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Subject: **Chemistry**

Class: **SS 1**

Week 4

CARBON

Topic overview

Carbon – its compounds – sources of carbo – structure of carbon – allotropes of carbon – diamond and graphite – properties and uses based on structure.

Introduction

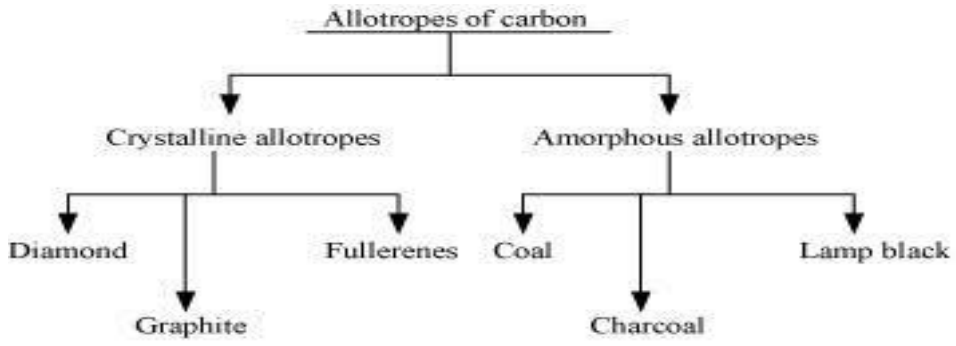
Carbon is a non-metal and the first member of the group IV elements in the periodic table. It is represented as ${}^{12}_{6}C$ where 6 is the atomic number and 12 is the mass number. The electronic configuration of carbon is $1S^2\ 2S^2\ 2P^2$ (2, 4).

Carbon atom uses the 2S and 2P electrons for bonding, hence it has a valency of 4. Carbon is unique (being the only one of its kind) among the elements because its atoms have the ability to link together by covalent single, double and triple bonds forming straight and branched chains as well as ring structure. This is called **catenation**.

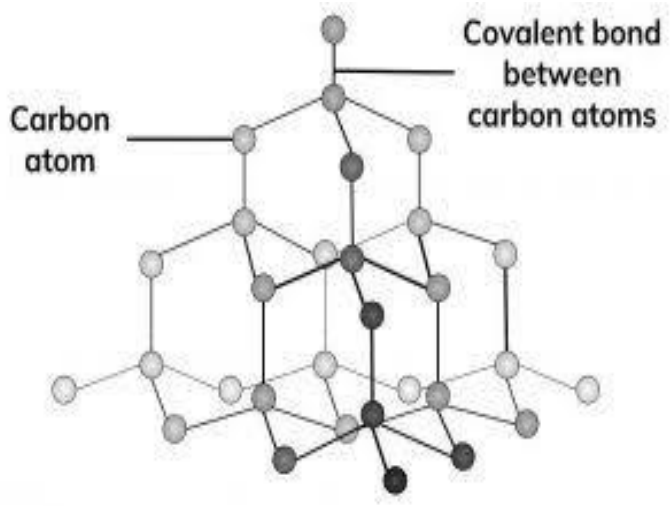
ALLOTROPES OF CARBON

Allotropy could be defined as the existence of an element in two or more forms in the same physical state. The different forms of the element are called allotropes. Allotropes have different bonding patterns or arrangements leading to different physical properties. There are currently three crystalline allotropes of carbon namely

I. Diamond
II. Graphite
III. Fullerenes



DIAMOND



Diamond has a giant three-dimensional (3-D) octahedral structure. Each carbon atom is bonded tetrahedrally by covalent bond to four octahedral atoms.

