) Displacement of non-metals: More reactive non-metal displaces less reactive non-metal from the compound.

$$2Ca_3N_2 + 3O_2 \longrightarrow 6CaO + 2N_2$$

$$2MgO + 2F_2 \longrightarrow 2MgF_2 + O_2$$

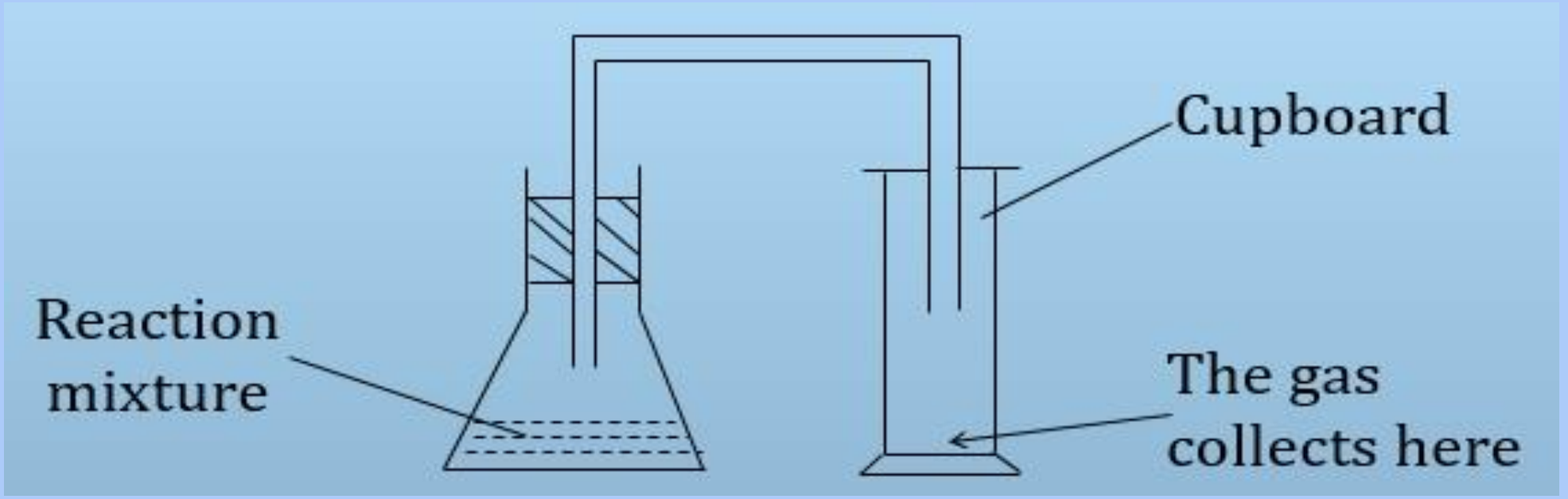
Difference between metals and non-metals

	Metal	Non - metal
1	Good conductor of electricity	Poor conductor of electricity
2	Good conductor of heat	Poor conductor of heat
3	Form basic and amphoteric oxides	Forms acidic and neutral oxides
4	High boiling and melting point	Low boiling and melting point
5	Ionize by electron loss	Ionize by electron gain
6	High density	Low density

Methods of collecting different gases

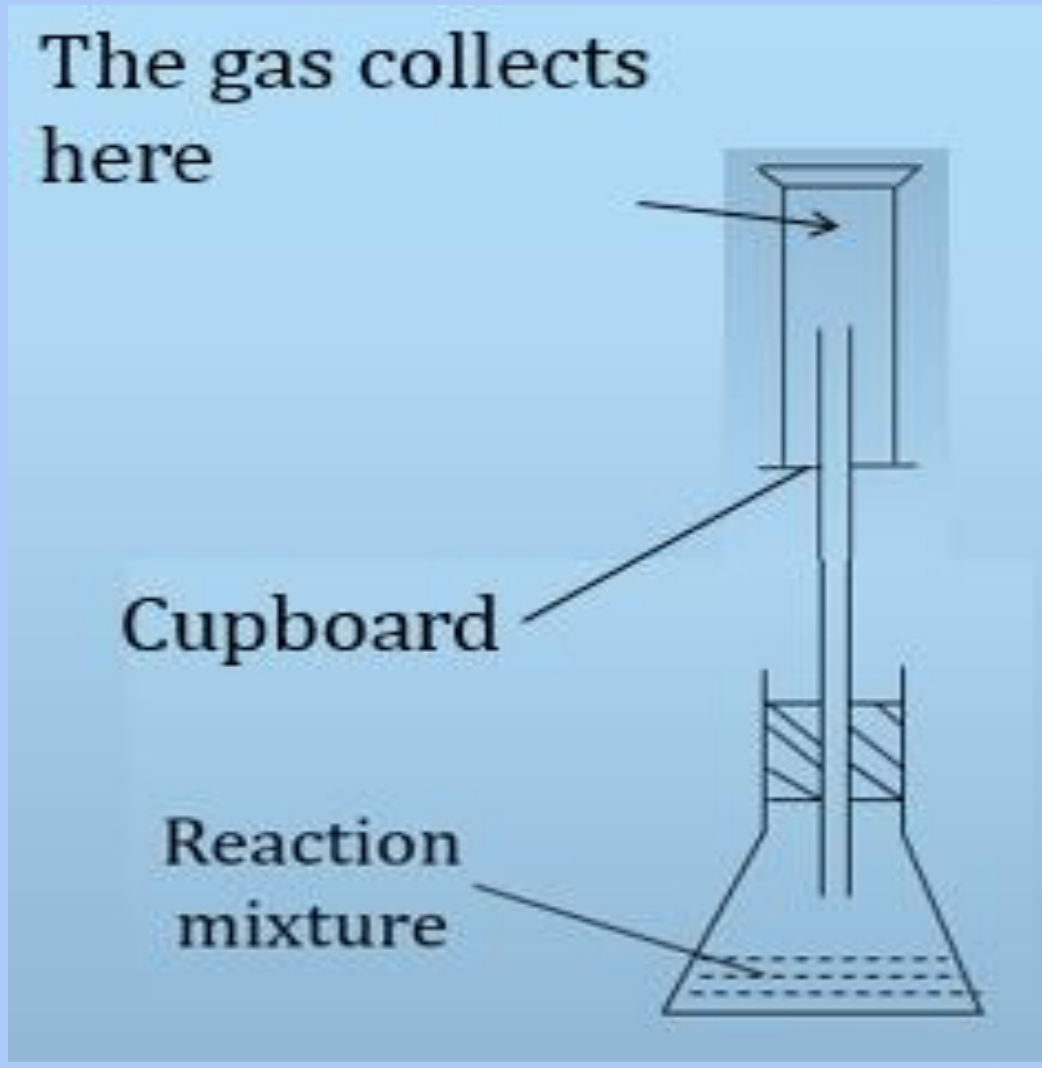
1) Downward delivery (upward displacement of air)

- The gas is collected by this method if it is ***dense than air***.
- In this method the gas passes through the delivery tube into the gas jar where it sinks to the bottom due to its density pushing air upwards.



2) Upward delivery (downward displacement of air)

- The gas is collected by this method if it is ***less dense than air***.
- In this method the gas passes through the delivery tube into the gas jar where it floats up to pushing air downwards.
- Normally the gas jar is inverted (upside down) when the gas is collected by this method.

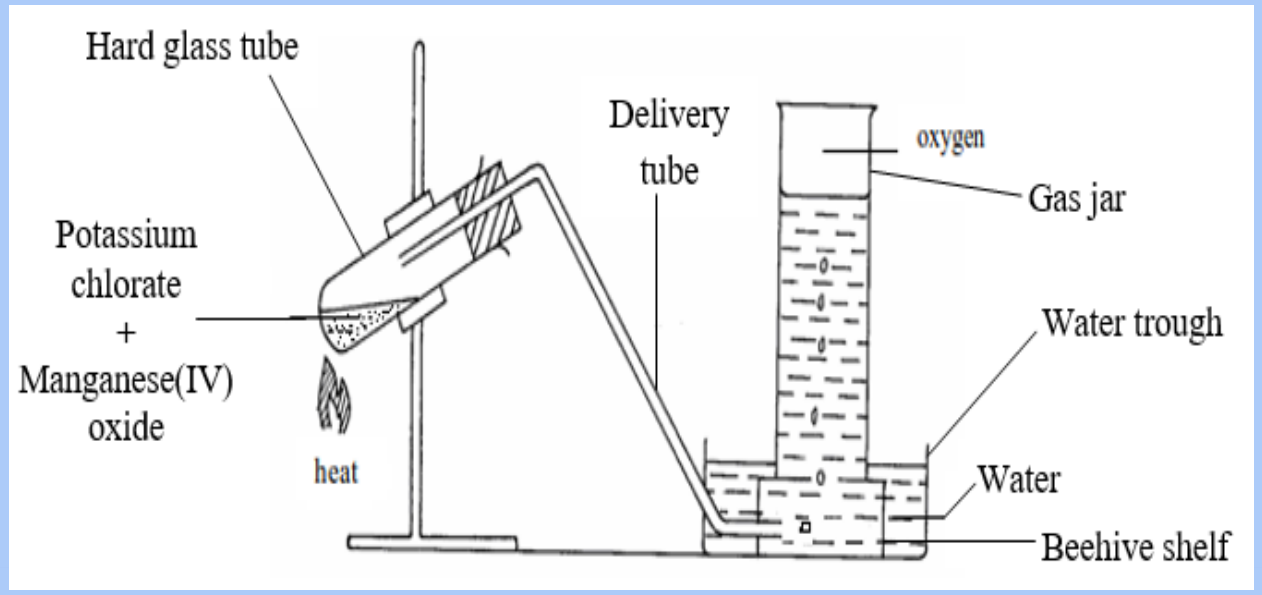


3) Downward displacement of water

- The gas is collected by this method if it is either insoluble or slightly soluble in water.

Example oxygen and hydrogen.

- In this method the gas jar is inverted and put on the beehive shelf which is in the water trough containing water.
- As the gas is produced it pushes water in the gas jar downwards, hence its name.



1.2 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 main source of chlorine in most industrial processes.

Preparation of Chlorine

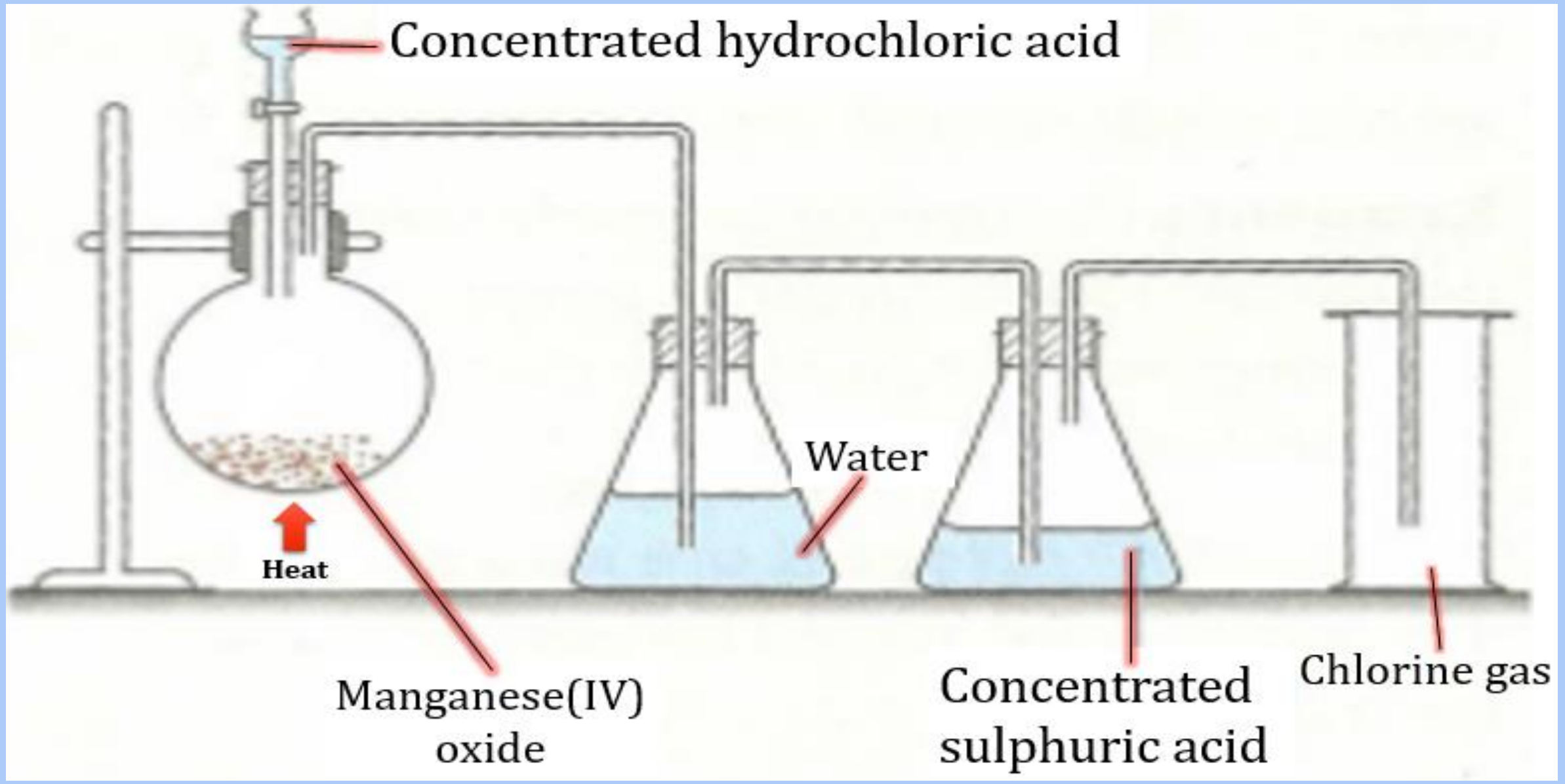
- It prepared by oxidation of conc.HCl .
- Oxidizing agents which are commonly used are:

i) Manganese(IV) oxide: Here heat is required

$$MnO_{2(s)} + 4HCl_{(l)} \xrightarrow{\Delta} Cl_{2(g)} + MnCl_{2(aq)} + 2H_2O_{(l)}$$

ii) Potassium permanganate: This is strong oxidizing agent so no heat is required

$$2KMnO_{4(aq)} + 16HCl_{(l)} \longrightarrow 2MnCl_{2(aq)} + 2KCl_{(aq)} + 8H_2O_{(aq)} + 5Cl_{2(g)}$$


Concentrated hydrochloric acid
Water
Heat
Manganese(IV) oxide
Concentrated sulphuric acid
Chlorine gas

Important Points to Note

- Water in the first conical flask is to remove any acid spray and hydrogen chloride gas.
- Conc. Sulphuric acid in the second conical flask for dry chlorine gas.
- When we use potassium permanganate no need to use heat because it is very strong oxidizing agent.

Physical Properties of Chlorine

i) Chlorine gas is greenish-yellow in colour with pungent irritating smell.

ii) It is denser than air.

iii) It is poisonous gas, when inhaled it may cause suffocation, constriction of the chest and oedema.

Chemical Properties of Chlorine

1) It is soluble in water to form pale yellow solution known as chlorine water.

$$Cl_{2\,(g)} + H_2O_{\,(l)} \longrightarrow \underbrace{HCl_{\,(aq)} + HOCl_{\,(aq)}}_{\textit{Chlorine water}}$$

Chlorine water is a mixture of ***chloric (I) acid***, HOCl (hypochlorous acid)and ***hydrochloric acid*** (HCl). This mixture has bleaching property, hence can decolourize the dye.

2) It forms yellow deposits of sulphur when treated with hydrogen sulphide gas.

$$H_2S_{(g)} + Cl_{2(g)} \longrightarrow HCl_{(g)} + S_{(s)}$$

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3) Chlorine is a strong oxidizing agent. It oxidizes the iron (II) chloride to iron (III) chloride.

$$2FeCl_{2(aq)} + Cl_{2(g)} \longrightarrow 2FeCl_{3(aq)}$$

4) Chlorine reacts with hydrogen gas to form hydrogen chloride gas.

$$H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$$

5) Chlorine reacts with ***cold*** ***sodium*** or ***potassium hydroxide*** solution to form a ***mixture of chloride*** and ***hypochlorite*** which are ***bleaching agents***.

$$2NaOH_{(aq)} + Cl_{2(g)} \longrightarrow \underbrace{NaCl_{(aq)} + NaOCl_{(aq)}}_{\textit{bleaching agents}} + H_2O_{(l)}$$

6) The gas reacts with a ***hot*** ***sodium*** or ***potassium hydroxide*** solution to give a mixture of ***chloride*** and ***chlorate***.

$$NaOH_{(aq)} + Cl_{2(g)} \longrightarrow NaCl_{(aq)} + NaClO_{3(aq)} + H_2O_{(l)}$$

Test for chlorine gas

- The gas is greenish – yellow in colour.
- It turns moist blue litmus paper into red then bleached.
- It has pungent smell

Test for chlorine gas - YouTube.mp4

Uses of Chlorine

i) Chlorine is used as a bleaching agent in textile industries and in the paper industry to bleach wood pulp.

ii) Chlorine can be used as a germicide and a disinfectant.

iii) It is used to treat drinking water, water in swimming pools and sewage.

iv) Chlorine is used to prepare hydrogen chloride gas, which is dissolved in water to form hydrochloric acid.

v) Chlorine is used to manufacture tetrachloromethane which is used as a solvent.

vi) Chlorine is used to manufacture plastics such as ***polyvinylchloride (PVC).*** PVC is used in making insulators.