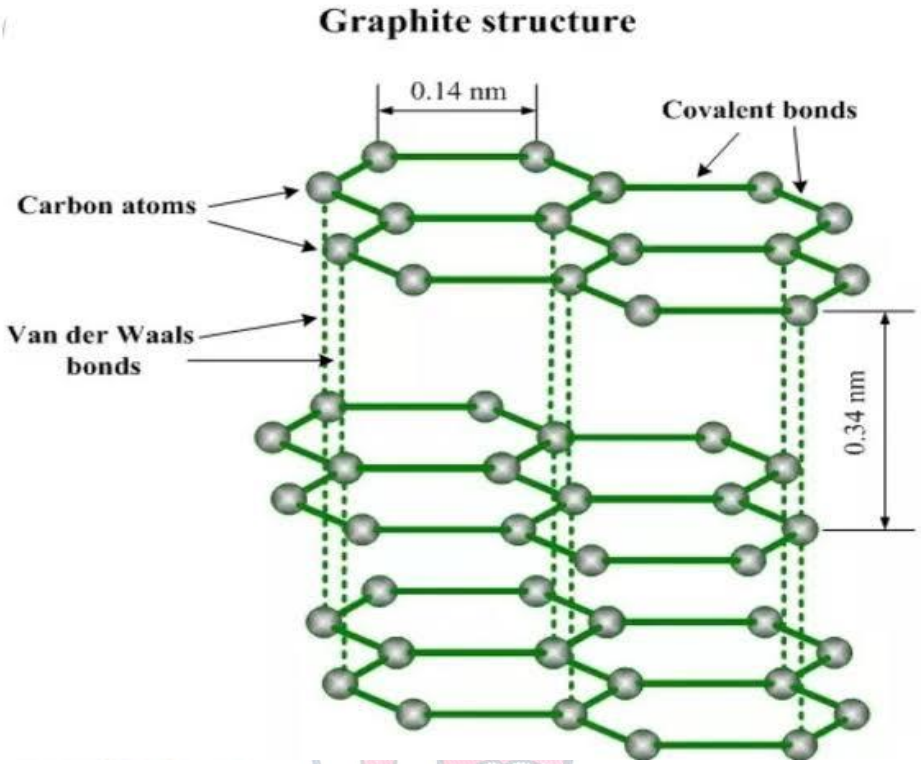
Properties of Diamond

i. Diamond is the hardest allotrope of carbon
ii. It is the purest type of carbon
iii. Its bond angle is given by 109 ^{0}A
iv. It is colourless
v. It has an octahedral shape
vi. It is transparent in nature.

Uses of Diamond

a. Due to its hardness and toughness, it is used in producing hand tools used for cutting
b. It serves as jewellery because of its high refractive index and dispersion power

GRAPHITE



In graphite, a carbon atom is covalently bonded to three other carbon atoms in a planar hexagonal arrangement.

Properties of Graphite

i. It is opaque in nature
ii. It conducts electricity due to the fact that it has mobile electrons
iii. It is soft and its layer can easily slide over each other
iv. It is easily packed together with air spaces
v. It has a high melting point but low density

Uses of Graphite

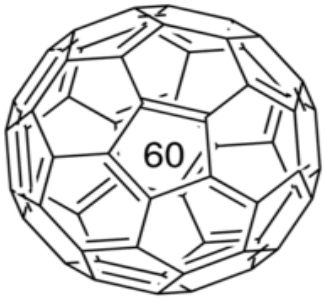
a. It is used as electrodes because of mobile electrons that are unbounded which conduct electricity
b. It serves as lubricants
c. It is used in making lead pencil when mixed with clay
d. It is used as pigment in paint due to its black colour

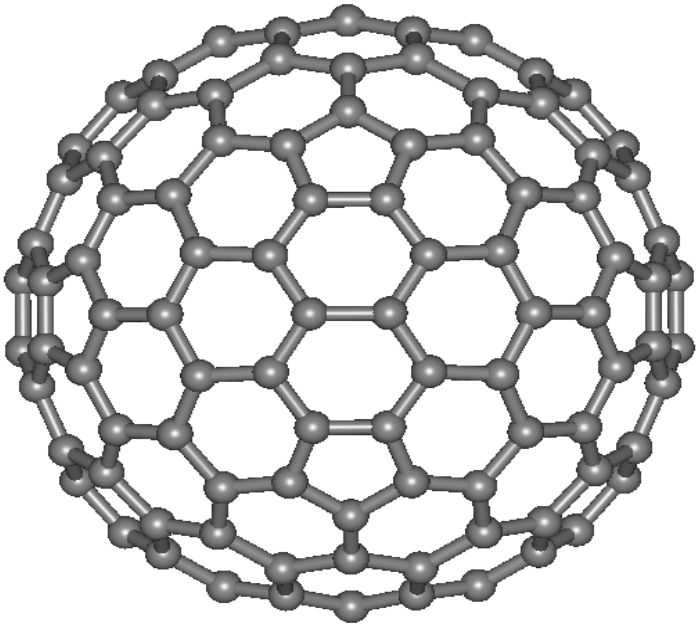
DIFFERENCES BETWEEN DIAMOND AND GRAPHITE

	Criteria	DIAMOND	GRAPHITE
1.	**Surface**	It is octahedral in shape	It is hexagonal in shape
2.	**Colour**	Transparent	Opaque
3.	**Purity**	Purest type of carbon	Impure type
4.	**Bond angle**	Its bond angle is 109 ^{0}A	Its bond angle is 120 ^{0}A
5.	**Hardness**	It is hardest form of carbon	It is soft
6.	**Conduction of electricity**	It does not conduct electricity due to absence of electrons	It conducts electricity due to the existence of mobile electrons
7.	**Structure**	It is closely packed together	It is loosely packed with air space
8.	**Uses**	a. It is used in cutting glass due to its hardness b. It is used in making jewelleries due to its good refractive index and dispersion power.	a. Graphite is used as electrodes because of its mobile electrons b. It serves as lubricant c. Use din making pencil when mixed with clay.

FULLERENES

Fullerenes are the most recently discovered for of carbon. A typical and most stable fullerenes is C_{60}. Fullerenes have a globe-shaped, cage-like arrangement of carbon atoms because they resemble the structure of a **geodesic dome.** Fullerenes were named in honour of the American engineer R. Buckminster FULLER., who is famous for his geodesic dome designs. Fullerenes are also called **carbon balls** or Bucky balls because they resemble tiny soccer balls.





Properties of Fullerenes

i. It is discovered that they are oxidizing agents and are electron acceptors.
ii. They are super conductors of heat and electric current

Uses of Fullerenes

a. It is used as long-distance transmission cables
b. It is used in the manufacture of computer chips

Week 5

AMORPHOUS CARBON

Topic Overview

Characteristics of amorphous carbon – charcoal (soot) – lamp black – sugar charcoal;
- combustion of carbon allotropes.

Definition

Amorphous carbon is a non-crystalline form of carbon. It is made up of small crystals of graphite and exists in many forms such as;

I. Charcoal (soot)
II. Lamp black
III. Sugar charcoal

CHARCOAL (soot)

This is a porous amorphous carbon with a graphite-like structure. It is made by heating wood with a limited supply of air. Charcoal is used for cooking and ironing clothes. It is used for absorbing gases and poisonous substances in the body.

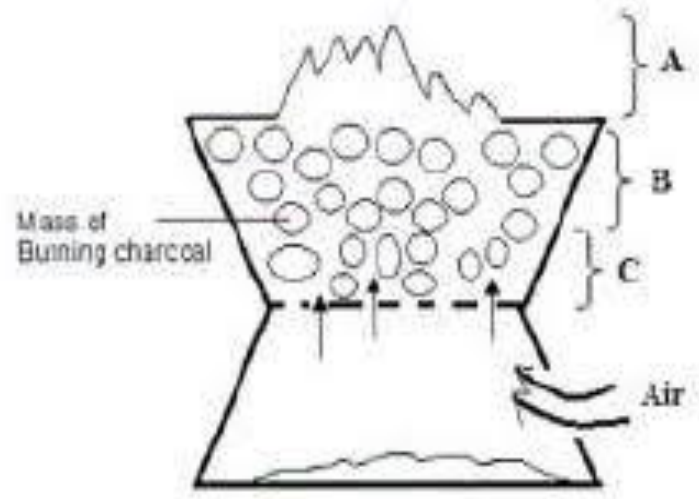
LAMP BLACK

This is formed by burning oils in a limited supply of air. It is used for making printers ink and shoe polish.