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1.3 HYDROGEN CHLORIDE

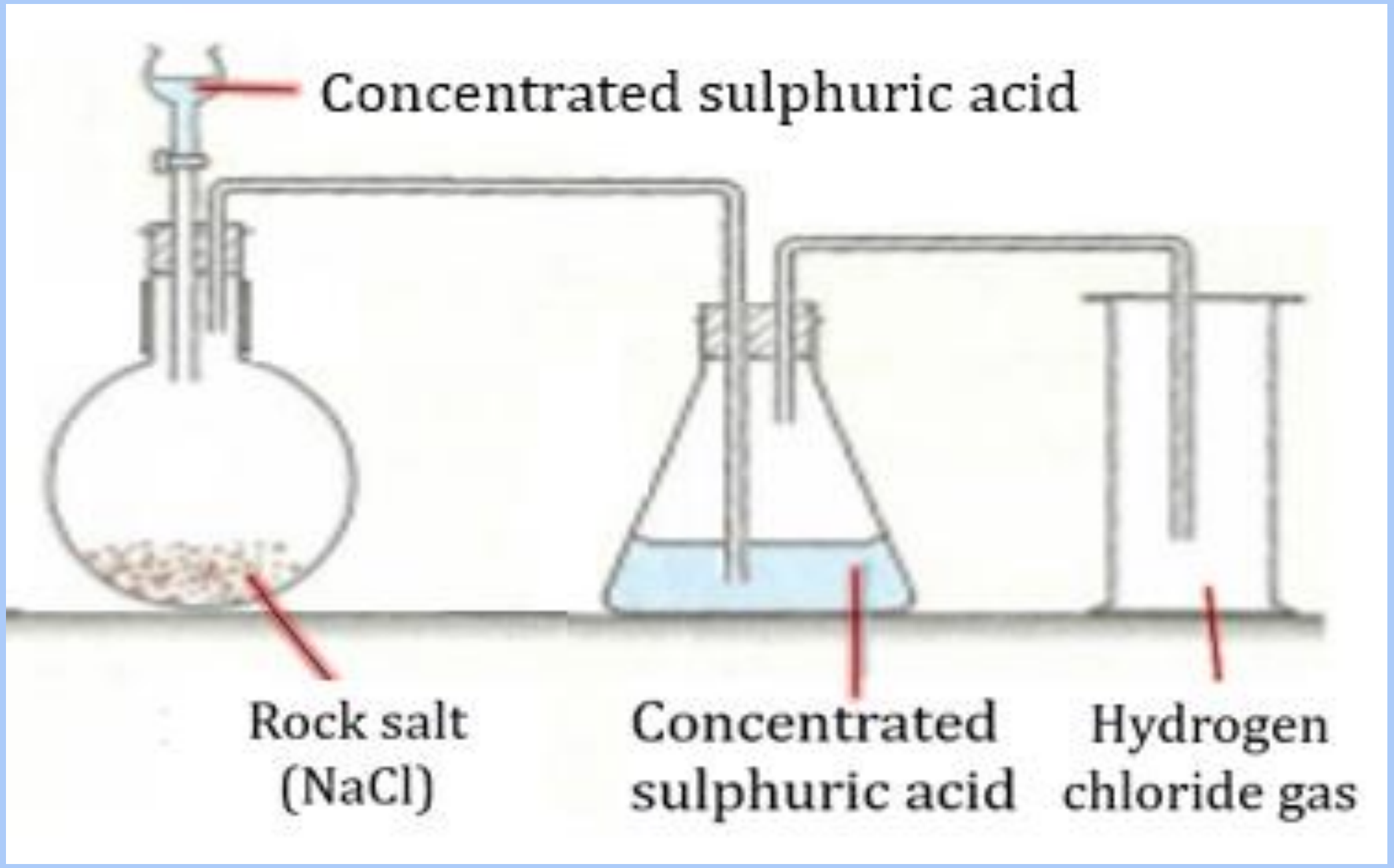
- Hydrogen chloride gas is a compound of chlorine and hydrogen. Its formula is HCl.
- It is highly soluble in water, when it dissolves it form hydrochloric acid.

Preparation of Hydrogen Chloride Gas

- Hydrogen chloride gas can be prepared in the laboratory by reacting rock salt (sodium chloride) with concentrated Sulphuric acid.
- This reaction gives sodium hydrogen sulphate and hydrogen chloride gas.

$$NaCl_{(s)} + H_2SO_{4(l)} \longrightarrow NaHSO_{4(aq)} + HCl_{(g)}$$

- The gas is passed through concentrated sulphuric acid in order to dry it and finally collected in the gas jar by ***downward delivery***.


Concentrated sulphuric acid
Rock salt
(NaCl)
Concentrated
sulphuric acid
Hydrogen
chloride gas

Physical Properties of Hydrogen Chloride Gas

i) It is colourless gas with a pungent choking smell and the sharp taste of acids.

ii) It does not burn and it extinguishes a burning wooden splint.

iii) It is dense than air, thus it is collected by downward delivery.

iv) It turns a wet blue litmus paper into red(if litmus is dry no action)

v) It is very soluble in water.

Chemical Properties of Hydrogen Chloride Gas

1) Reacts with ammonia gas to form dense white fumes of ammonium chloride.

$$HCl_{(g)} + NH_{3(g)} \longrightarrow NH_4Cl_{(s)}$$

2) The gas dissolves in water to form hydrochloric acid.

$$HCl_{(g)} \xrightarrow{H_2O} HCl_{(aq)}$$

Chemical Properties of hydrochloric acid

1) It reacts with metal to produce metal chloride and hydrogen gas.

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

2) It reacts with carbonates of more reactive metals to give a metal chloride, carbon dioxide gas and water.

$$CaCO_{3(s)} + HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

3) Dilute hydrochloric acid reacts with some metal oxide or hydroxide to give a salt and water as the only.

$$K_2O_{(aq)} + 2HCl_{(aq)} \longrightarrow 2KCl_{(aq)} + H_2O_{(l)}$$

$$NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$$

Test for hydrogen chloride gas

- It has pungent smell.
- It forms dense white fumes with gaseous ammonia.
- It turns moist blue litmus paper into red.

Uses of Hydrogen HCl gas/ HCl Acid

i) *Controlling pH in chemical processes*: high quality hydrochloric acid is used to control the pH of the water used in the manufacture of food and medicines.

ii) *It is used qualitative analysis* Example in preliminary tests and flame test.

iii) *Used in refining of edible oils and fats*.

iv) *Used in concentration of some metal ores*.

v) *Production of organic compounds such as polyvinyl chloride(PVC)*

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vi) Cleaning metals: It is used to remove rust (oxide) from iron and lime scale from boilers.

$$Fe_2O_{3(s)} + 6HCl_{(aq)} \longrightarrow 2FeCl_{3(aq)} + 3H_2O_{(l)}$$

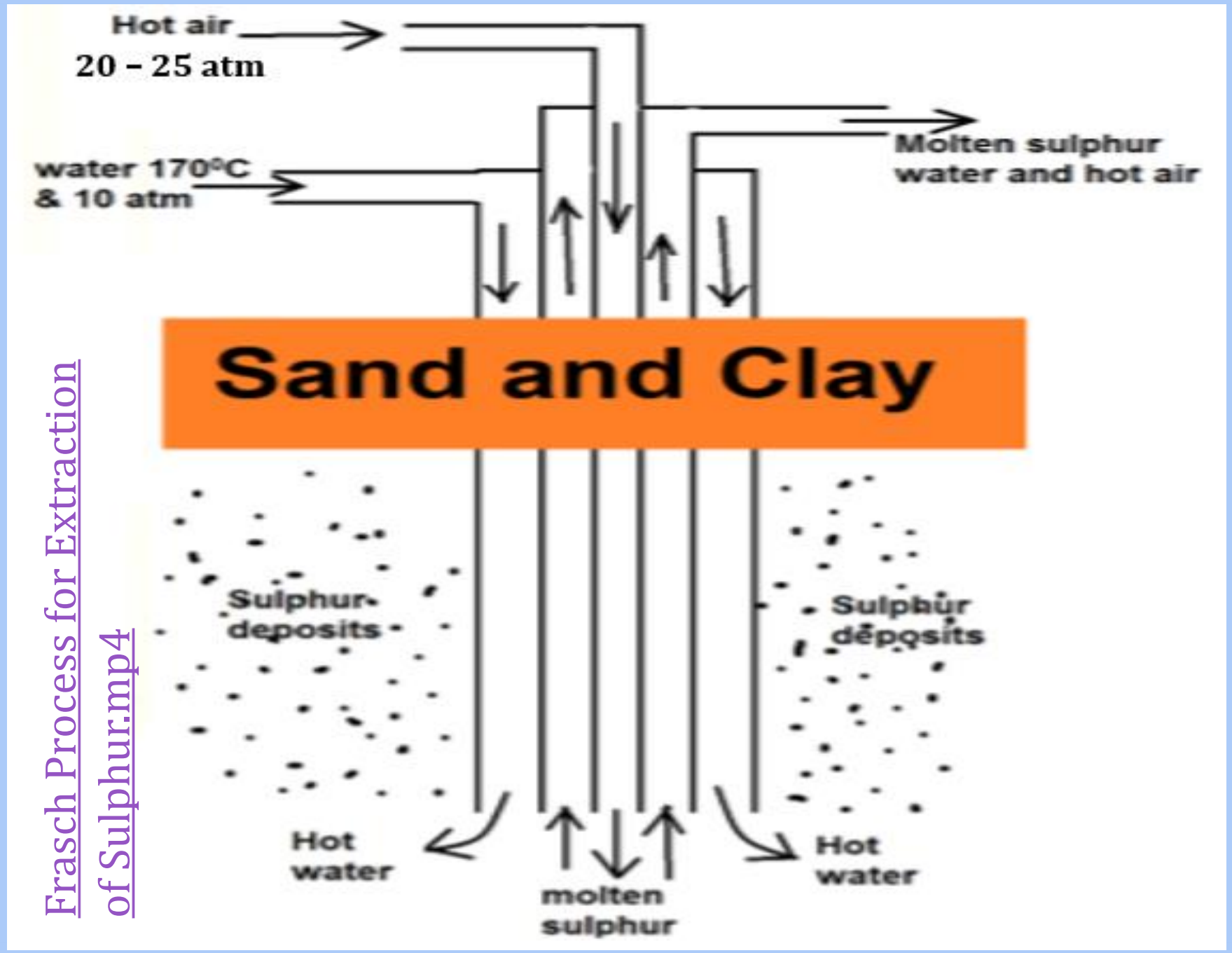
1.4 SULPHUR

- Sulphur is a yellow crystalline non-metallic solid.
- It occupies the 16^{th} position in the Periodic Table.
- Its atomic number is 16 and is a member of Group VI elements.
- It occurs naturally as free element in hot springs and volcanic areas.
- It also occur naturally in combined state. The major ores of sulphur are:-
  - Iron pyrites (FeS_2)
  - Copper pyrites ($CuFeS_2$)
  - Gypsum ($CaSO_4.2H_2O$)

Extraction of Sulphur

- A scientist called Herman Frasch discovered the method of extraction of sulphur from the sulphur bed.
- The extraction of sulphur is called ***Frasch process***.
- Solid Sulphur is found at over 200 meters below the earth's surface.
- In this process three concentric pipes are inserted down through the rocks and clay to sulphur deposits.

- ***Super heated water*** (170 ℃ – 180℃) is forced down through the ***outer pipe*** to melt Sulphur.
- ***Hot compressed air(20 – 25atm)*** is forced down through the ***inner pipe*** to force the molten sulphur out.
- ***The froth of sulphur*** is forced to the earth's surface through the ***middle pipe*** by the compressed air.
  - The molten sulphur is then collected in vats(tanks), where the water drains off and the sulphur solidifies.



Frasch Process for Extraction of Sulphur.mp4

Allotropes of Sulphur

- ***Allotropy*** is the existence of an element in two or more different physical forms in the same physical state.
- The different physical forms of an element which exist in the same physical state are called ***allotropes***.
- There are two main allotropes of sulphur include
    i) Monoclinic Sulphur
    ii) Rhombic Sulphur

❖Other allotropes of are:

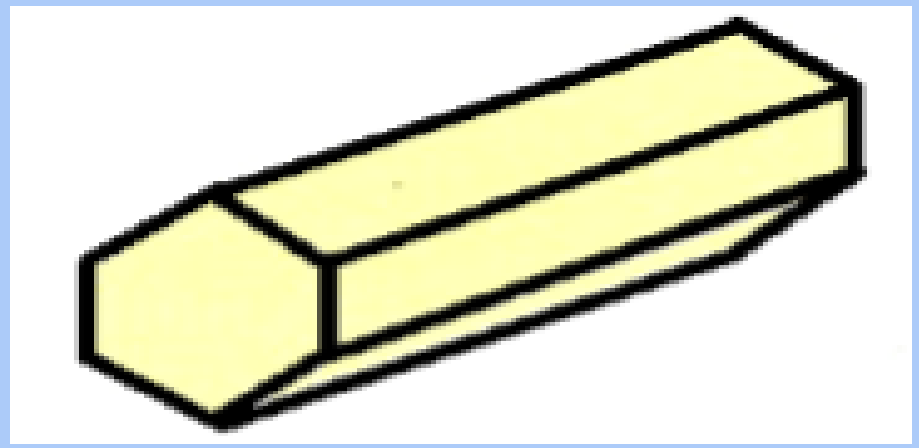
iii) Plastic Sulphur

iv) Amorphous Sulphur

v) Colloidal Sulphur

i) Monoclinic Sulphur

- Monoclinic sulphur is obtained by allowing molten sulphur to solidify.
- The crystals are ***needle-shaped***.
- Monoclinic sulphur is pale yellow in colour.
- It is also known as prismatic sulphur or beta sulphur (β-sulphur).
- It is soluble in toluene.
- It is stable above 96°C.
- Melts at 120°C.



ii) Rhombic Sulphur

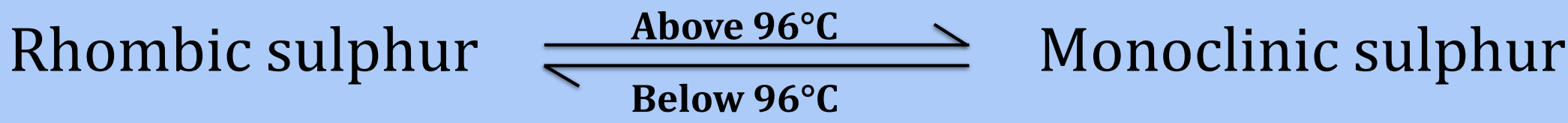
- Rhombic sulphur is obtained when sulphur crystallizes from solution in ***carbon disulphide***.
- The crystals of rhombic sulphur have an ***octahedral shape***.
- Rhombic sulphur is also known as alpha sulphur (α-sulphur).
- It is stable below 96°C.
- It is bright yellow in colour.
- It is soluble in carbon disulphide(CS_2)
- It melts at 115°C.

Differences between rhombic and monoclinic Sulphur

S/N	Monoclinic Sulphur	Rhombic Sulphur
1	The crystals have ***needle shape***	The crystals have ***octahedral shape***
2	It is pale yellow in colour	It is bright yellow in colour
3	It is known as prismatic sulphur or beta sulphur (β-sulphur).	It is also known as alpha sulphur (α-sulphur).
4	It is soluble in toluene	It is soluble in carbon disulphide(CS_2)
5	It is stable above 96℃	It is stable below 96℃
6	It melts at 120℃	It melts at 115℃

Important points to note

- When left standing at room temperature, monoclinic sulphur gradually changes to rhombic sulphur.
- If rhombic sulphur is melted and partly allowed to crystallize slowly, needle like crystals of monoclinic sulphur are formed.



iii) Plastic Sulphur

- Plastic sulphur is a tough plastic substance formed when molten sulphur is poured into cold water.
- It is insoluble in carbon disulphide.
- It is obtained by boiling powdered sulphur and pour it into cold water.
- Later it turns into rhombic sulphur.

iv) Amorphous Sulphur

- It is Sulphur which is an insoluble white Sulphur that remains when fine powder of pure Sulphur(flower of Sulphur) react with carbon disulphide.
- It can also be made by several ways.

❖ Incomplete combustion of hydrogen sulphide.

$$H_2S_{(g)} + O_{2(g)} \longrightarrow S_{(s)} + H_2O_{(l)}$$

❖ Oxidation of metallic sulphide by dilute HCl, H_2SO_4 or HNO_3

$$MgS_{(s)} + 2HNO_{3(aq)} \longrightarrow Mg(NO_3)_{2(aq)} + 2S_{(s)} + 2H_2O_{(l)}$$

❖ Reaction of sodium thiosulphate with dilute HCl, H_2SO_4 or HNO_3

$$Na_2S_2O_{3(aq)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(l)} + S_{(s)} + SO_{2(g)}$$

Physical Properties of Sulphur

i) Sulphur is a yellow solid non-metal.

ii) It is insoluble in water but soluble in nonpolar solvents such as carbon disulphide and methylbenzene (toluene).

Chemical Properties of Sulphur

- In chemical reactions, sulphur exhibits both ***reducing*** and ***oxidizing properties***.

A) As oxidizing agent (Oxidant)

1) Reaction with metals

- Heated sulphur reacts with metals such as iron, copper, zinc and tin, to give metal sulphides.

$$Fe_{(s)} + S_{(s)} \longrightarrow FeS_{(s)}$$

$$Cu_{(s)} + S_{(s)} \longrightarrow CuS_{(s)}$$

2) Reaction with hydrogen

- When hydrogen gas is bubbled through molten sulphur, hydrogen sulphide is formed.

$$H_{2(g)} + S_{(s)} \longrightarrow H_2S_{(g)}$$

- However this is not a convenient method of preparing hydrogen sulphide gas.

3) Reaction with carbon

- Sulphur reacts with carbon to form carbon disulphide.

$$S_{(s)} + C_{(s)} \longrightarrow CS_{2(l)}$$

A) As reducing agent (Reductant)

1) Reaction with acids

- Sulphur is oxidized by strong concentrated acids such as concentrated sulphuric acid and nitric acid.

$$H_2SO_{4(l)} + S_{(s)} \longrightarrow SO_{2(g)} + H_2O_{(l)}$$

2) Reaction with other non-metals

- Sulphur directly combines with fluorine and chlorine.

$$S_{(s)} + F_{2(g)} \longrightarrow SF_{6(l)}$$

$$S_{(s)} + Cl_{2(g)} \longrightarrow SCl_{2(l)}$$

Uses of Sulphur

i) It 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.

iii) Used to make gunpowder (a mixture of potassium nitrate, carbon and sulphur).

iv) It is is used in the vulcanization of natural rubber.
Vulcanization is the process of making naturally soft rubber harder by reacting it with sulphur.

v) It is used to dust vines to prevent the growth of fungi.

vi) It is used in the manufacture of plastics.

1.5 SULPHURIC ACID

- Sulphuric acid is an important reagent produced industrially by contact process.
- The contact process involves the following steps
  i) Production of Sulphur dioxide
  ii) Purification of Sulphur dioxide
  iii) Catalytic oxidation of Sulphur dioxide to Sulphur trioxide
  iv) Conversion of Sulphur trioxide to sulphuric acid

i) Production of Sulphur dioxide

- The sulphur dioxide may be obtained through the following methods

  i) Burning sulphur in air.

  $$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(s)}$$

  ii) Burning metal sulphide in air

  $$4FeS_{(s)} + 7O_{2(g)} \longrightarrow 4SO_{2(g)} + 2Fe_2O_{3(s)}$$

ii) Purification of Sulphur dioxide

- Sulphur dioxide obtained in the first stage is purified by remove impurities, such as ***dust*** and ***arsenic (III) oxide***.
- If the impurities are left, they may *poison* the catalyst in the next stage and make it *inactive*.
- Sulphur dioxide is then passed through *concentrated sulphuric acid* for drying it.

iii) Catalytic oxidation of Sulphur dioxide to Sulphur trioxide

- A clean dried gaseous mixture of SO_2 and air (O_2) is passed through the oxidation chamber loosely packed with vanadium pentaoxide or platinum at 450°C and normal atmospheric pressure. Since vanadium pentaoxide is cheapest it preferred.
- During this process SO_2 and the catalyst remains in contact, hence the name contact process.
- This is an exothermic reaction.

$$SO_{2(g)} + O_{2(g)} \underset{450^0C}{\overset{V_2O_5}{\rightleftharpoons}} SO_{3(g)} + \mathbf{\Delta H = -198\ kJ}$$

iv) Conversion of Sulphur trioxide to sulphuric acid

- The sulphur trioxide from the conversion chamber is passed through a heat exchanger to remove excess heat.

❖ In the absorption tower SO_3 is dissolved in concentrated sulphuric acid to form ***oleum*** (fuming sulphuric acid).

$$SO_{3(g)} + H_2SO_{4(l)} \longrightarrow H_2S_2O_{7(l)}$$

❖ Oleum is then diluted to give concentrated sulphuric acid.

$$H_2S_2O_{7(l)} + H_2O_{(l)} \longrightarrow H_2SO_{4(l)}$$

- Manufacture Of Sulphuric Acid By Contact Process -.mp4

Important point to note

- When sulphur trioxide gas is dissolved in water sulphuric acid is formed, but this is not convenient method of preparing sulphuric acid. Why?