SUGAR CHARCOAL

This is a very pure form of amorphous carbon. It is made by removing the element of water from sugar.

COMBUSTION OF CARBON ALLOTROPES



At level A

In this case, there is a plentiful; supply of air and the charcoal burns to produce Carbon IV Oxide only as given by the equation below.

$$C + O_2 \longrightarrow CO_2$$

At level B

At this level which is the middle of the charcoal heap, the supply of air is very unlimited. As a result of this, the ascending CO_2 from A level becomes reduced to CO by the carbon

$$CO_2 + C \longrightarrow 2CO$$

At level C

At this level, air is being supplied at a plentiful amount so that the Carbon II Oxide formed at the B level is then re-oxidized to give Carbon IV Oxide. In this case, it was discovered that some carbon II oxide escaped oxidation and contaminates the atmosphere. And that is dangerous if the area around the fire is not well ventilated because Carbon II Oxide is very poisonous.

$$2CO + O_2 \longrightarrow 2CO_2$$

PROPERTIES OF CARBON

a) Combustion

Carbon undergoes combustion readily

$C + O_2 \longrightarrow CO_2$ (in plenty supply of air)

$2C + O_2 \longrightarrow 2CO$ (in a limited supply of air)

b) As a reducing agent

It reduces certain metallic oxides to their metals.

$PbO + C_{(s)} \longrightarrow Pb + CO$

c) Combination with other elements

Carbon combine with other elements at high temperature to form carbides

$C + 2S \longrightarrow CS_2$

d) Reaction with acid

Carbon is not attacked by dilute acid but hot concentrated oxidizing acids attack carbon

$C + 2H_2SO_4 \longrightarrow CO_2 + 2SO_2 + 2H_2O$

$C + 4HNO_3 \longrightarrow CO_2 + 4NO_2 + 2H_2O$

Carbon is also acting as a reducing agent in each of the reactions as illustrated above.

Week 6

COAL

Topic overview

Coal – industrial distillation of coal – products and uses – coke gasification – uses of the constituents.

Coal is referred to as an impure form of carbon consisting mainly of carbon, hydrogen, oxygen, nitrogen, Sulphur and some phosphorus.

Coal is formed by bacterial decomposition of of vegetation over a long period of time of about 200 million years in the presence of varying high temperature and pesusure caused by deposition of layers of sand and mud.

TYPES OF COAL

There are about three (3) main types of coal which are;

1. Anthracites 90% of carbon
2. Bituminous 80 – 88% of carbon
3. Lignite or brown coal 60 – 70% of carbon

ANTHRACITE

This is the type of coal which is the hardest among the other types. It contains 85 – 90% of carbon.

BITUMINOUS COAL

It is the type of coal which is soft among others and has 80% of carbon content.

LIGNITE COAL

Lignite coal is brown in colour and contains 67% of carbon.

DESTRCTIVE DISTILLATION OF COAL

This is referred to as a chemical process by which coal is heated to a high temperature of about 200 ^{0}C in the absence of air. The process is also called **pyrolysis.**

In the process, it was found that the important products obtained from this process are;

a. Coal gas
b. Ammoniacal liquor
c. Coal tar
d. Coke

COAL GAS

Coal gas is a mixture of different gases such as hydrogen (H_2), methane (CH_3) and Carbon II Oxide (CO) gas. It is used as gas.