Ans: This is because when sulphur trioxide is dissolved directly in water the is highly exothermic and the heat produced vaporizes the sulphuric acid formed. This makes it difficult to collect the acid formed.

Physical Properties of Conc. H_2SO_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) Concentrated sulphuric acid has no effect on litmus paper.

iv) It does not conduct electricity.

v) 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 at all.

Chemical Properties of Dil. H_2SO_4

1) Reacts with metals to form a sulphate of the metal and hydrogen gas(Zn and Fe reacts the same way).

$$Mg_{(s)} + H_2S0_{4\,(aq)} \longrightarrow MgSO_{4\,(aq)} + H_{2(g)}$$

2) Reacts with metal hydroxides and oxides to form salt and water only. This is called neutralization reaction.

$$2NaOH_{(aq)} + H_2S0_{4\,(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$$

3) Reacts with metal carbonates to give a metal sulphate, carbon dioxide and water.

$$Na_2CO_{3\,(aq)} + H_2S0_{4\,(aq)} \longrightarrow Na_2SO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$$

Chemical Properties of Conc. H_2SO_4

1) As a dehydrating agent

It removes the elements of water (oxygen and hydrogen) from a compound to form a new compound.

$$C_{12}H_{22}O_{11(s)} \xrightarrow{Conc.H_2SO_4} 12C_{(s)} + 11H_2O_{(l)}$$

Sugar ***black***

$$CuSO_4.5H_2O_{(s)} \xrightarrow{Conc.H_2SO_4} CuSO_{4(s)} + 5H_2O_{(l)}$$

Blue ***White***

2) It 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.

3) It is oxidizing agent. It oxidizes both metals and non-metals while it is reduced to sulphur dioxide.

$$C_{(s)} + 2H_2SO_{4\,(l)} \longrightarrow CO_{2(g)} + SO_{2(g)} + H_2O_{(l)}$$

$$S_{(s)} + 2H_2SO_{4\,(l)} \longrightarrow SO_{2(g)} + H_2O_{(l)}$$

Uses of Sulphuric Acid

i) Is used to remove rust and scale from rolled iron sheets in steel making industries

ii) Is used in manufacturing of fertilizer

iii) Is used in the manufacture of aluminium sulphate. $Al_2(SO_4)_3$ is used in water treatment plants to filter impurities and to improve the taste of the water.

iv) A large quantity of sulphuric acid is used in refining petroleum.

v) Sulphuric acid is used in lead-acid (car) batteries

vi) Used as a dehydrating agent in its concentrated form

vii) Is used in the manufacture of a wide range of pigments .

1.6 SULPHUR DIOXIDE

- Sulphur dioxide is a binary compound of sulphur with oxygen.
- A binary compound is the one which is made up of two elements, but not necessarily two atoms.

Preparation of Sulphur Dioxide

1) Burning sulphur in air (oxygen).

$$S_{(s)} + O_{2(g)} \longrightarrow SO_{2(g)}$$

2) Burning metal sulphide.

$$4FeS_{(s)} + 7O_{2(g)} \longrightarrow 4SO_{2(g)} + 2Fe_2O_{3(s)}$$

3) Reaction between copper turnings and concentrated sulphuric acid

$$Cu_{(s)} + 2H_2SO_{4\ (l)} \longrightarrow CuSO_{4\ (s)} + SO_{2\ (g)} + 2H_2O_{(l)}$$

4)In the laboratory, sulphur dioxide is prepared by reacting a sulphite or a hydrogen sulphite with an acid

$$Na_2SO_{3(s)} + H_2SO_{4\ (aq)} \longrightarrow Na_2SO_{4(aq)} + H_2O_{(l)} + SO_{2(g)}$$

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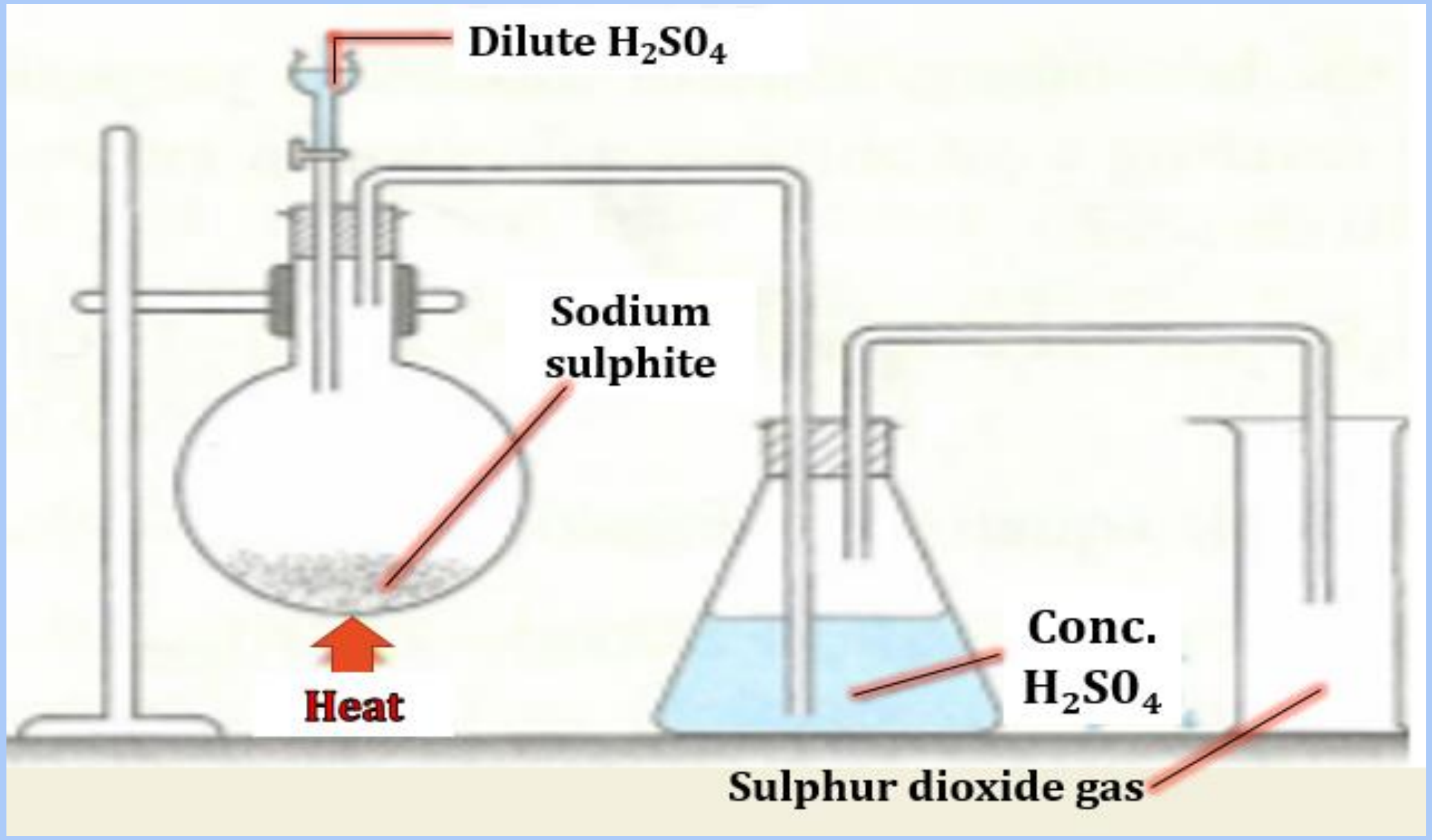

Dilute H_2SO_4
Sodium sulphite
Heat
Conc. H_2SO_4
Sulphur dioxide gas

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

1. Dissolve in water to form acidic solution of sulphuric(iv) acid which is commonly known as ***sulphurous acid***.

$$SO_{2(g)} + H_2O_{(l)} \longrightarrow H_2S0_{3\,(aq)}$$

2. Sulphur dioxide reacts with oxygen

$$SO_{2(g)} + O_{2(g)} \longrightarrow S0_{3(g)}$$

3. Sulphur dioxide acts as reducing agent

i) It reduces potassium permanganate to manganese sulphate.

$$2KMnO_{4(aq)} + 5SO_{2(g)} + 2H_2O_{(l)} \longrightarrow 2MnSO_{4(aq)} + K_2SO_{4(aq)} + 2H_2SO_{4(aq)}$$

Purple → **Colourless**

ii) Potassium dichromate (VI) solutions to chromic sulphate.

$$K_2Cr_2O_{7(aq)} + H_2SO_{4(aq)} + 3SO_{2(g)} \longrightarrow Cr_2(SO_4)_{3(aq)} + K_2SO_{4(aq)} + H_2O_{(l)}$$

Orange → **Green**

iii) It reduces halogens in presence of water to hydrogen halide

$$SO_{2(g)} + Cl_{2(g)} + 2H_2O_{(l)} \longrightarrow 2HCl_{(aq)} + H_2SO_{4(aq)}$$

$$SO_{2(g)} + Br_{2(g)} + 2H_2O_{(l)} \longrightarrow 2HBr_{(aq)} + H_2SO_{4(aq)}$$

$$SO_{2(g)} + I_{2(g)} + 2H_2O_{(l)} \longrightarrow 2HI_{(aq)} + H_2SO_{4(aq)}$$

iv) It reduces iron(iii) to iron(ii)

$$Fe_2(SO_4)_{3(aq)} + SO_{2(g)} + 2H_2O_{(l)} \longrightarrow 2FeSO_{4(aq)} + 2H_2SO_{4(aq)}$$

3. Sulphur dioxide acts as oxidizing agent

i) Sulphur dioxide oxidizes hydrogen sulphide to Sulphur

$$SO_{2(g)} + 2H_2S_{(g)} \longrightarrow 2H_2O_{(l)} + 3S_{(s)}$$

Yellow precipitates

Test for Sulphur Dioxide

- It changes the filter paper soaked in acidified potassium dichromate (VI) from orange to green due to the reduction of dichromate (VI) to chromate (III).
- Sulphur dioxide also decolorizes acidified potassium permanganate solution.

Pollution Effects of Sulphur Dioxide

i) It causes acidic rain.
ii) It can cause impairment of respiratory function.
iii) It causes heart diseases.
iv) It is a major air pollutant.

Uses of Sulphur Dioxide

1) Used in manufacture of sulphuric acid.
2) It is used as a bleaching agent for fibres. Example wool, silk, straw and sponges.
3) It is used in the manufacture of calcium hydrogensulphites which is used for bleaching wood-pulp.
4) It is used for fumigating houses and clothing to kill micro-organisms.
5) Sulphur dioxide is used in small doses as a preservative of some liquids such as lemon and orange juices by preventing fermentation.

6) Liquid sulphur dioxide is used in refrigerators because it liquefies at three atmospheres at room temperature.

1.7 NITROGEN

- Nitrogen exists in gaseous state as a diatomic molecule.
- 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
- In this process air is passed through a solution of sodium hydroxide to remove carbon dioxide.

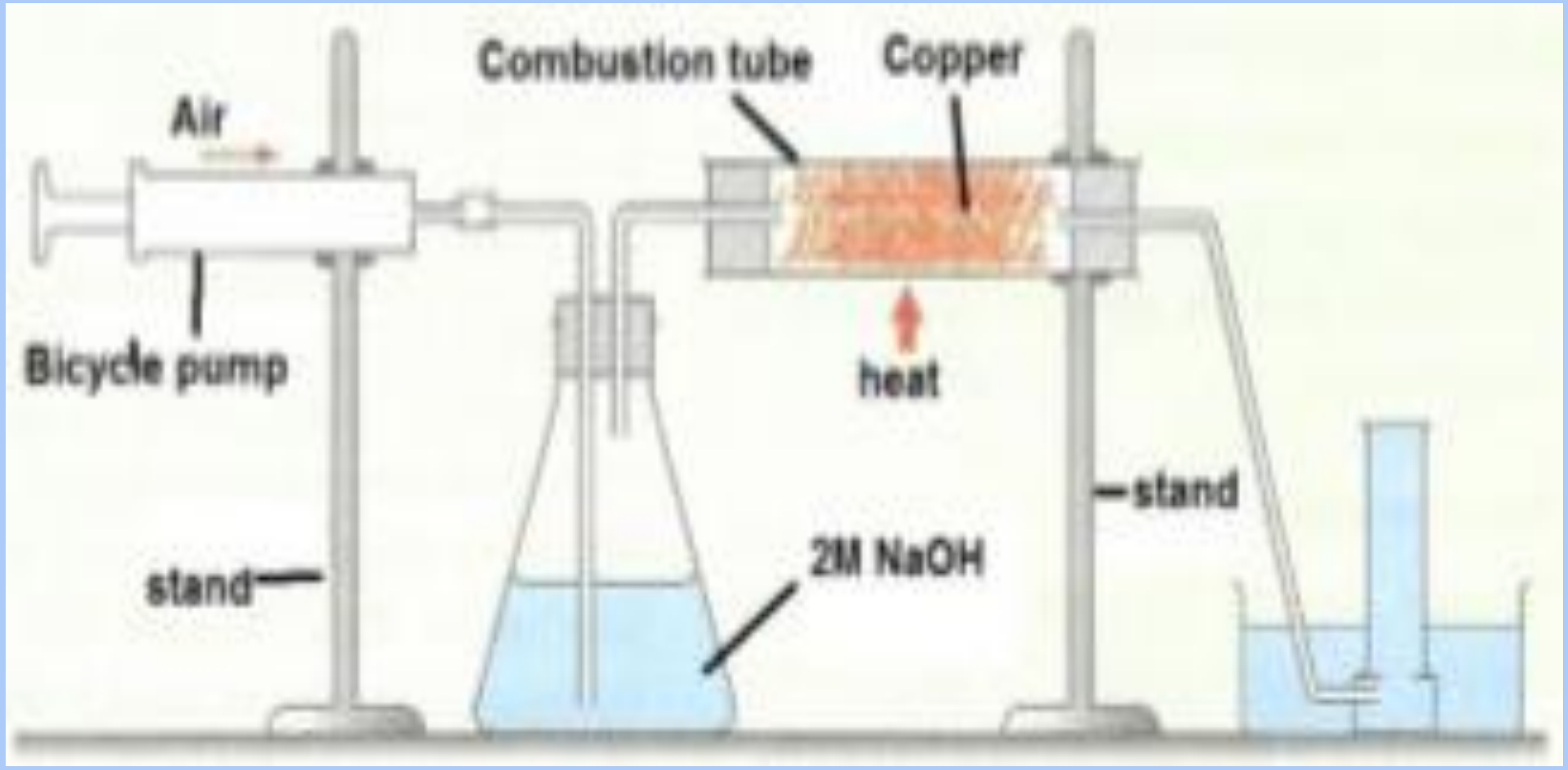
$$NaOH_{(aq)} + CO_{2(g)} \longrightarrow NaHCO_{3(aq)}$$

- Then passed in the combustion tube, where hot copper turnings (brown) react with oxygen present in air.

$$Cu_{(s)} + O_{2(g)} \longrightarrow CuO_{(s)}$$

Brown Black

❖The gas can be dried by passing it in the conc. sulphuric acid.


Air
Combustion tube
Copper
Bicycle pump
heat
stand
stand
2M NaOH

Physical Properties of Nitrogen

- It is almost insoluble in water.
- It can be liquefied to form liquid nitrogen.
- Nitrogen is a colourless, odourless and tasteless gas.
- It has a boiling point of -196°C.
- Nitrogen prepared from air is denser than pure nitrogen since it contains the noble gases.

Chemical Properties of Nitrogen

- Nitrogen gas is stable below 3000°C. It only takes part in reactions at very high temperatures.

1. It neither burn nor support combustion.
2. When heated, it combines with oxygen to form nitrogen monoxide gas.

$$N_{2(g)} + O_{2(g)} \xrightarrow{\Delta} 2NO_{(g)}$$

3. Nitrogen reacts with hydrogen when heated to form ammonia.

$$N_{2(g)} + H_{2(g)} \rightleftharpoons NH_{3(g)}$$

4. When heated together with metals, nitrogen forms metal nitrides

$$Mg_{(s)} + N_{2(g)} \xrightarrow{\Delta} Mg_3N_{2(g)}$$

Uses of Nitrogen

i) Manufacture of fertilizers. Example Diammonium phosphate (DAP), calcium ammonium nitrate (CAN)

ii) Nitrogen gas is used as a refrigerant because of its low boiling point (inert atmosphere -196°C).

iii) It is used to provide an inert atmosphere for storing and processing reactive substances.

iv) Nitrogen is used in the manufacture of synthetic fibres such as nylons.

v) Is used in manufacturing ammonia through the Haber process.

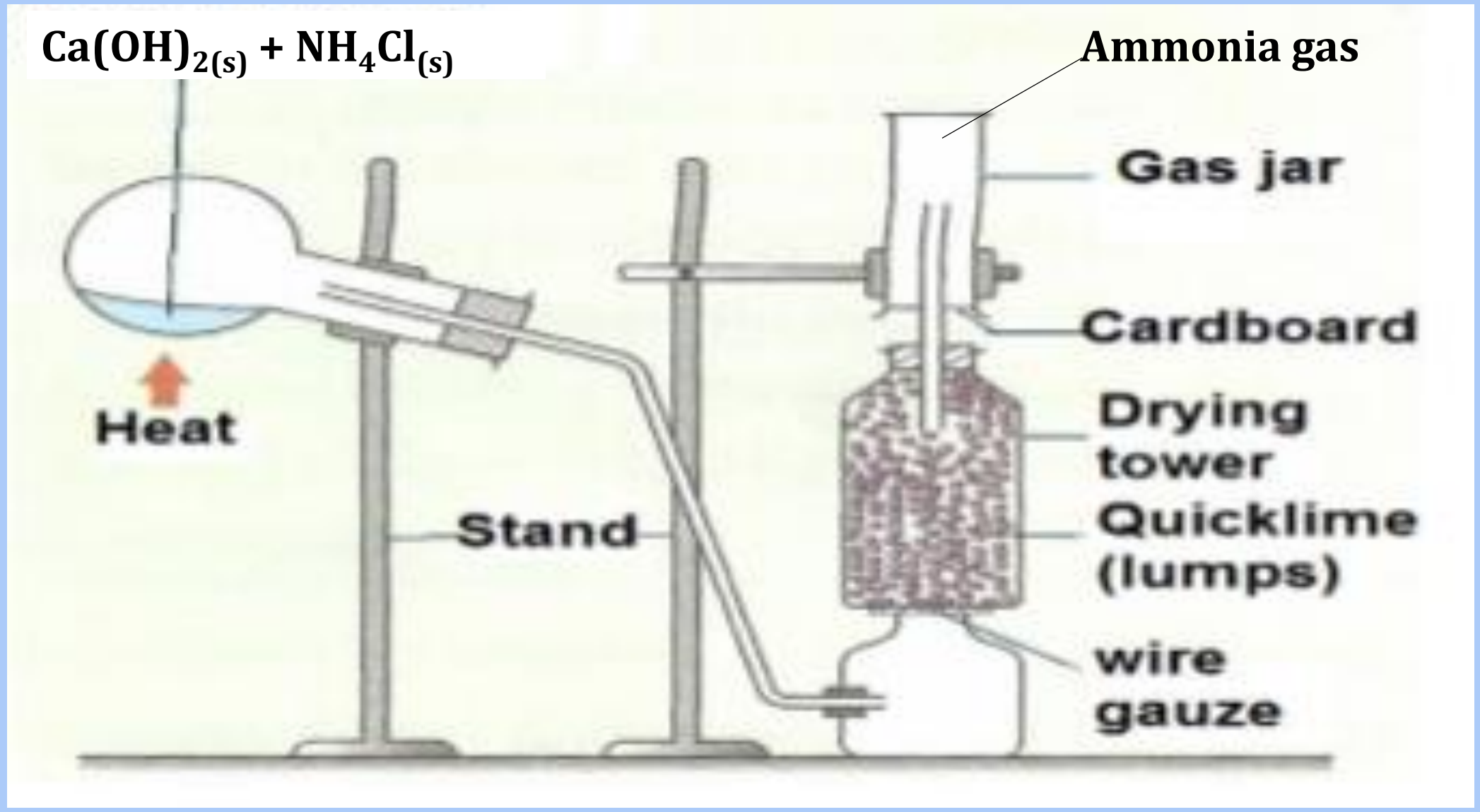
$$N_{2(g)} + H_{2(g)} \rightleftharpoons NH_{3(g)}$$

1.8 AMMONIA

- Ammonia is a compound of hydrogen and nitrogen.
- It exists in nitrogenous organic materials such as hoofs and horns of animals.
- Its chemical formula is NH_3.

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.



$$NH_4Cl_{(s)} + Ca(OH)_{2(s)} \longrightarrow CaCl_{2(aq)} + NH_{3(g)} + H_2O_{(l)}$$

Important Points to note

- The round-bottomed flask is ***tilted*** to prevent any condensed water from running back into the hot flask, which would make the flask crack.
- The common drying agents such as ***concentrated sulphuric acid*** and ***calcium chloride*** are not used because they react with the gas.

$$NH_{3(g)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(s)}$$

$$NH_{3(g)} + CaCl_{2(s)} \rightarrow CaCl_2.8NH_{3(s)}$$

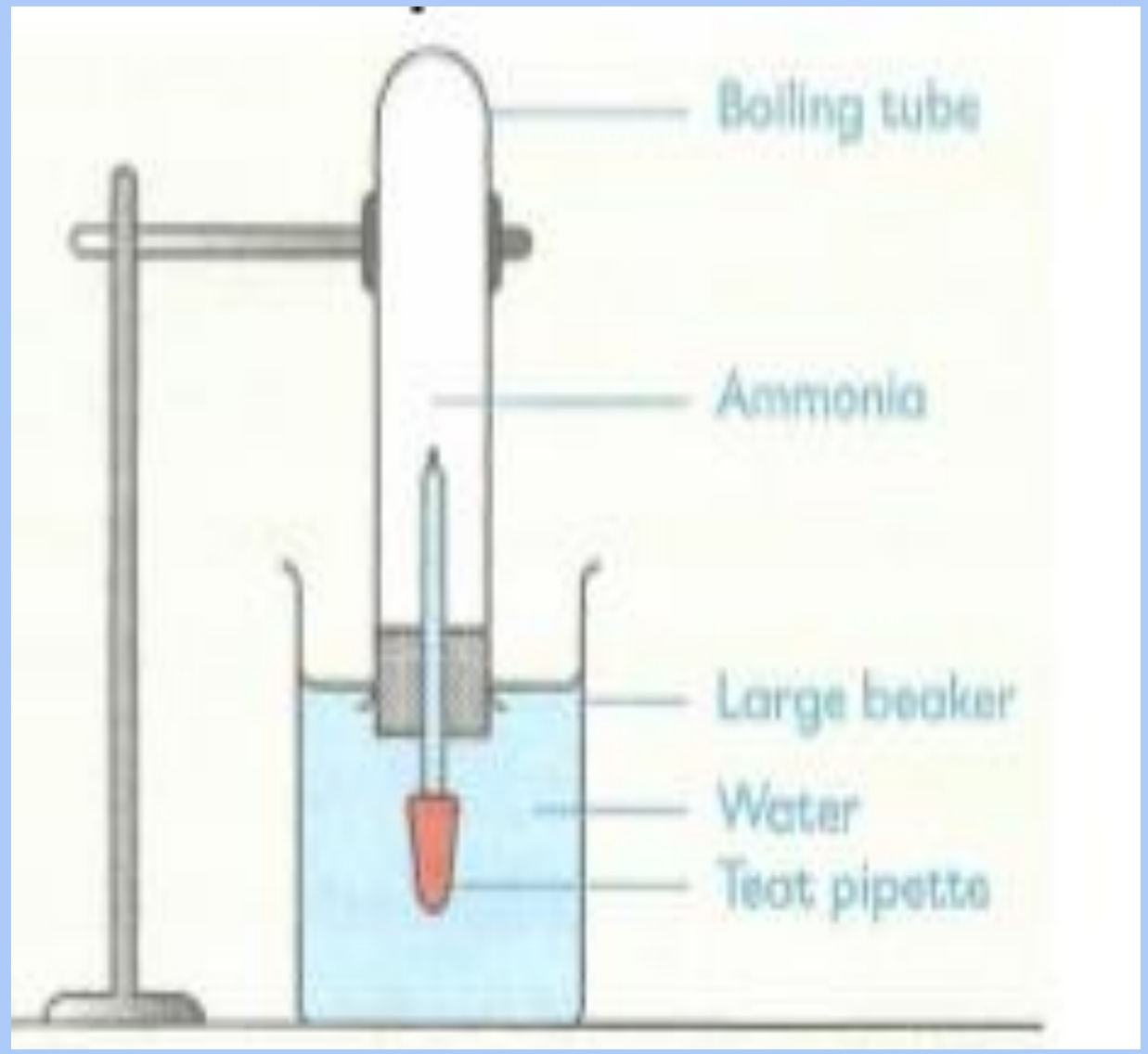
- When sodium hydroxide or potassium hydroxide are used, they are used in solution form because they are very reactive in solid form.

Physical properties of ammonia

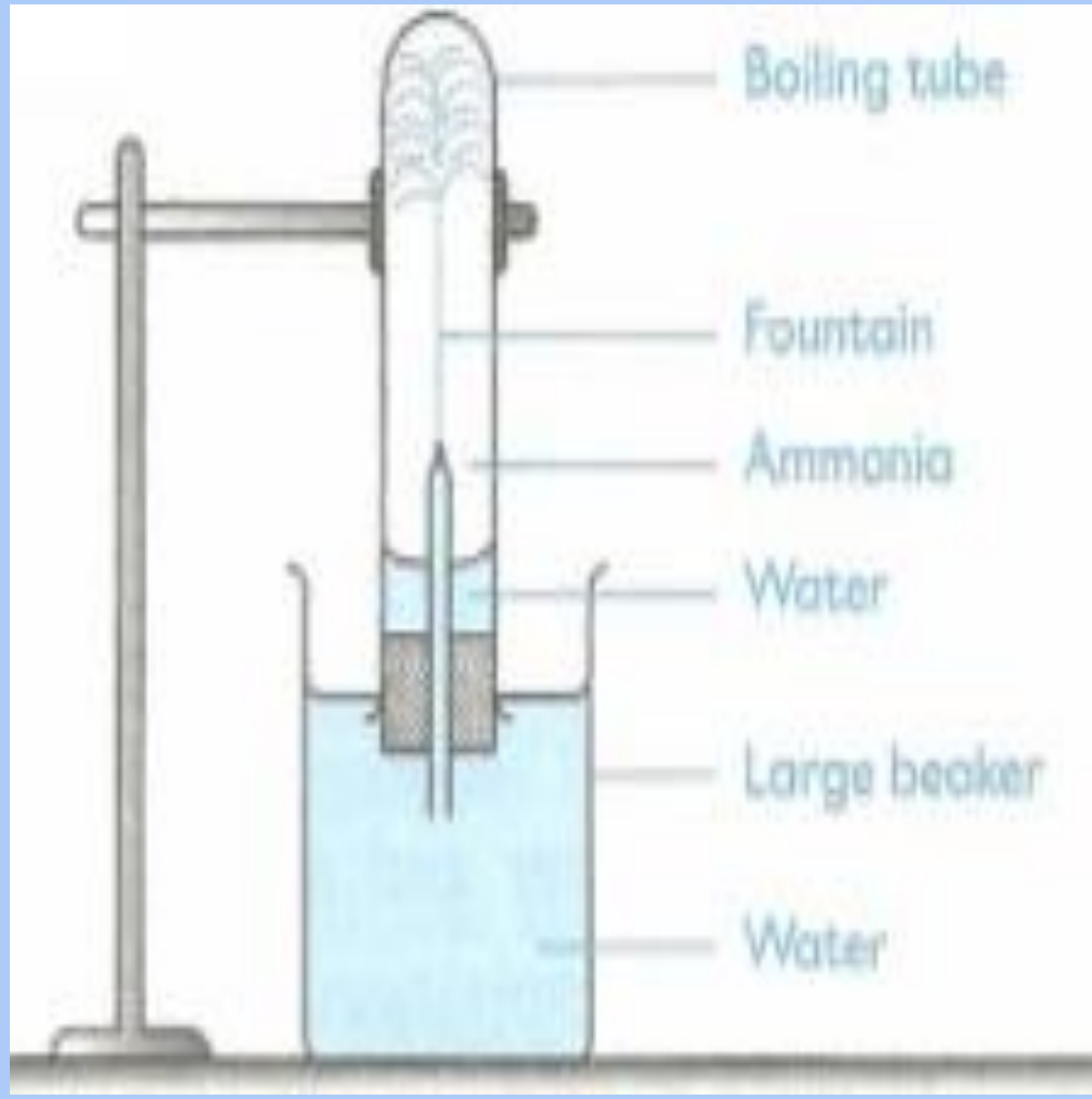
i) Ammonia is a colourless gas with a pungent choking smell
ii) It is less dense than air
iii) Ammonia is highly soluble in water
iv) It turns wet, red litmus paper into blue.

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.



Chemical properties of ammonia

1) When ammonia and hydrogen chloride are mixed, dense white fumes of ammonium chloride are formed.

$$NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$$

2) When ammonia gas is passed over heated copper (II) oxide, the gas is oxidized to nitrogen and water while the oxide is reduced to copper.

$$3CuO_{(s)} + 2NH_{3(g)} \rightarrow 3Cu_{(s)} + 3H_2O_{(l)} + N_{2(g)}$$

3) Reacts with acids to form ammonium salts

$$NH_{3(g)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(s)}$$

Uses of Ammonia

1. Manufacture of fertilizers example: CAN,DAP,
2. 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

Test for ammonia gas

- When a glass rod is inserted in the hydrochloric acid and placed at the mouth of the gas jar containing ammonia, dense white fumes of ammonium chloride are formed.

$$NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$$

- It turns moist red litmus paper into blue.

1.9 CARBON

- Carbon is a Group IV and Period 2 element.
- It is 17th abundant element in the earth's crust by mass.
- It usually forms covalent bonds when combining with other elements.
- Carbon is found in a variety of natural substances including *shells*, *coal*, *diamond*, and *graphite*.
- It is also found in compounds of carbonates such as chalk.

Allotropes of Carbon

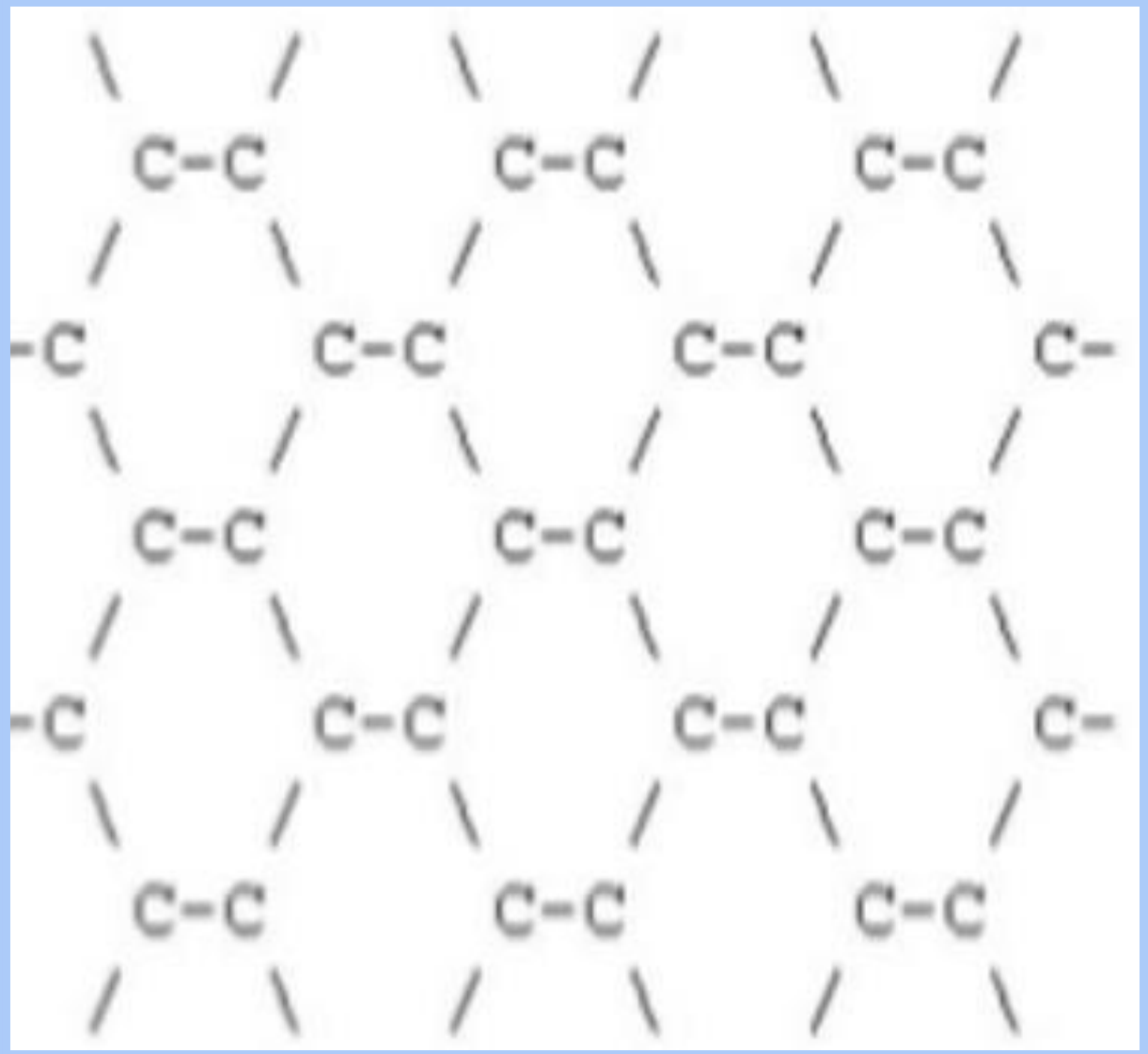
- Carbon exists in three main forms include
  1. Graphite Carbon
  2. Diamond Carbon
  3. Amorphous Carbon

1. Graphite Carbon

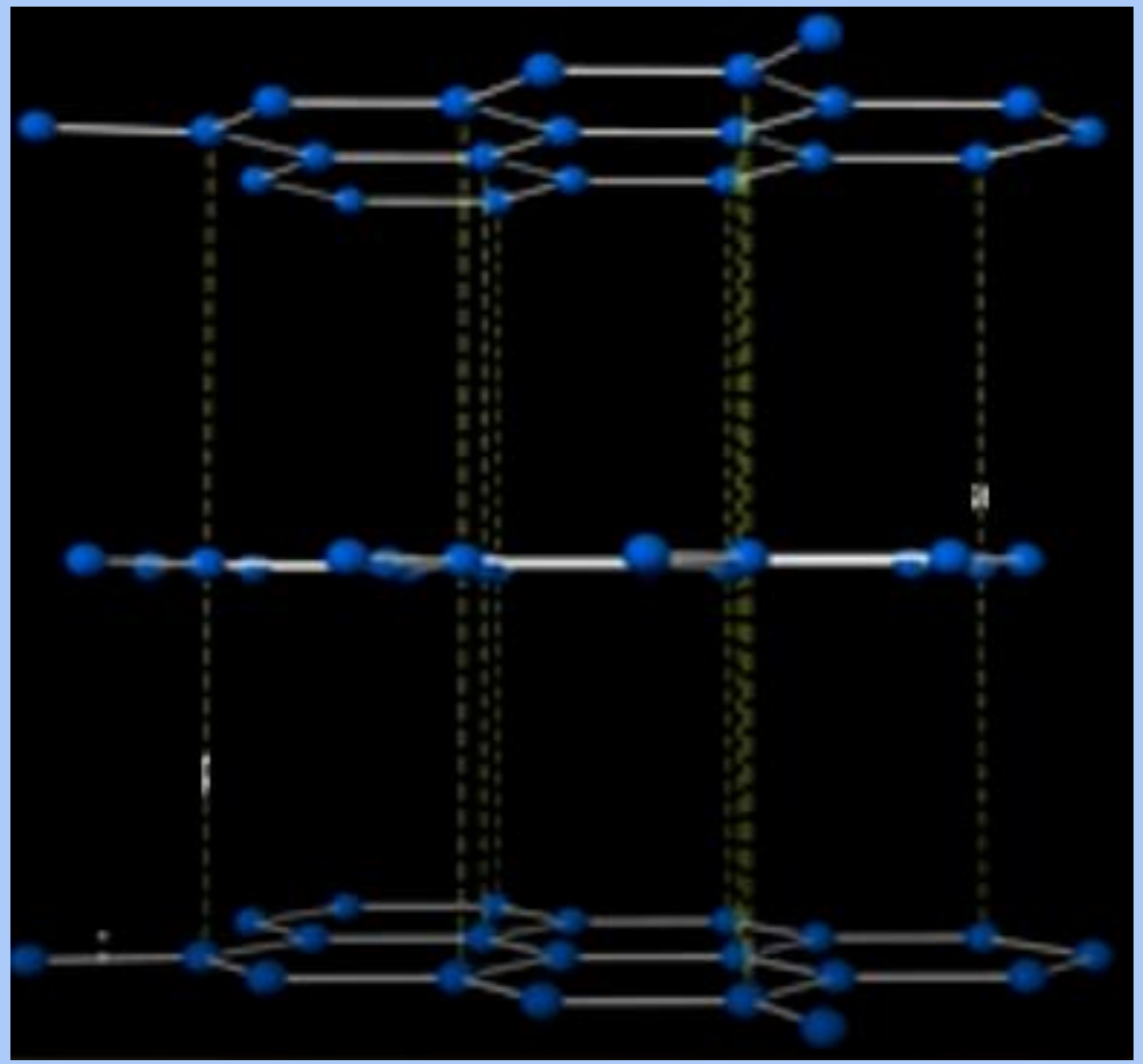
- Each carbon atom is bonded to three other carbon atoms, giving it a trigonal structure.
- *Three out of the four valence electrons* of each carbon atom are used in bond formation.
- The fourth electron is referred to as a *delocalized electron*, and is free to move in the graphite structure.
- The 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*.