AMMONIACAL LIQUOR

This is one of the fractions of the destructive distillation of coal obtained when ammonia and benzene are redistilled. Ammonia is used in the manufacture of fertilizers such as $(NH_4)\ SO_4$. Benzene is a source of other chemicals and drugs.

COAL TAR

Many important components such as benzene, toluene, phenol, naphthalene, and pitch. The compounds are used for making drugs, disinfectants, and dye. Pitch is commonly used for road construction.

COKE

It is the non-volatile residue of the destructive distillation of coal. It is about 90% carbon.

I. It is used as a reducing agent, in the industrial extraction of iron.
II. It is also applied in making steel when alloyed with iron metal
III. Gaseous fuels such as water gas and produce gas are produced using coke.

GASIFICATION OF COKE

This involves blowing air or steam through a bed of coke heated to above half its normal combustion temperature of about 1000 ^{0}C to decompose then to produce a combustible mixture of gases. When air is used, **producer gas** is formed while **water gas** is formed when steam is used.

PRODUCER GAS

It is producing by passing a controlled amount of air through a thick layer of red-hot coke in a furnace.

$$C + O_2 + 4N_2 \longrightarrow 2CO + 4N_2$$

producer gas

Uses of produce gas

i. It is used to heat retorts and glass furnace.
ii. It is a source of nitrogen in the manufacture of ammonia in the Haber Process.

WATER GAS

The gas is produced when jet of steam is passed through a thick layer of red-hot coke. The steam reacts with coke to give a 1: 1 mixture of CO (carbon II oxide) and H_2 (Hydrogen) known as water gas.

$$C + H_2O + \text{heat} \longrightarrow \underset{\text{water gas}}{CO + H_2}$$

the above reaction is endothermic

NB: it is worthy to note that produce gas and water gas are usually generated alternatively in the same furnace.

Uses of water gas

I. Water gas is used as fuel and for the manufacture of hydrogen.

Water gas is a better fuel than the producer gas because both components of water gas CO and H_2 are combustible whereas only one-third of the producer gas, CO is combustible.

DIFFERENCES BETWEEN PRODUCER GAS AND WATER GAS

	PRODUCER GAS	WATER GAS
1.	Produced with air	Produced with steam or water
2.	A source of nitrogen	A source of hydrogen
3.	Generates less heat	Generates more heat
4.	Only one component burns, i.e. CO	Both components burn, i.e. CO and H_2
5.	It consists of CO and N_2	Consists CO and H_2
6.	It is for both industrial and domestic uses.	It is only used in industries due to safety considerations
7.	It contains less CO	It contains more CO
8.	It is less dangerous	It is more dangerous