Graphite crystal

Bond formation



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

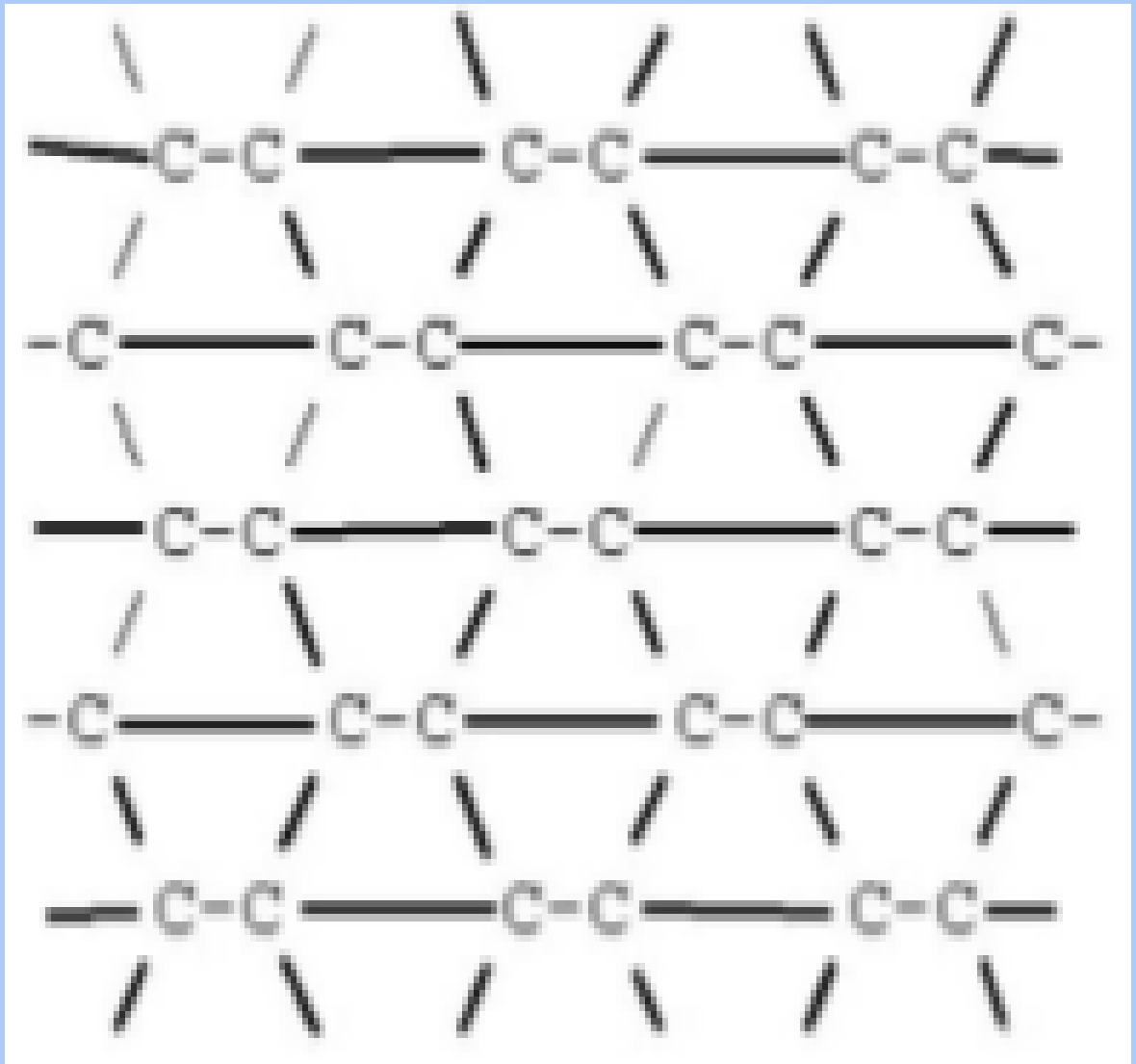
iii) It is mixed with clay to make the lead in pencils.

Diamond Carbon

- In diamond, all the *four valence electrons* of a carbon atom are used in bonding.
- This forms four strong covalent bonds in each carbon atom.
- The electrons form a ***tetrahedral shape***.
- Here no free delocalized electron available

Diamond crystal

Bond formation



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 (3,550°C) and boiling point (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.
- The major types of amorphous carbon are
  i. Charcoal
  ii. Soot
  iii. Coke

i) Charcoal

- Is a substance made by destructive distillation of woods and bones of animals.
- It is very light and porous.
- Charcoal made from destructive distillation wood is called ***wood charcoal*** whereas that made from destructive distillation of animal bones is called ***animal charcoal***.
- ***Destructive distillation*** is the process of burning a substance in absence of air.

Uses of charcoal

i. Used as gas absorber. Example gas mask contains carbon to absorb poisonous gases in air.
ii. Used as fuel
iii. Used to absorb coloring materials from a substance.

Example animal charcoal is used to absorb brown colour of sugar when they are heated together.

Important points to note

- When charcoal is heated in limited supply of air (O_2) carbon monoxide is formed.

$$2C_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{(g)}$$

- Therefore it is not safe to burn the charcoal inside the room which is poorly ventilated, because a person sleeping inside will suffocate.
- This is because carbon monoxide forms very strong covalent bond with the haemoglobin, hence forbid it from combining with oxygen.

ii) Coke

- This is a residue obtained from destructive distillation of coal.

Uses of coke

- It is very useful fuel.
- Used as reducing agent in extraction of metals.

iii) Lampblack (Soot)

- This is obtained from incomplete combustion of fuel.
- It is commonly found in kitchen chimneys and kerosene lamps.

Uses of lampblack

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 for making carbon papers.

iv) Used for making cosmetics for darkening eye lashes called *mascara*.

v) Used in making shoe polish.

Chemical Properties of Carbon

(i) Reaction with oxygen

- Carbon burns in limited supply of oxygen

$$2C_{(s)} + O_{2(g)} \xrightarrow{\Delta} 2CO_{(g)}$$

- When carbon burn in excess oxygen carbon dioxide gas is formed.

$$C_{(s)} + O_{2(g)} \xrightarrow{\Delta} CO_{2(g)}$$

(ii) Carbon reduces oxides of less reactive metals to their respective metals.

$$ZnO_{(s)} + C_{(s)} \longrightarrow Zn_{(s)} + CO_{(g)}$$

- Carbon reduces hot concentrated nitric acid and concentrated sulphuric acid.

$$4HNO_{3\,(l)} + C_{(s)} \longrightarrow 4NO_{2\,(g)} + CO_{2\,(g)} + 2H_2O_{(l)}$$

$$2H_2SO_{4\,(l)} + C_{(s)} \longrightarrow 2SO_{2\,(g)} + CO_{2\,(g)} + 2H_2O_{(l)}$$

1.10 CARBON DIOXIDE

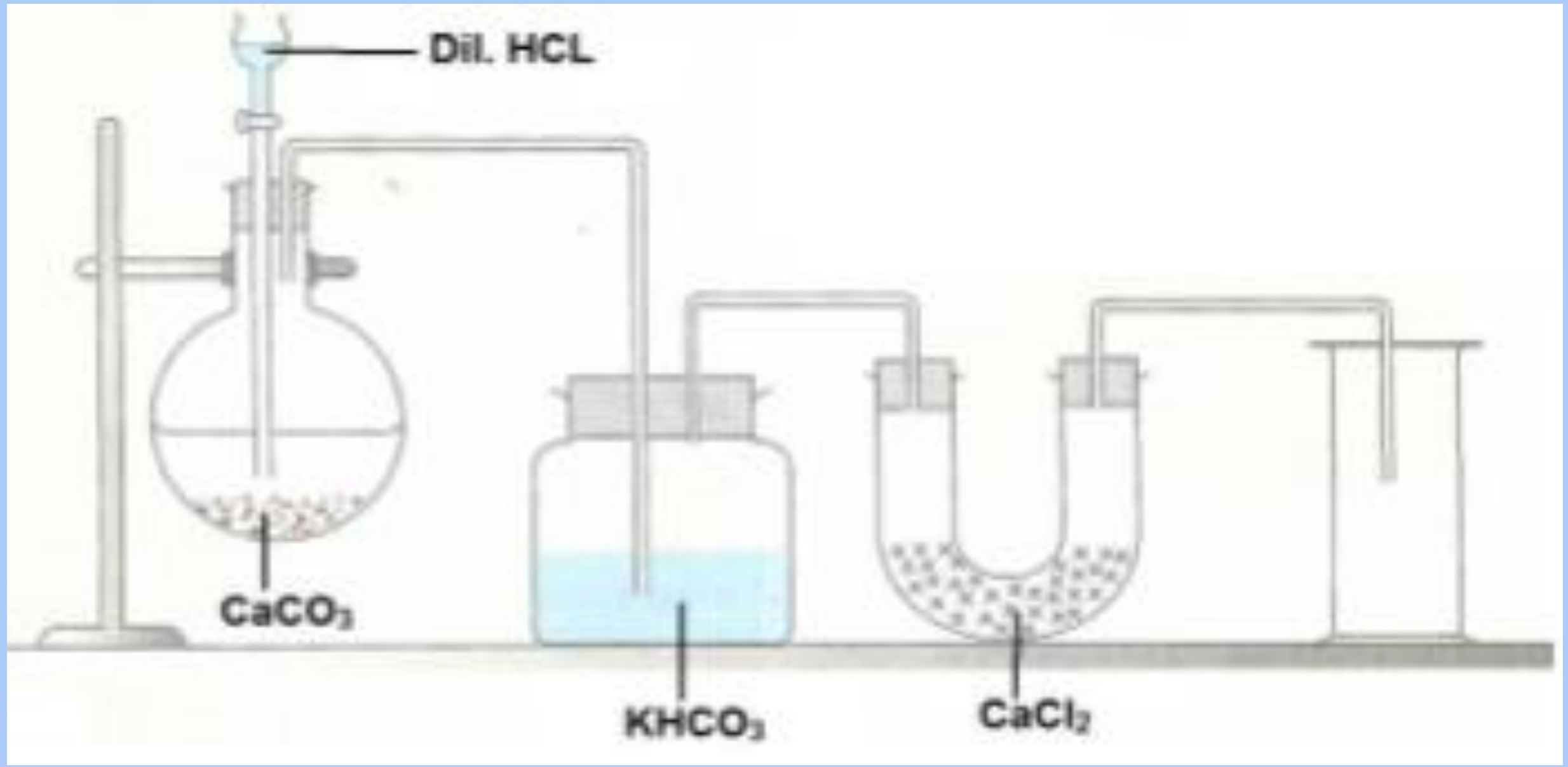
- Carbon dioxide is the binary covalent compound formed between carbon and oxygen.
- In the atmosphere carbon dioxide is 0.03% by volume.

Preparation of Carbon Dioxide

- Carbon dioxide can be prepared in the laboratory by the action of *dilute hydrochloric acid* on *marble chips* (calcium carbonate).
- Dilute hydrochloric acid reacts with marble chips to give calcium chloride, water and carbon dioxide.

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$$

- The gas is passed through potassium hydrogen carbonate solution to 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.


Dil. HCL
$CaCO_3$
$KHCO_3$
$CaCl_2$

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. It sublimes at atmospheric pressure.
v. It extinguishes the burning splint.

Chemical Properties

1. Carbon dioxide does not support combustion.
2. The gas is slightly acidic.
3. It reacts with soluble metal hydroxide to form carbonate.

$$Ca(OH)_{2(aq)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$$

4. When magnesium is heated, it reacts with carbon dioxide to form magnesium oxide.

$$Mg_{(s)} + CO_{2(g)} \rightarrow MgO_{(s)} + C_{(s)}$$

5. Reacts with water to form carbonic acid

$$H_2O_{(l)} + CO_{2(g)} \rightleftharpoons H_2CO_{3(l)}$$

Test for carbon dioxide

- Carbon dioxide turns lime water milky. This is due to the formation calcium carbonate precipitates.

$$Ca(OH)_{2(aq)} + CO_{2(g)} \rightarrow CaCO_{3(s)} + H_2O_{(l)}$$

White precipitates

- When lighted wooden splint is inserted in the test tube containing carbon dioxide, the wooden splint goes out.

TOPIC 3

SOIL CHEMISTRY

3.1 Soil Formation

- ***Soil chemistry*** is the study of various chemical nutrients present in the soil and their influence on the properties of the soil.

  Example: acidity and alkalinity

- ***Soil*** is the top most layer of the earth's crust.

Compositions of the soil

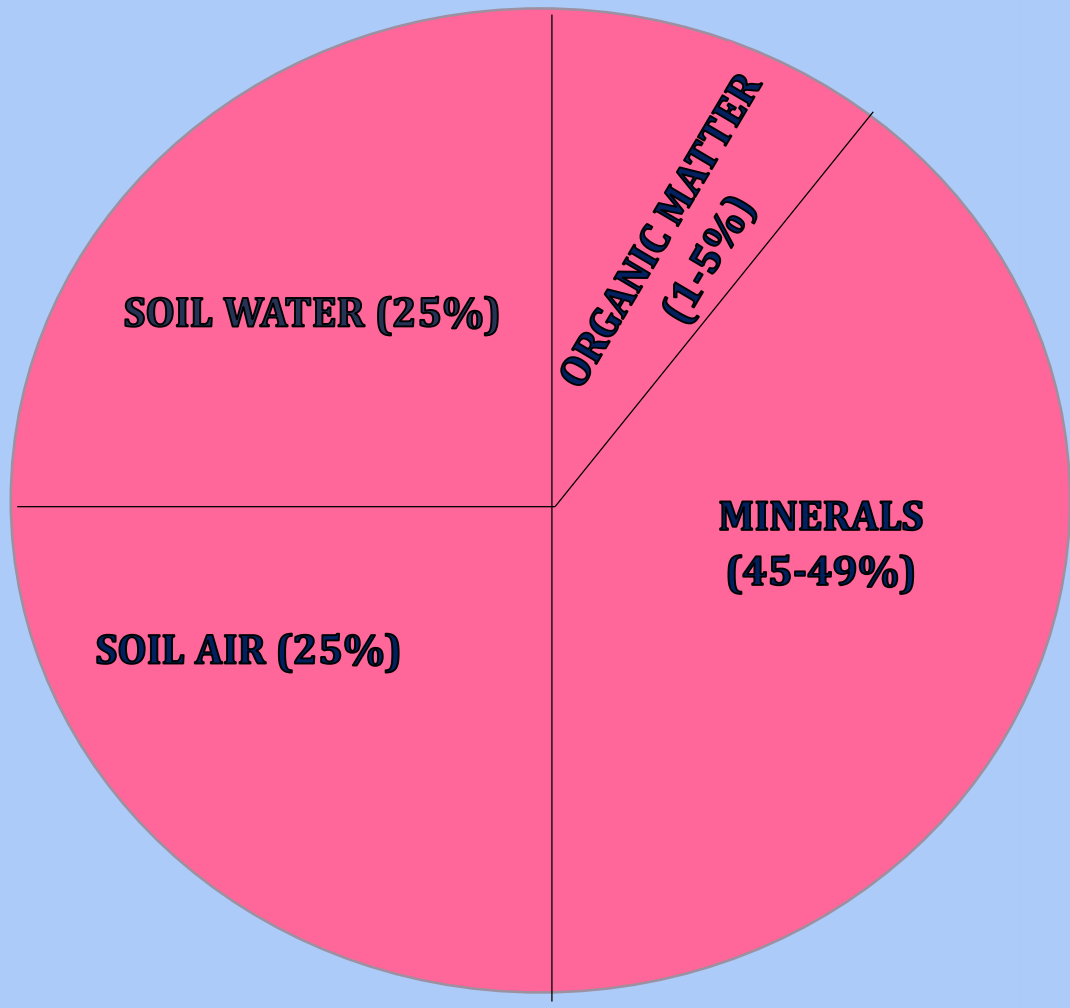
- Soil is the *unconsolidated* top layer of the earth's crust composed of the following:

i. Solid phase 50%

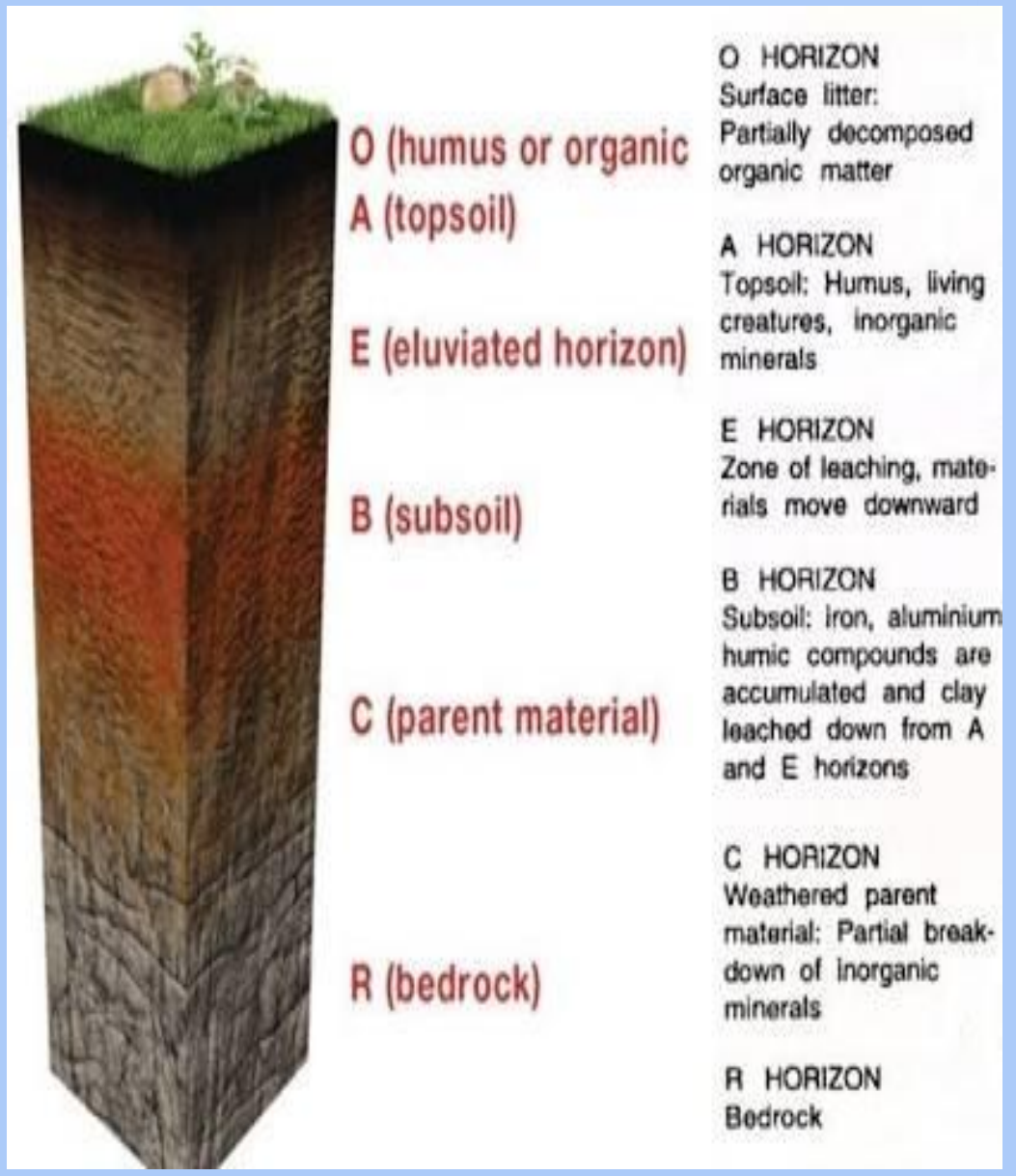
- ⋆ *Minerals(inorganic matter) 45 – 49%*
- ⋆ *Organic matter 1 – 5%*

ii. Soil water 25%

iii. Soil air 25%



- Soil Formation is a very gradual process which occurs through ***weathering***.
- **Weathering** is the physical and chemical breakdown of the rock material near the earth's surface.
- The process of weathering involves a series of changes that alter the ***form***, ***colour***, ***texture*** and ***composition*** of the rock particles.
- This process leads formation of layers (horizons) in the soil profile.



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Agents of weathering

- The factors that facilitate the weathering process includes:
  i) Water
  ii) Gravity
  iii) Air (oxygen and carbon dioxide)
  iv) Plants and animals
  v) Temperature changes
  vi) Human beings

Types of weathering

- There are three main types of weathering, namely

i) Physical weathering

ii) Biological weathering

iii) Chemical weathering

i) Physical weathering

- Physical weathering is disintegration of rock material without change its chemical composition.
- In this process the big rocks are broken down into small rocks.
- It 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 through which physical weathering takes place

a) Pressure release

- This occurs when the overlying rocks are removed by erosion.
- With release pressure the rock to expands, which result in the stress within the rock.
- Cracks are formed parallel to the rock surface.
- Over a period of time, the outer layers of the rock break away in sheets.

b) Exfoliation

- This occurs in hot deserts where temperature rises to over 40℃ and night fall to below 10℃.
- This repeated heating and cooling causes expansion and contraction of the rock.
- This create stress in the rock causing it to crack and finally the outer layer of the rock peels off.

c) Frost shattering

- This 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 into fine particles.

d) Crystallization

- Is the weathering by growth of salt crystal.
- In hottest region (desert) evaporation draws ground water containing dissolved salts upward into the pores of the rock.
- When the water evaporates, the salts are left behind as crystal.
- Salt crystals create stress in the rock, weakening it and break it down into grains.

ii) Biological weathering

- Biological weathering is disintegration of rock material which is caused by the living things.
- This involves
  a) Roots growing into the cracks and joint in the rocks
  b) Burrowing animals such as a ***moles***, ***earthworms*** and ***termites*** making tunnels(holes) in the ground.
  c) Human activities, such as *building roads* and *cultivating land*

iii) Chemical weathering

- Is the breakdown of rocks by ***chemical alternation*** of constituent minerals.
- chemical weathering destroy (change) internal structure of the minerals.
- chemical weathering occur common in *warm* and *wet* areas.
- The main agents of chemical weathering are:
  a) Water
  b) Carbonic acid

i.) Dissolution

- The mineral (rocks) is dissolved in water.
- For example **calcite rock** ($CaCO_3$) dissolved in acidic rain to form calcium bicarbonate ($Ca(HCO_3)_2$)
- The dissolved rocks are washed down through the soil

$$CaCO_{3(s)} + H_2CO_{3(aq)} \rightarrow Ca(HCO_3)_{2(aq)}$$

$$Ca(HCO_3)_{2(aq)} \rightarrow Ca^{2+}_{(aq)} + 2HCO_3^-{}_{(aq)}$$

Overall **:** $CaCO_{3(s)} + H_2CO_{3(aq)} \rightarrow Ca^{2+}_{(aq)} + 2HCO_3^-{}_{(aq)}$

(Calcite) (Carbonic acid) (Calcium ion) (Bicarbonate ion)

- **ii)Hydrolysis**

- Hydrogen ions (H+) and hydroxyl ions (OH-) replace other ions in a mineral.
- Hydrolysis takes place in the presence of water.

Example:

$$KAlSi_3O_{8(s)} + 4H^+_{(aq)} + 2H_20_{(l)} \rightarrow 4K^+_{(aq)} + Al_4Si_4O_{10}(OH)_8 + 8SiO_2$$

(orthoclase) (Clay minerals) (Silica)

- **iii) Oxidation**

- Oxygen reacts with other minerals, changing the oxidation state of ions.
- The oxidation is common in iron-bearing minerals.
- For example pyroxene (FeSiO3) reacts with oxygen to form magnetite (Fe3O4) and silica (SiO2)

$$6FeSiO_{3(s)} + O_{2(g)} \rightarrow 2Fe_3O_{4(aq)} + 6SiO_{2(s)}$$

Factors Influencing Soil Formation

i) Parent rock material
ii) Climate change
iii) Living organisms
iv) Time in which parent rock is exposed to weathering process
v) Topography of the area

i) Parent rock material

- The nature of the parent rock material may determine the *type of the soil formed*, *rate of soil formation, soil texture, physical and chemical properties* of the soil.
- ***Soil texture*** is the relative proportions of the different particle sizes in the soil. This affects water permeability of the soil.
- *Basic rocks* such as ***limestone*** are easily weathered than *acidic rock* which contain ***silicate***.
- **Porous rocks** provide *large surface area* for chemicals to act on it hence easily weathered.

ii)Climate change

- *Rainfall* provides water, which is the main agent of weathering.
- *Temperature change* cause alternate expansion and contraction of rock which result into breakdown of the rock into smaller particles.
- *High temperature* speed up the rate of chemical reactions and activity of micro-organism hence speed up weathering process and vice versa.
- *Wind* acts as a transportation agent and carries weathered materials from one place to another

iii) Living organisms

- Living organisms such as ***plants*** and ***animals*** contribute towards the organic matter present in the soil.
- Soil formed in area of a lot of vegetation cover have high organic matter contents. The higher the organic matter contents the higher the microbial activity.
- Plants root and burrowing animal help in breaking the rock into smaller particles.

iv) Time in which the parent rock is exposed to weathering process

- Some soils are said to be younger than others.
- The time at which the rock has been exposed to weathering process can influence the soil formation process.
- The younger soils are thinner and deepens as the soil matures.
- The longer the rock is exposed to weathering process the older and deeper the soil becomes.

V) Topography of the area

- Topography is the appearance of the landscape.
- Soil on the top of hilly area are heavily leached.
- Soil found in flat land and low lying area tend to be more fertile and deep mainly because of deposition of materials from the top.
- Soil in lower and flatter areas tend to be darker in colour because they have more organic matter.

SOIL TEXTURE

- Is the relative proportions of the different particle sizes in the soil.
- The soil texture determines the soil properties and how productive the soil can be.
- The particles in the soil are classified according to their sizes.
- The following are the textural classes of soil particles arranged in order of their increase in size.

❖ ***Clay*<*Silt*<*Fine sand*<*Coarse sand*<*Fine gravel*<*Gravel***

Particle size Increases

Types of soil

- Depending on the soil texture, soil can be classified as follows:

i) Sandy soil

ii) Loamy soil

iii) Clay soil

i) Sandy soils

- Are the soils which sand particles the predominant components in the soil sample. Contain more than ***70% sand***.
- It is not good for cultivation since it must be watered repeatedly.

Characteristics of sandy soil

i. Have good drainage and aeration.
ii. They are easily eroded by wind or water if no vegetation cover.
iii. Have poor water and nutrients holding capacity.
iv. The particles are loosely held.

ii) Loamy soils

- Are the soils which contain *equal* proportions of *sand* and *silt* and less than 30% of *clay particles*.
- Loamy soils are ideal for garden and other agricultural uses.

Characteristics of loamy soils

i. Have good water and nutrients holding capacity.

ii. Allow excess water to drain away.

iii. Have adequate soil air.

iv. Contains enough soil colloids.

iii) Clay soils

- Are the soils which contain less than 50% sand and more than 30% clay in the soil sample.

Characteristics of clay soils

i. Have poor drainage and aeration.
ii. Have high nutrients and water holding capacity.
iii. Are very sticky when wet and hard when dry.
iv. Have high ion adsorption capacity.
v. Have difficult root penetration due to its hardness.



Importance of soil texture

i) ***Root penetration***: Light soils allow easy root penetration while heavy soils retard root penetration and pant growth, particularly in dry seasons.

ii) ***Water infiltration***: is the downward movement of water. It is maximum in light soils but its just opposite for heavy soils.

iii) ***Soil fertility:*** fine textured soils are susceptible to leaching. Also have much soil colloids which absorbs plant nutrients hence greater fertility.

iv) ***Water movement:*** Light soils allow water movement due to poor water holding capacity.

v) ***Soil aeration:*** Fine textured soils have enough soil air.

3.2 Soil Reaction

- Is the property of a soil being ***acidic***, ***basic*** or ***neutral***.
- This is determined by the concentrations of **H^+** and **OH^-** in the soil solutions.
- When **H^+** ions are in greater concentration than **OH^-** ions the soil becomes ***acidic*** and vice versa.
- But when both ions are in *equal concentration*, the soil becomes *neutral*.
- When ***metallic cations*** absorbed in the soil are *greater than* **H^+** ions then soil reaction takes place leading to formation of **OH^-** ions.

Soil pH

- Is the measure of the concentration of *hydrogen ions* ($\mathbf{H^+}$) present in the soil.
- Soil with pH less than 7 is *acidic*, the one with pH above 7 is *basic* and the one with pH of 7 is *neutral*.
- Most soil range between pH 3.5 and 11.

pH	Description	pH	Description
1.0 – 4.0	Very strong acidic	7.1 – 8.0	Faint alkaline
4.0 – 5.0	Strong acidic	8.0 – 9.0	Moderately alkaline
5.0 – 6.0	Moderately acidic	9.0 – 10.0	Strongly alkaline
6.0 – 6.9	Faint acidic	10.0 – 14.0	Very strongly alkaline
7.0	Neutral		

Significance of soil pH

i. Helps to estimate the amendments to bring about the required condition.
ii. Enable us to determine the microbial activities
iii. Enable us to select crop to plant associate with pH value
iv. Enable us to determine kind of some nutrients available in soil.

Example: #pH 6.5 – 7.5 favours N, K, P and Mg.

Acidic soil favours Fe, Mn, Cu, Cl and Zn.

Factors affecting soil pH

i. ***Parent rock***: Soil formed from basic rocks has higher pH value than those formed from acidic rocks
ii. ***Rainfall***: Soils formed under high rainfall (acidic rain) conditions are more acidic than those formed under dry conditions.
iii. ***Human activities***: Pollution alter the pH of the soil such as harmful gases releases by vehicles.
iv. ***Application of fertilizers***: Manure and fertilizers contain ammonium or urea lower the pH value of the soil(increase acidity).

Measurement soil pH

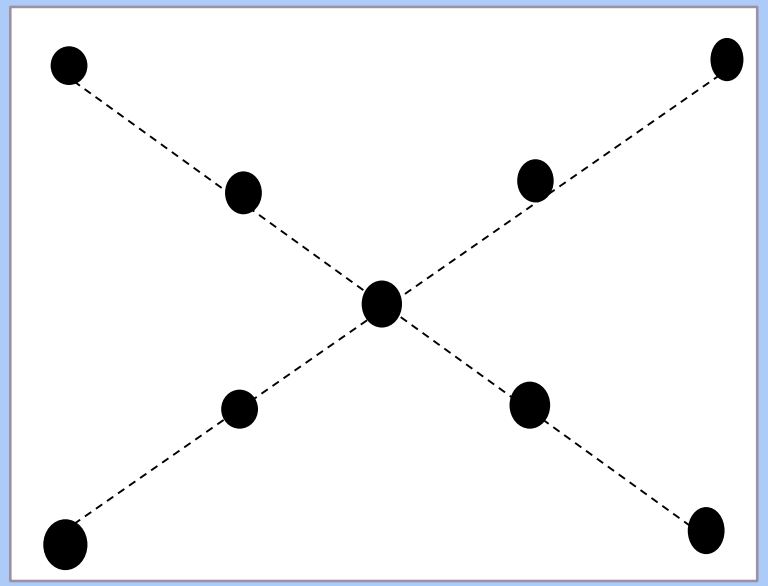
- The pH of the soil is measured by using pH-meter or universal indicator dyes.
- pH-meter is more accurate but it is not commonly used because it is quite expensive.
- The use of universal indicator dyes is easiest and most convenient method used.
- pH testing is carried out so as to determine the pH amendments that may be required.
- When measuring soil pH the soil sample should be collected form different points of the field.

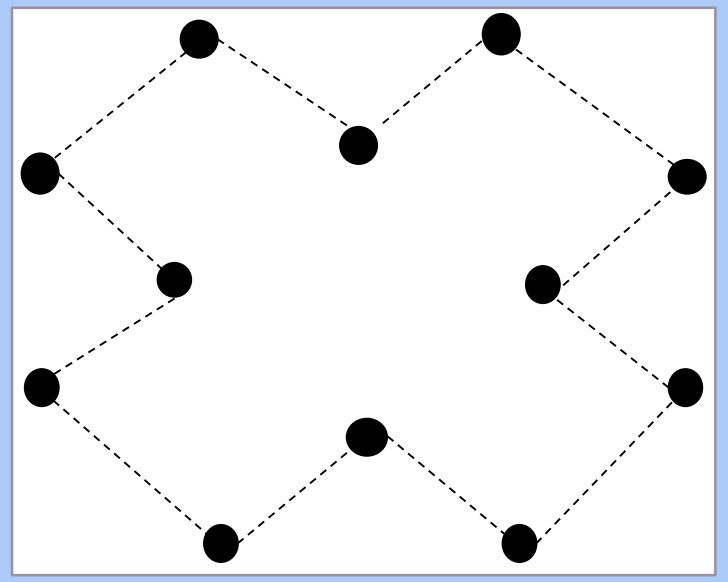
pH Metre

Methods of collecting samples for pH test

Transverse method: Collecting soil samples diagonally within the farm.

Zigzag method: Collecting samples in zigzag pattern within the farm.





Managing soil pH

- This is the adjustment of the soil pH to a required range to suite the crop required.
- Common methods of modifying soil pH includes the following:-
  i. Addition of amendment materials
  ii. Use of fertilizers
  iii. Tillage practices
  iv. Using organic matter
  v. Improving drainage

Addition of amendment material

- Amendment is any inorganic material added to the soil to change the pH of the soil.
- The amendment chosen depends on whether the soil is acidic or alkaline.

Modifying the pH of acidic soils

- The most common methods of increasing the soil pH is liming.
- ***Liming*** is the process of adding alkaline materials (Ca and Mg rich) in order to increase the soil pH.
- The liming materials commonly used are:-
  a) Magnesium carbonate ($MgCO_3$)
  b) Quick lime (CaO)
  c) Slaked lime ($Ca(OH)_2$)
  d) Wood ash

Modifying the pH of alkaline soils

- A common amendment used to acidify alkaline soil is Sulphur. It is oxidized by micro-organisms to produce sulphate (SO_4^{2-}) and hydrogen ions (H^+).
- The hydrogen ions lower the pH of the soil.
- $FeSO_4$ and $Al_2(SO_4)_3$ used to lower the pH of the soil Reason: contain acidic Cations (Fe^{2+} and Al^{3+})
- Ammonium-based fertilizer and manure are used to lower soil pH. They are oxidized by soil micro-organism producing hydrogen ions (H^+).

Soil Acidity

- Is the tendency of a soil to have pH of less than 7.
- ***Acidic soil*** is the soil which hydrogen ions (H^+) are the determinant ions in the *soil solution* and *soil colloids*.
- The soil colloid is the *most active portion of the soil* and largely determine the properties of the soil.
- ***Potential acidity*** is the acidity of the soil where by H^+ ions are held in colloidal surfaces(particles) and are not free to move. This is often due to presence of Al^{3+} ions on the colloidal exchange surface.
- ***Active acidity*** is the acidity of the soil where by H^+ ions are held in a soil solution.

Causes of soil acidity

- Decaying of organic matter: This process produces carbon dioxide(CO_2) which then react with water in the soil to form carbonic acid.

$$CO_{2(g)} + H_2O_{(l)} \rightarrow H_2CO_{3(aq)}$$

- Presence of some ions like Cl^- and SO_4^{2-}: These are brought by inorganic fertilizers.
- Leaching of basic elements like Na, Mg, K, and Ca: This may be due to heavy rainfall or irrigation.
- Acidic rainfall
- Acidic parent rock.

3.3 PLANT NUTRIENTS IN THE SOIL

- These are the chemical elements which are required by the plants for *proper growth* and *productivity*.
- Some are needed for making *enzymes* and *hormones*.
- One of the characteristic of fertile soil is to give all plant nutrient in proper amount.
- ***Essential plant nutrients*** are the nutrients which are in metabolic functions and the plant can't complete its life cycle without them.

Classification of essential plant nutrients

- The essential nutrients are;

(1)Carbon(C), (2)Hydrogen(H), (3)Oxygen(O), (4)Nitrogen (N), (5)Phosphorus (P), (6)Potassium (K), (7)Magnesium (Mg), (8)Calcium(Ca), (9)Sulphur(S), (10)Zinc(Zn), (11)Iron(Fe), (12)Manganese(Mn), (13)Boron (B), (14)Chlorine (Cl), (15)Copper (Cu) and (16)Molybdenum(Mo).

- There are two major types of plat nutrient which are as follows:-

i) Macro nutrients

ii) Micro nutrients

i) Macro Nutrients

- These are nutrients required in by plant in large quantities for the proper growth of plant.
  - ❖ The macronutrients are **Nitrogen (N),Phosphorus (P),Potassium (K), Magnesium (Mg) , Calcium(Ca) and sulphur(S).**
- They are subdivided into two groups which are

a) Primary macronutrient.

b) Secondary macronutrient.

a) Primary macronutrients

- These are the nutrients required by plants in large quantity.
- They are said to be *most limiting nutrients* in plant growth.
- Primary macronutrients are:-
  - **Nitrogen (N)**
  - **Phosphorus (P)**
  - **Potassium (K)**.

b) Secondary macronutrients

- These are the nutrients that are required in a relatively small quantity if you compare with primary macronutrient.
- Secondary macronutrients include
  - **Magnesium (Mg)**
  - **Calcium(Ca)**
  - **Sulphur(S)**.

ii) Micro Nutrients

- These are the nutrients which are required by plants in *trace amount*.
- However these nutrients are also important to the plant since they are also *essential nutrients*. Their absence in plant, will affect their proper growth.
- The micronutrients are **Zinc(Zn), iron(Fe), Manganese(Mn), Boron (B), Chlorine (Cl), Copper (Cu) and Molybdenum (Mn).**

Functions Of Primary Macronutrients

1) Nitrogen

- Is the *most essential* element among the essential nutrients.
- It occurs naturally in gaseous state(N_2) in the atmosphere.
- Plants absorbs nitrogen in form of nitrate (NO_3^-) or ammonium(NH_4^+).
- Conversion of atmospheric nitrogen into absorbable form is done mostly by bacteria. But also lightening can do it.
- It is less bound to the soil particles, hence easily leached if not used by the plant.

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. 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. 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. Premature leaf fall.
ii. Stunted growth in plants.
iii. It may lead to chlorosis. ***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. This lowers the efficiency of plant to photosynthesize.

Effects of excess nitrogen

i. Reduces sugar content
ii. Delay maturity
iii. Reduces crop yield.
iv. It lowers the quality of the crops.
v. Cause scorching effect to the leaves

2) Potassium

- It the second most essential element after nitrogen.
- It is a component of clay element of clay particles, hence it is most abundant in clay soil compared to others.
- Potassium is absorbed by the plant in form of potassium ions (K^+).
- It is relatively less tightly bound to soil particles.