ASSIGNMENT

Answer the following questions

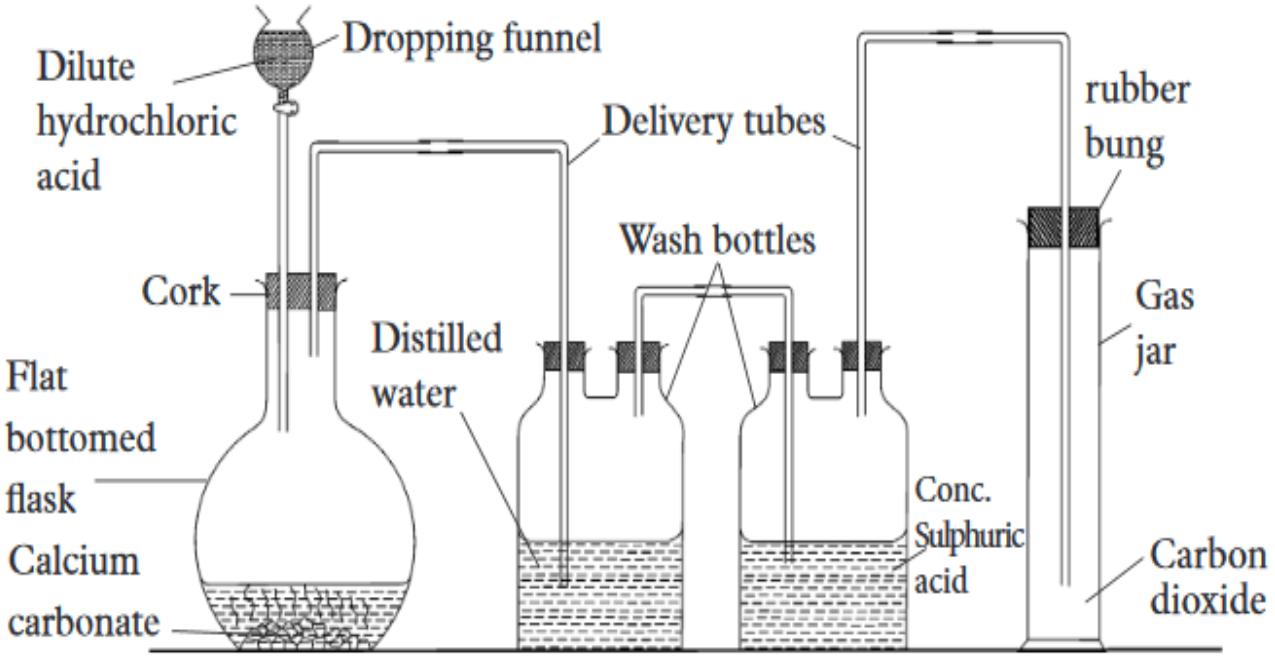
(a) Describe how coal is formed
(b) Mention three (3) types of coal and explain any two
(c) Write eight (8) differences between producer gas and water gas using equation where necessary.
(d) Explain how producer gas is formed. (20 marks)

Week 7

CARBON IV OXIDE

It had been discovered that air contains about 0.03% by volume of Carbon IV Oxide.

LABORATORY PREPARATION OF CARBON IV OXIDE



In preparing carbon iv oxide in the laboratory, we make use of dilute hydrochloric acid and calcium trioxocarbonate iv, conical flask and gas jar. The above set-up was shown in fig xy above.

To prepare CO_2 in the laboratory, first of all collect some quantities of calcium trioxocarbonate IV and placed in a conical flask. Then with the aid of thistle funnel inserted into the flask that already contains Calcium trioxocarbonate IV, introduce the dil HCl. Immediately, there will be effervescence and a gas are given off which is colourless and odorless and is collected over water.

$$CaCO_3 + HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

Pure and dry Carbon IV Oxide is obtained by passing the gas through a solution of Potassium Hydrogen Trioxocarbonate IV ($KHCO_3$) to remove the acid impurity. It is then passed through conc. H_2SO_4 (tetraoxosulphate IV acid) or fused calcium chloride to dry the gas. It is then collected by downward delivery due to the fact that it is denser than air.

PHYSICAL PROPERTIES OF CO_2 (carbon iv oxide)

1. Pure carbon iv oxide is colourless and odourless.
2. It doesn't support combustion. This can be demonstrated by placing a burning candle or (burning splint) in a gas jar of CO_2, it is extinguished
3. It is heavier than air. When an inverted gas jar of CO_2 is placed in contact with another gas jar containing a burning candle, the candle will soon be extinguished. This is because CO_2 being denser than air will displace the air initially in the gas jar then extinguishes the candle.
4. Carbon IV Oxide is easily liquefied at low temperature with pressure that is higher than 5 atmospheres.