Function of Potassium

i. Important in carbohydrate formation and translocation of food.
ii. Useful in neutralization of organic acids in plants.
iii. Regulate osmosis in the cell.
iv. Regulate nitrogen and phosphorous uptake.
v. It is a component of chlorophyll molecule.
vi. Improve tissue formation.
vii. Assists in protein synthesis.
viii. Strengthens plant stalk, 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. Reduce carbohydrate production and translocation.
v. Leaf margins become *scorched* (burned) while central part remains green.
vi. Stunted growth.

NB: Excessive supply of potassium is **not toxic**, but it only *inhibit absorption of other nutrients*.

3) Phosphorus

- This exists in organic or inorganic form.
- It is absorbed in form of phosphate(PO_4^{3+}).
- Phosphate is obtained after decomposition of organic matter by microorganism eg. Bacteria.
- It is tightly bound to soil particles and remains in place unless used by the plant or washed into streams.

Functions of phosphorus

i. Helps in root nodule formation in leguminous plants.
ii. Strengthens plant stem, thus prevent logging.
iii. It helps storage and transfer of energy in plants.
iv. It is a constituent of nucleoproteins(required during cell division)
v. Essential in flowering, hence fruit and seed formation
vi. Important in protein, fat and carbohydrate synthesis
vii. Promote resistance to the disease in plants
viii. Increase grain yield in cereals
ix. Hastens (fastens) plant maturity

Effects of phosphorus deficiency

i. Slows growth.
ii. Poor roots and barks development.
iii. Increase production of anthocyanin (purplish colouration)
iv. Lowers development of flowers and seeds.

Effects of excessive phosphorus

i. Stunted growth
ii. Harm beneficial root fungi called mycorrhizae, which help the plant to absorb water and nutrients.
iii. Decreases plant's ability to absorb Zn(deficiency of Zn lead to Bleaching of plant tissues)
iv. Decreases plant's ability to uptake Fe(deficiency of Fe causes yellowing between leaf veins).
v. Increased weed growth.

NB: Phosphorus can stay in the soil in excess amount for ***three*** to ***five years***. Thus, never add phosphorus before running test.

LOSS OF PLANT NUTRIENTS

- Unmanaged soils loses their fertility.
- If nutrients are not supplied in the correct quantity, the yield will be lowered.
- In the soil plant nutrients may be lost in many different ways.

WAYS THROUGH WHICH SOIL LOSES NUTRIENTS

i) Soil erosion-Removal and carrying away of top fertile soil.

ii) Mono-cropping-Is the practice of growing one type of crop repeatedly on the same piece of land. This exhausts the soil nutrients from the soil.

iii) Overgrazing-Is the practice of grazing animals on the same piece of land repeatedly to the point of leaving the land bare.

iv) Overstocking-Is the keeping of too many animals on a piece of land than it can support.

v) ***Deforestation***- Is the cutting down trees without planting others

vi) ***Burning of vegetation***- When burning the vegetation the microorganisms are killed and destroys the organic matter.

vii) ***Leaching***- Is the process through which soluble plant nutrients are washed into the lower layer of soil and beyond the root zone.

viii) ***Poor farming methods***- This destroy or exhaust plant nutrients in the soil.

MANAGING OF SOIL NUTRIENTS

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

i) Prevention of soil erosion

- The following are the ways in which soil erosion can be prevented.

a) Strip cropping

- Is the cultivation in which different crops are sown in alternate strips to prevent soil erosion.

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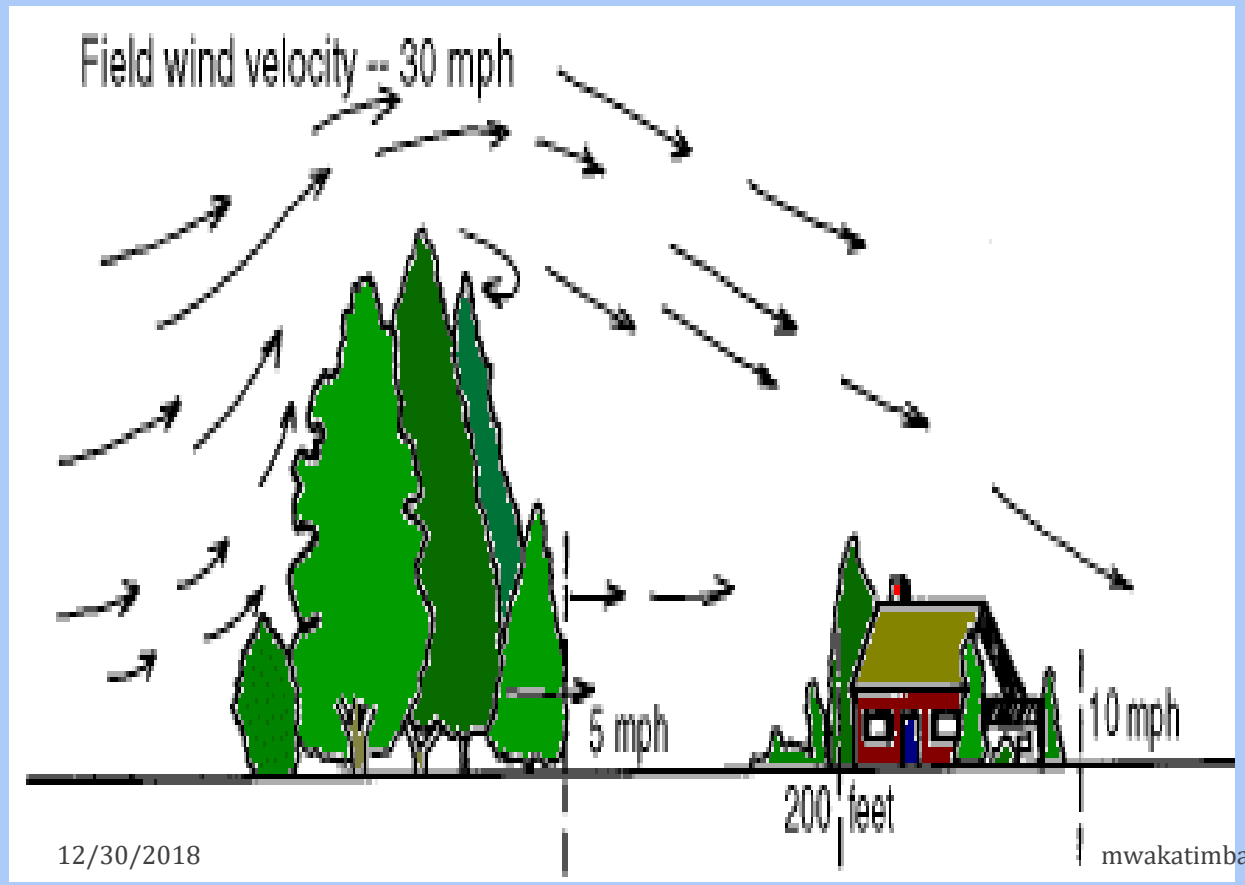
b)Planting windbreakers

- Are trees and tall grasses planted in strips to reduce the speed and intensity of wind.



c) Contour farming

- Is the cultivation across the slope.
- The ***ridges*** and ***depression*** made across the slope slows down the speed of surface run-off and traps any eroded soils.

d)Terracing

- Is the levelled section of cultivated hilly area designed to check the speed of water flowing on the surface.
- The keep water on the land and forbid its down flow.

ii) Crop rotation

- Is the practice of growing different crops on the same field at different times in an orderly sequence.
- The sequence involves leguminous crops.

Importance of Crop rotation

- It improve nitrogen content of the soil
- Balance utilizing of the soil nutrients
- Helps to control pests and diseases

iii) Good harvesting practices

- Is the practice of leaving plant remains to rot(decay) in the soil after harvesting.

Importance of good harvesting practice

- It helps to restore soil fertility by returning the nutrients back into the soil.
- It improves soil texture.
- It helps to reduce soil erosion.

iv) Controlled grazing

- This is done by keeping right number of animals on a piece of land to prevent overgrazing.
- It can be done by rotational grazing, this does not leave the land bare and allows the vegetation to recover.

v) Intercropping (Mixed cropping)

- Is the practice of growing different crops on the same land at same time.
- Cereal crops are usually grown with leguminous plants.
- This helps to prevent soil erosion and fix nitrogen into soil.

Example: Maize and beans

vi) Applying manures

- These are the organic substances derived from animal wastes and plant remains.
- The organic matter binds soil particles together forming stable aggregate which prevents soil erosion.
- It regulates soil pH and improves water and nutrients holding capacity.

vii) Minimum tillage

- Is the practice of keeping operations on the land such as ploughing at minimum level.
- This aims to avoid over cultivation which destroy soil structure and lead to *soil erosion* and *leaching*.
- This may be done by
  - *Fallowing*- Leaving land unseeded after being ploughed.
  - *Uprooting*- Pulling the weeds out of the ground
  - *Slashing of weed*- cutting down the weeds by sweeping movement.

viii) Agroforestry

- Planting trees together with agricultural crops to protect the soil erosion.

ix) Mulching

- Covering the bare soil with a layer of organic matter such as straw, grasses, leaves and rice husks protect the soil erosion
- It helps to conserve soil moisture and suppresses the growth of weeds.
- Mulching keep the soil cool and adds to the organic matter in the soil

Mulching

3.4 MANURE AND FERTILIZERS
3.4.1 Manures

- Manure is decomposed organic substance derived from animal waste and plant residues.
- When the organic substances are completely decomposed the nutrients are set free to be taken by the plant.

Types of manure

(i) Farmyard manure

(ii) Green manure

(iii) Kraal manure

(iv) Poultry manure

(v) Compost manure

(i) Farmyard manure

- Is the manure which is made from the decayed grass and waste of farm animals.

Example: cattle, horse, sheep, pigs and rabbits.

- Nutrient content of farmyard manure varies depending on the animal and food eaten by an animal or/and type of grasses used.
- Manure Stored in optimum air and water to prevent oxidation, which cause heat that lose nitrogen as a gas.
- Too much water cause loss of nutrients through leaching.

(ii) Green manure

- Is the type of manure formed when plant or crop variety grown and turned into the soil to improve fertility.
- Most plants used for green manure are the mixture of *grasses* and *legumes*.
- It maintain and improve the organic matter of soil and encourage microbial activities.
- Improves nitrogen content in the soil since legumes are mostly used.
- Green manure also prevents erosion and leaching

(iii) Poultry manure

- Is the manure which is made from the waste of domestic birds.

Example: chickens and pigeons

- Has high amount of *nitrogen*, *phosphorus* and *potassium* and some other trace elements for crop production.
- It improves physical and chemical properties of soil,
- It also improve microbial activities.

(iv) Kraal manure

- Is a manure which is made from waste products of the animals.

Example: cattle, horse, sheep, pigs, rabbits.

(v) Compost manure

- Made from different types of decayed organic matter such animal waste and plant residue or plant material only/animal wastes only. It has very high nutrient content.

Preparation of compost manure

- Preparation of compost manure involves two main stages, which includes;

1) Site selection
2) Preparation methods

1) Site selection

- The site for preparation of the compost manure is selected by considering the following:

i) ***Drainage***: Site should be drained to prevent water logging, which causes leaching of the nutrients from the manure.

ii) ***Direction of the prevailing wind*** **:**Compost manure preparation should not be located to the place where wind blow from compost manure to the *homestead*. This is done to prevents bad odour to the settlement area.

iii) Accessibility: The site should easily accessible for easy transportation on of the material used.

iv) Site of the farm: Compost manure should located at centre of the farm for easy transportation around the farm.

2) Preparation methods

- Compost manure can prepared by using two methods, includes;

i) Preparation by using pit method

ii) Preparation by using heap (stack) method

i) Preparation by using pit method

- The following procedure is used to prepare compost manure by using pit method

1. Dig the compost pit: It should be about 1m deep and1.5 – 2 m wide and of a suitable length.
2. Fill the pit with material filled in layers of 10 – 15cm, this should be done as follows
   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

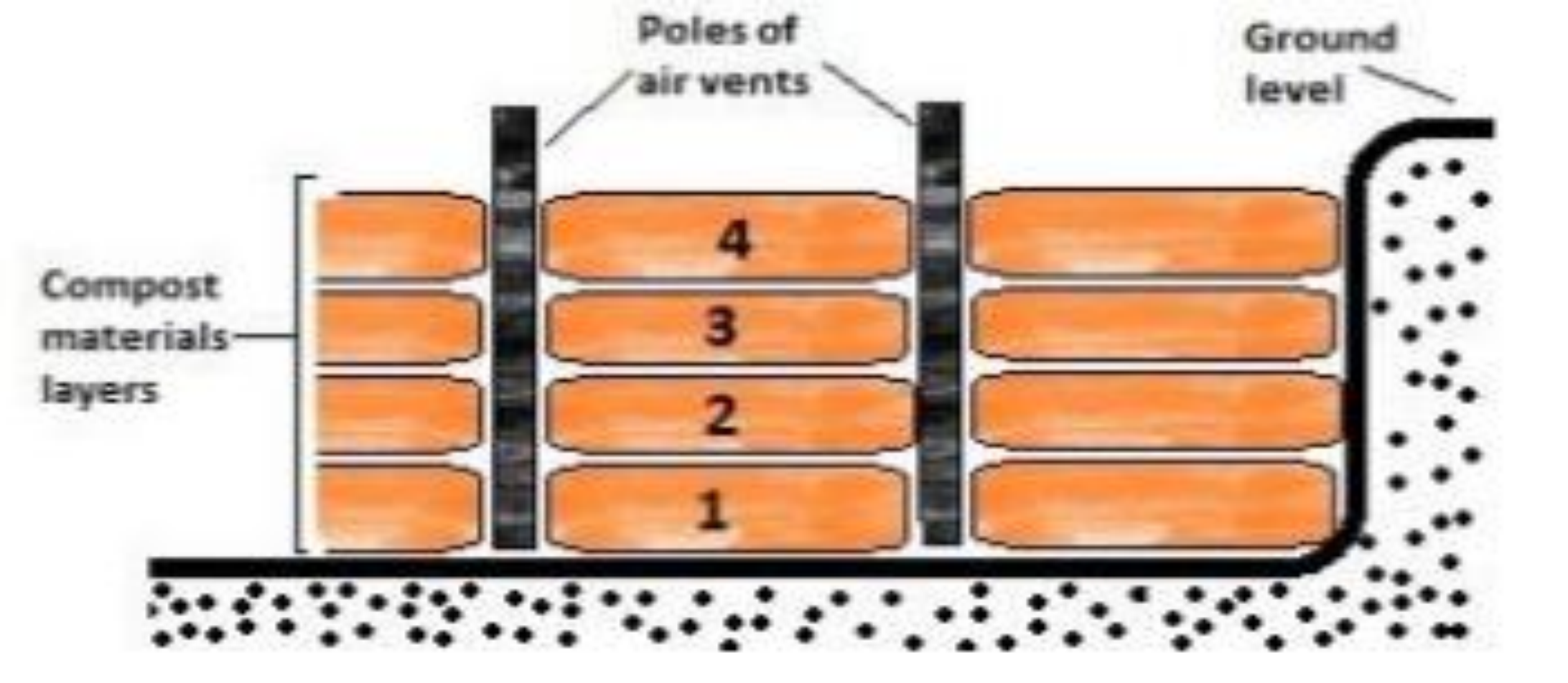
(c) Add some well decomposed manure to provide nutrients to micro organism

(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

NOTE:The vegetative materials used should be young. If old plant residues are used, nitrogenous fertilizers should be added to raise the level of nitrogen.

3. Repeat step (2) until the pit is full.Cover the pit with a layer of top soil



- Then materials should be turned three times while in the pit.
  - The first turning should be done after 15 days, the second one another 15 days and the last one after a month.
  - After each turn the materials should be mixed thoroughly and moistened with water

NOTE: During rainy season , the pit should be covered to prevent entry of water which may cause water logging. This may lead to poor decomposition and leaching.

ii) Preparation using heap method

- The following procedure are used to prepare compost by using heap method

1. Scrape off surface vegetation and top soil from the selected site. Level the ground
2. Fix pegs at a distance of 2m apart to form the four corners of the heap. The heap should be about 1.5m high.
3. Fill the heap with the materials in the following order:

(a) Start the heap with a 20 cm layer of fibrous material such as leaves, hay, straw or any other refuse materials.

(b)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.

(c)Repeat the pattern of 20cm of fibrous material and 10 cm nitrogenous material until heap height is achieved.

Wet the heap after each layer.

4. Fix wood planks on the side to hold the materials in position.

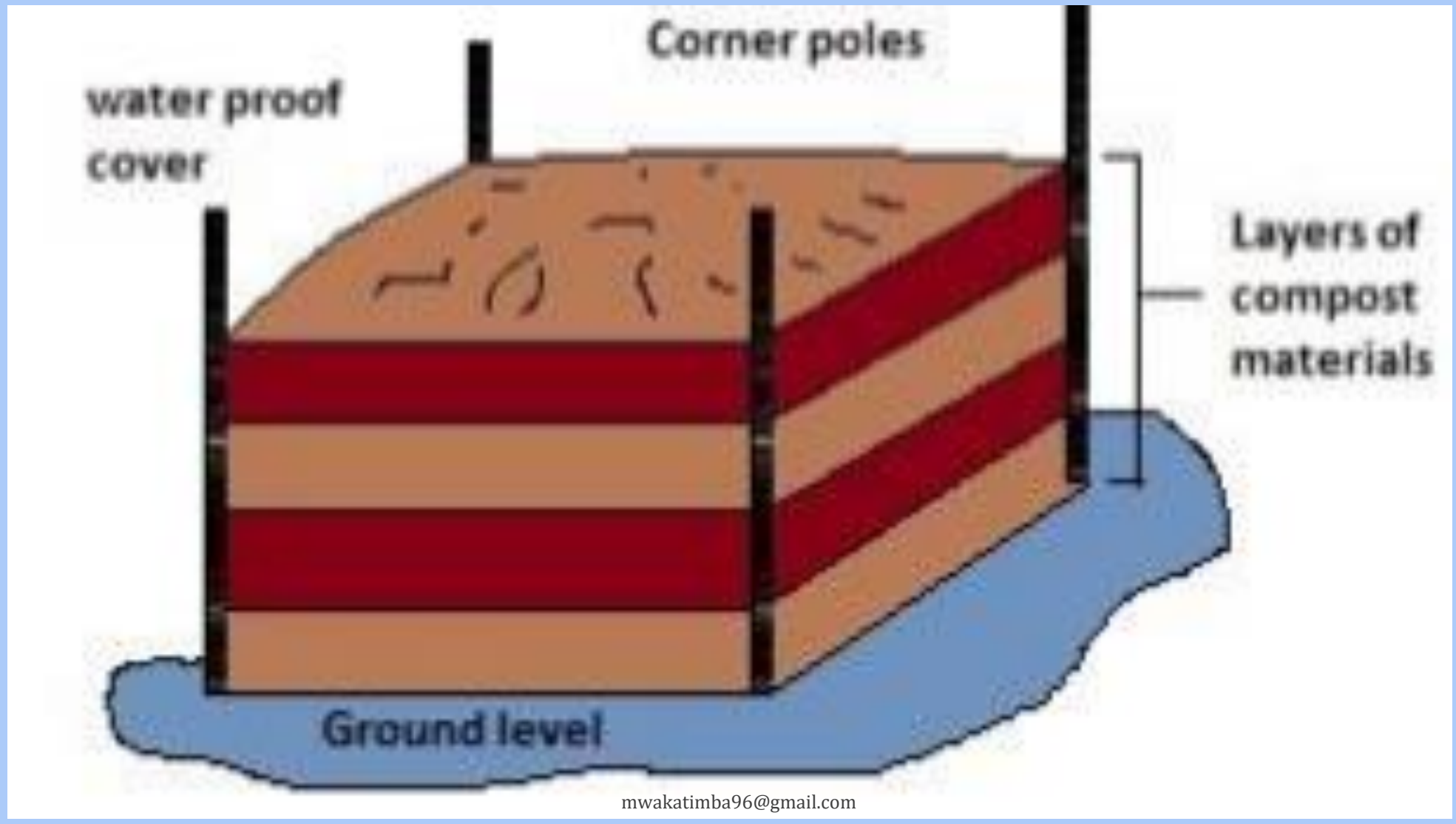
5. Cover the heap with soil or hay(mown grass) to retain heat.