CHEMICAL PROPERTIES OF CO_2

I. Carbon IV Oxide dissolves in water to form trioxocarbonate IV acid which is a weak acid.

$$H_2O + CO_2 \longrightarrow H_2CO_3$$

The acid decomposes to water and CO_2 on heating

$$H_2CO_3 \longrightarrow H_2O + CO_2$$

II. Reaction with burning magnesium. The gas neither burns nor support combustion but when burning magnesium is put in a gas of the gas, the intense heat produced by the burning metal decomposes the gas to black carbon and oxygen. The magnesium continues to burn and the oxygen then combines with the burning magnesium.

$$2Mg_{(s)} + CO_{2(g)} \longrightarrow 2MgO + C_{(s)}$$

III. Reaction with alkalis. The gas is an acidic gas so, it readily reacts with solution of alkalis like NaOH, KOH, and $Ca(OH)_2$

$$2NaOH + CO_2 \longrightarrow Na_2CO_3$$

On passing excess CO_2 into the alkaline solution of sodium hydroxide, a white precipitate of insoluble sodium hydroxide trioxocarbonate IV is formed.

$$Na_2CO_3 + H_2O + CO_2 \longrightarrow 2NaHCO_3$$

IV. Reactions with lime water, $Ca(OH)_2$. When CO_2 is bubbled into lime water, it turns milky

$$CO_2 + Ca(OH)_2 \longrightarrow CaCO_3 + H_2O$$

On bubbling excess CO_2 into the milky solution, the milkiness disappears due to the formation of soluble calcium hydrogen trioxocarbonate IV.

$$CaCO_3 + H_2O + CO_2 \longrightarrow Ca(HCO_3)_2$$

milky solution — colourless solution

If excess gas is passed into the mixture, the precipitate dissolves and the solution become clean due to the formation of soluble, $Ca(HCO_2)_3$

V. Reaction with red-hot coke. If CO_2 is passed over red-hot coke, the gas is reduced to CO.
$CO + C \longrightarrow 2CO$

USES OF CARBON IV OXIDE (CO_2)

i) It is used in fire extinguisher because it doesn't support combustion and it is heavier than air.
ii) Dry ice (solid CO_2) is used as a refrigerant.
iii) It is used for the manufacture of $NaHCO_3$ (sodium hydrogen trioxocarbonate IV (Na_2CO_3) in the Solvay Process.
iv) It is used for making carbonated drinks like soda water, coca cola, RC, Bigi, La Casera, etc.
v) It is used as a leavening agent in baking
vi) Green plants use it to make sugar during photosynthesis.

TESTS FOR CARBON DIOXIDE (CO_2)

The suspected gas is passed into the lime water. If the lime water turns milky, then the suspected gas is CO2.

Week 8

CARBON II OXIDE

Carbon II Oxide is another oxide of carbon. It is produced when carbon or any organic matter is burned in a limited or inadequate supply of oxygen.