Turn the heap at intervals of 6 and 12 weeks, until complete decomposition of the compost has occurred.

NB:

- The turning helps to improve air circulation for proper decomposition.
- Manure is always ready for use after about 6 months.
- Heap method is better method to be used during rain season than pit method.

Heap method



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Advantages 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 leached out.
vi. Do not change soil pH greatly.
vii. Releases a wide range of nutrients.
viii. It stays in the soil for a very long time.
ix. It provide food and shelter for microorganisms.

Disadvantage of manure

i. It has low nutrient content per unit volume. Thus they are used in large quantity to supply the required amount of nutrients.
ii. Manure may spread ***pests***, ***diseases*** or ***weed seeds*** when infested materials are used.
iii. It is not suitable for immediate recovery of the nutrient. This is because manure release nutrients slowly.
iv. Manure can easily lose nutrients if poorly stored
v. Manure have high moisture content which makes it difficult to store and transport
vi. Increase soil acidity

3.4.2 Fertilizers

- Fertilizer is an inorganic substance which is added to soil to supply *one* or *more plant nutrients*.
- Fertilizers are added to bring about a sudden recovery of the missing plant nutrient(s).
- They contains different macro and micronutrients in a proportion which is known.

Classification of Fertilizers

- Fertilizers are classified on basis of

1. Nutrients content
2. Time of application
3. Effects on soil pH

1. Basing on the Nutrients content

- In terms of nutrient contents, fertilizer can be subdivided into three categories
  a) Strait fertilizers
  b) Compound fertilizers
  c) Mixed fertilizers

a) Strait fertilizers

- Straight fertilizers contains only one of the primary macronutrients
- There three classes of Straight fertilizers, includes

i) Nitrogenous fertilizers

ii) Phosphatic fertilizers

iii) Potassic fertilizers

i) Nitrogenous fertilizer

- It is a fertilizer which contains nitrogen as the only primary macronutrients.

Example

- Calcium ammonium nitrate(CAN) [$NH_4NO_3 + CaCO_3$]
- Ammonium sulphate nitrate (ASN) **[**$NH_4NO_3 + (NH_4)_2SO_4$**]**
- Sulphate of Ammonia (SA) [$(NH_4)_2SO_4$]
- 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. Cause Scorching effect to the plant parts when it is in excess.
vi. Highly volatile under hot weather condition.
vii. They hygroscopic (absorb moisture from the atmosphere)
viii. Most of them have corrosive effect

ii) Potassic fertilizers

- It is a fertilizer which contains potassium as the only primary macronutrients.

Example:

- Potassium chloride (chloride of potash) (KCl)
- 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

iii) Phosphatic fertilizers

It is a fertilizer which contains *Phosphorus* as the 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. Slightly 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

b) Compound Fertilizers

- A compound fertilizer contains two or more of primary macronutrients.
- In compound fertilizer the primary micronutrients are chemically combined.

Example:

- Diammonium phosphate (DAP) $[(NH_4)_2PO_4]$
- Nitrophos
- Monoammonium phosphate (MAP)

NB: The fertilizer which contains all the three primary macronutrients is called **Complete fertilizer**.

c) Mixed fertilizers

- Is a physical mixture of straight fertilizers.
- Mixed fertilizers are made by thoroughly mixing of the ingredients mechanically or manually.
- They may contain two or three primary macronutrients.

2. Basing on the Time of application

- Depending on the time of application of fertilizer, fertilizer can be subdivided into two categories

a) Planting fertilizer

b) Top-dressing fertilizers

a) Planting fertilizer

- These are the fertilizers which are applied during planting.
- Normally *phosphatic* or *compound fertilizer* containing phosphorus may be used.

Example

- Single superphosphate (SSP) [Ca(H2PO4)CaSO4]
- Double superphosphate (DSP)
- Triple superphosphate (TSP)
- Diammonium phosphate (DAP) [$(NH_4)_2PO_4$]
- Monoammonium phosphate (MAP)

b) Top-dressing fertilizers

- Are the fertilizers which are applied when the crop is actively growing.
- These are mainly *nitrogenous* or *potassic fertilizers*.

Example:

- Calcium ammonium nitrate(CAN) [$NH_4NO_3 + CaCO_3$]
- Urea - [$CO(NH_2)_2$]
- Potassium chloride (chloride of potash) (KCl)
- Potassium sulphate (K_2SO_4)

3. Basing on the Effects on soil pH

- Fertilizer can be *acidic* or *neutral*
  - Calcium ammonium nitrate (CAN) is a ***neutral*** to ***slightly basic***
  - Almost all others fertilizers are ***acidic***

Fertilizer Analysis (Grade)

- Fertilizer analysis Is the percentage amount of each primary macronutrient in the fertilizer.
- It is usually indicated on the fertilizer bag.

Example:100Kg of **NPK** fertilizer of grade 20:20:20 contains 20 Kg of **N**, 20 Kg of $\mathbf{P_2O_5}$ and 20 Kg of $\mathbf{K_2O}$

$$\mathbf{P}=\frac{N}{TW}\mathbf{x100\%}$$

Where;

- **P** is a percentage of nutrient
- **N** is a nutrient content
- **TW** is a total weight of a fertilizer

Fertilizer ratio

- Is the simple ratio of the nutrients relative to each other in the fertilizer.
- Fertilizer ratio is calculated by dividing by the smallest number throughout in the fertilizer grade.

Example: A fertilizer of grade 20:20:20 has a ration of 1:1:1 of N: P_2O_5:K_2O.

Fertilizer ratio: $\frac{20}{20} : \frac{20}{20} : \frac{20}{20} = 1:1:1$

Determining the amount of fertilizer to apply

- The amount of fertilizer to apply per hectare depends on two major things

i) Amount of nutrient required in the soil.

ii) The fertilizer grade available.

Example:

A 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)

(b) Data

- Mass of nitrogen required, **N** = 120 kg
- Percentage of nitrogen, **P** = 21%
- Total weight of fertilizer, **TW** = ?

Solution

- From: : $\mathbf{P=\frac{N}{TW}x100\%}$
- Make **TW** the subject $\mathbf{TW=\frac{Nx100\%}{P}}$

$$\mathbf{TW=\frac{120kgx100\%}{21\%}}$$

$$\mathbf{TW=571.43kg}$$

➢Total mass of single superphosphate =**571.43 Kg**

(b) Data

- Mass of nitrogen required, N = 60 kg
- Percentage of nitrogen, **P** = 18%
- Total weight of fertilizer, **TW** = ?

Solution

- From: : $\mathbf{P=\frac{N}{TW}x100\%}$
- Make TW the subject $\mathbf{TW=\frac{Nx100\%}{P}}$

$$\mathbf{TW=\frac{60kgx100\%}{18\%}}$$

$$\mathbf{TW=333.33kg}$$

➢ Total mass of single superphosphate = **333.3 Kg**

(b) Data

- Mass of nitrogen required, N = 80 kg
- Percentage of nitrogen, **P** = 60%
- Total weight of fertilizer, **TW** = ?

Solution

- From: : $\mathbf{P=\frac{N}{TW}x100\%}$
- Make TW the subject $\mathbf{TW=\frac{Nx100\%}{P}}$

$$\mathbf{TW=\frac{80kgx100\%}{60\%}}$$

$$\mathbf{TW=133.33kg}$$

➢ Total mass of single superphosphate = **133.3 Kg**

Methods of fertilizer application

- The following are some of the methods used in application of fertilizers

i. Broadcasting methods.
ii. Placement methods
iii. Side dressing
iv. Foliar spraying
v. Drip application
vi. Banding

i) Broadcasting method

- Involves the random scattering of fertilizers on the farm.
- It can be done *manually* or by use of *fertilizer spread*.
- It used when soil is moist.
- This method is usually used when applying *nitrogenous* and *potassic fertilizers*.

ii) Placement method

- Fertilizer is put in the planting holes or drills.
- Then fertilizer mixed thoroughly with the soil before the placement of seeds.
- The method used when applying *phosphatic fertilizers*

iii) Side dressing method

- This is placement of Nitrogenous fertilizers at the side of the crop or around the growing crop.
- It mainly used on perennial crops like coffee.

iv) Foliar spraying method

- Involves the putting of fertilizers solution on the leaves of crop
- It is suitable during prolonged dry season
- It applied to avoid formation of complex compound which reduce the availability of plant nutrients.

v) Drip application

- Fertilizer is dissolved in water and applied to individual plants through pipes or bottles
- It is uneconomical method.
- It is commonly used in horticultural crop fields

vi) Banding

- Fertilizer placed either below or on the side of the seed or plant.
- Usually the fertilizer is placed at a distance of (6-9) cm from the seed or plant.

Advantages 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

3.5) SOIL FERTILITY AND PRODUCTIVITY

- **Soil fertility** Is the ability of the soil to provide nutrients in proper quantity and in a balance proportion for proper growth of plants.
- **Soil productivity** is the capacity of the soil in its normal environment to support plant growth.
- Soil fertility affects productivity, however fertile soil is not necessary productive.
- Other factors like pests, floods, weeds and others which may interfere productivity even if the soil is fertile.

Qn: Give reasons why a fertile soil is not necessary productive?

Ans: Fertile soil may not be necessarily be productive in case of any of the following factors apply:

i. Soil erosion can remove soil, nutrients or plants.
ii. Unfavorable weather condition for crop production.
iii. Invasion of pests or birds.
iv. Domination of the weeds in the farm.
v. Suitability of the soil for the type of crop grown.
vi. If it is located at the steep slope or hilly area.
vii. Viability of the seed sown.

Factors affect Soil productivity

i) Soil depth: Soil depth gives plant roots greater volume to obtain plant nutrients and provide strong anchorage.

***ii) Drainage*:** Good drainage is important for proper aeration of the soil, hence root healthy development.

***iii) Water holding capacity*:** High water holding capacity keeps enough water for plant use.

***iv) Soil pH*:** Correct (optimum) soil pH is important since different crops grow well under different soil pH.

***v) Pests and diseases*:** Productive and fertile soils are free from pests and diseases.

Causes of loss of soil fertility

i) Leaching: Nutrient soluble such as nitrogen carried to lower levels far from soil makes soil infertile.

ii) Soil capping: When soil covered with materials which do not allow water to pass into soil, thus expose the soil to erosion.

iii) Soil erosion: Soil erosion carries away fertile soil which makes soil infertile.

iv) Mono-cropping: This cause the plant to use all the nutrients it requires and leave unused nutrients which makes the soil infertile.

v) Cropping without nutrient replacement: If the nutrients are not replaced the soil become deficiency in the particular nutrients.

vi) Accumulation of salts: Salt cause deficiency of water in plants since salt have a tendency to absorb water from the plant by osmosis.

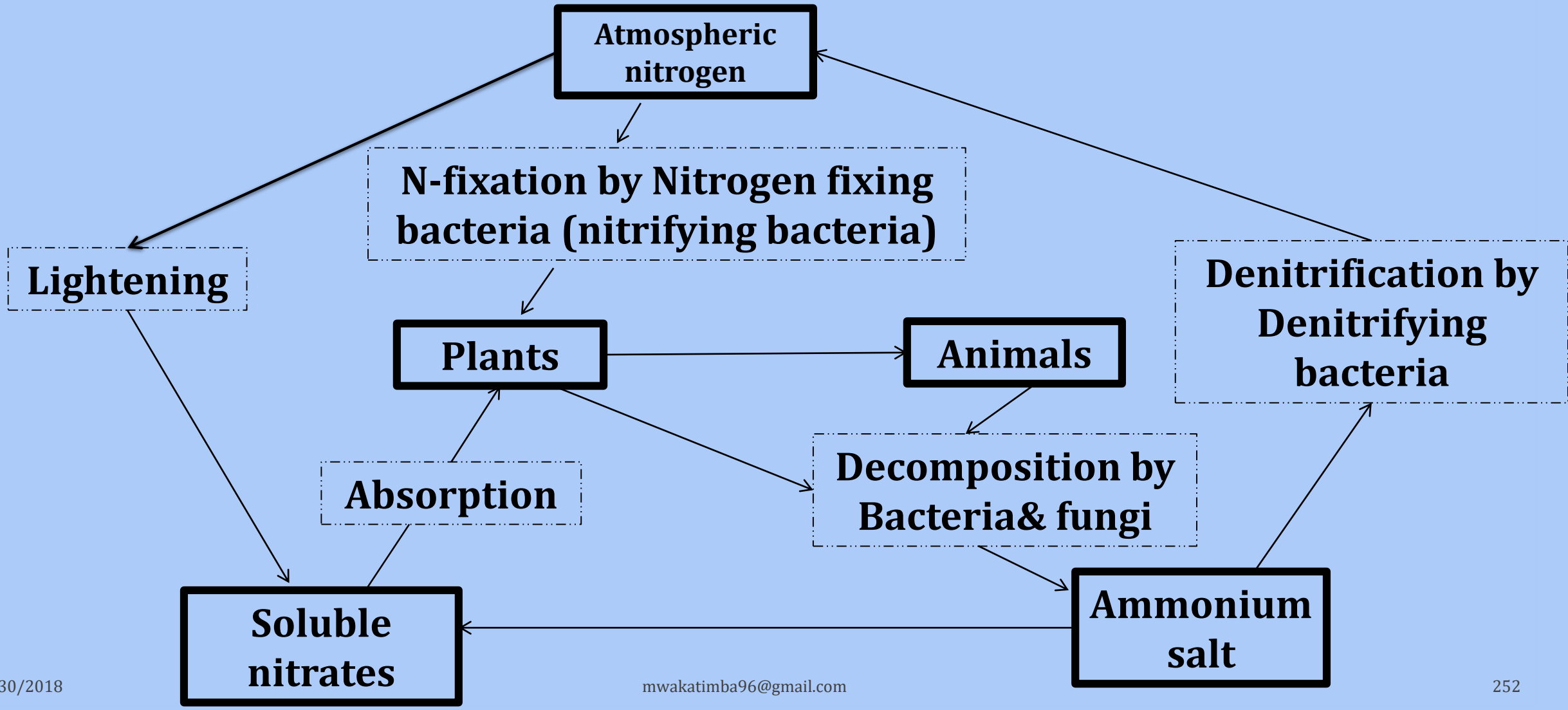
vii) Change in soil pH: Change in pH affect micro-organism activities and availability of some nutrients so soil become infertility.

viii) Burning of vegetation: This destroys organic matter and microbial activities. Also it exposes the soil to agents of soil erosion.

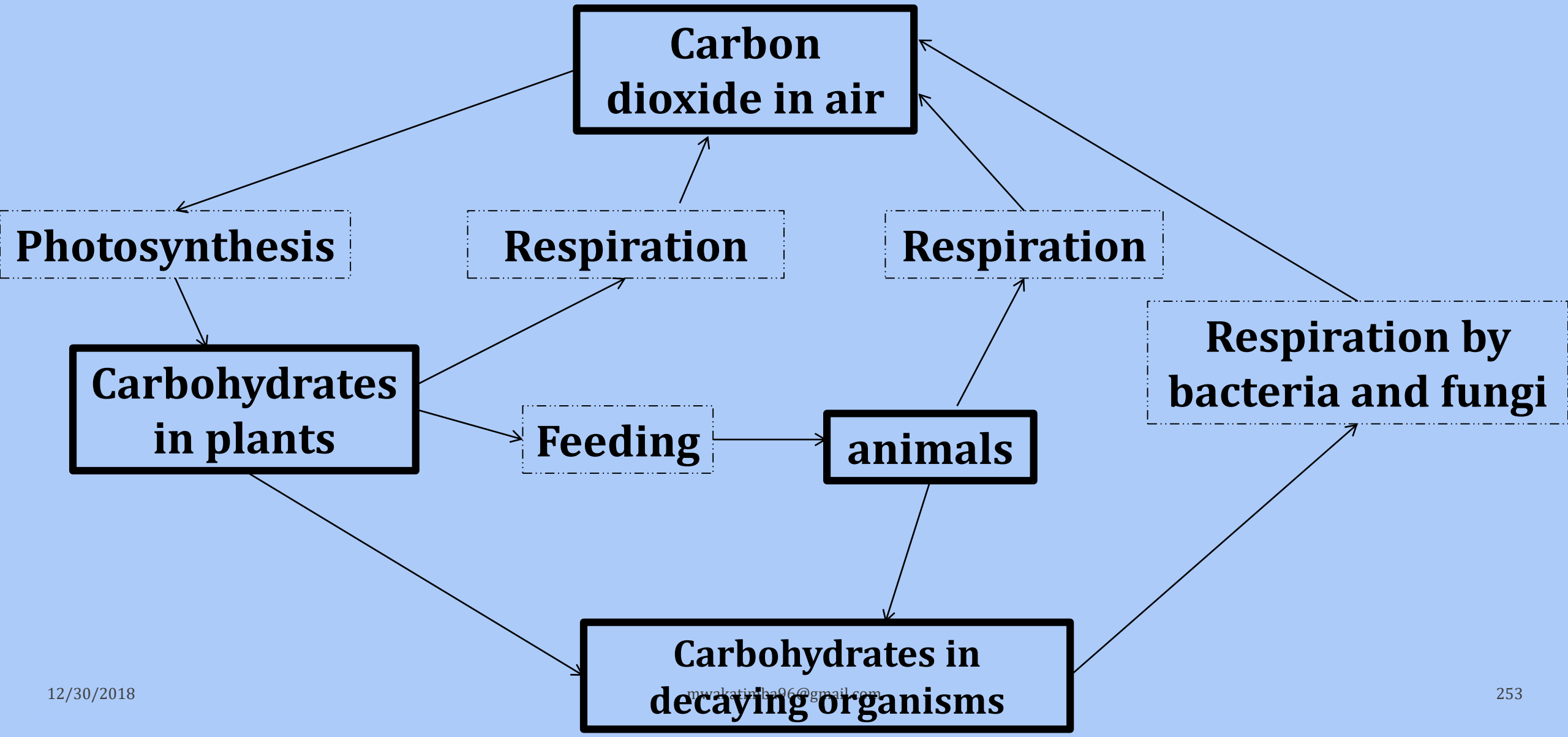
NUTRIENT CYCLE

- Always nutrients circulates between living and non-living component of the ecosystem.
- Microorganisms decomposes the organic matter and set the nutrients free ready to be taken by the plant again.
- Nutrient cycle ensures the availability of nutrients in the soil.
- In this section we are going to discuss two important nutrient cycles, these are:-
    a) Nitrogen cycle
    b) Carbon cycle

A) Nitrogen Cycle



B) Carbon Cycle



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