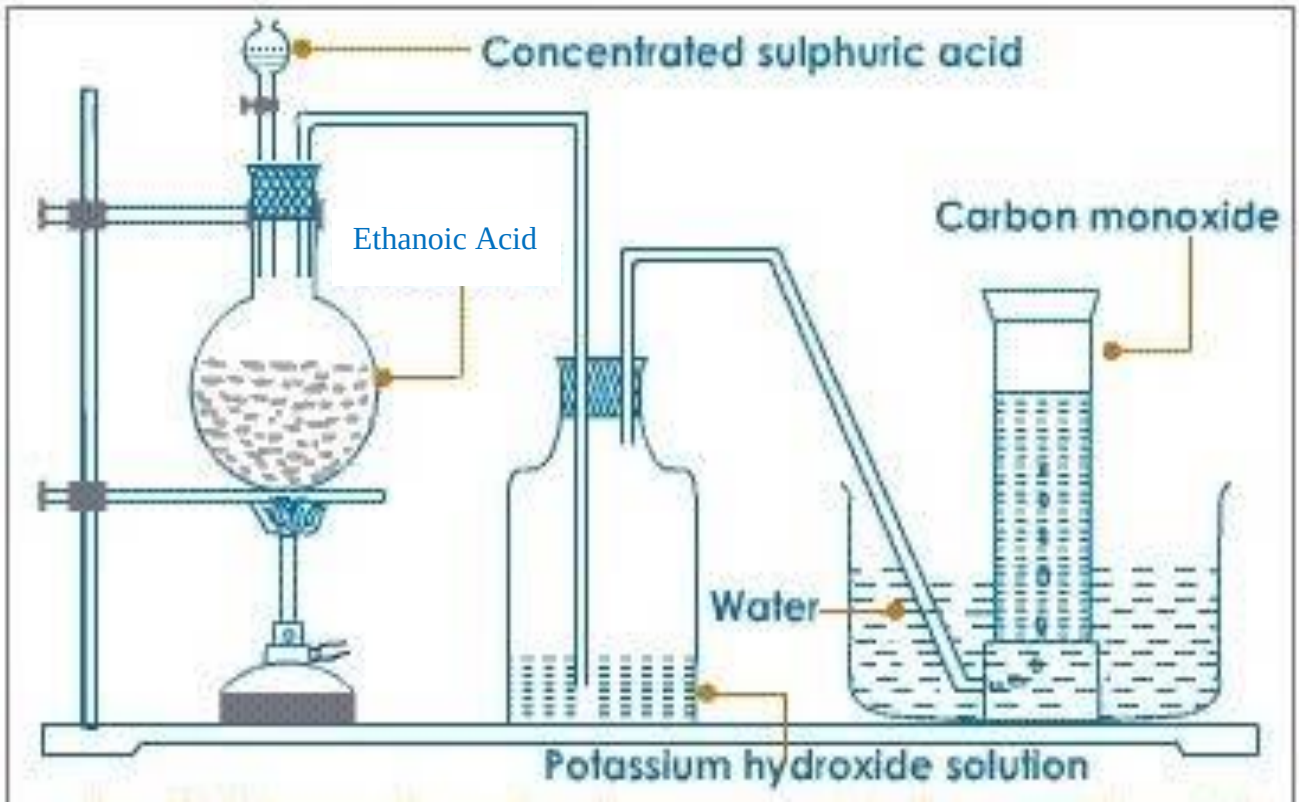
$2C + O_2 \longrightarrow 2CO + \text{heat}$

It had been discovered that carbon II oxide is unstable; it readily combines with hot air to form the more stable carbon IV oxide.

$$2CO_{(g)} + O_{2(g)} \longrightarrow 2CO_{2(g)}$$

Carbon II oxide is produced when whenever there is an incomplete combustion of carbon-containing fuels.

LABORATORY PREPARATION OF CARBON II OXIDE



In preparing carbon II oxide in the laboratory, we make use of the set-up above. We would use of concentrated Tetraoxosulphate VI acid, ethanoic acid and NaOH as the reagents. Thistle funnel, flat-bottomed flask, trough and gas jar are also part of the general set-up.

Firstly, collect some measured quantities of ethanoic acid crystals and put them inside a flat-bottomed. Also, introduce H_2SO_4 into the same flask then supply heat to the mixture. There is effervescence and mixture of gases are given off.

$$\begin{matrix} COOH \\ COOH \end{matrix} \xrightarrow[\text{heat}]{\text{Conc. } H_2SO_4} H_2O + CO_2 + CO$$

Or $H_2C_2O_4.\ 2H_2O \longrightarrow 3H_2O + CO_2 + CO$

The role of concentrated H_2SO_4 is to remove elements of water and as a dehydrating agent. If a mixture of CO (carbon II oxide) and CO_2 (carbon IV oxide) are passed through KOH (potassium hydroxide) or NaOH (sodium hydroxide), only CO_2 is absorbed which is an acidic oxide.

$$CO_2 + 2KOH \longrightarrow K_2CO_3 + H_2O$$

Other methods of producing CO includes;

i. Dehydration of methanoic acid using concentrated H_2SO_4
   $HCOOH \longrightarrow CO + H_2O$
ii. Burning carbon in a limited supply of air
   $2C + O_2 \longrightarrow 2CO_{(g)}$
iii. Industrial production of CO
   It is produced industrially by passing carbon IV oxide over a thick layer of red-hot coke or charcoal in a furnace or a long tube (as in the case of producer gas)
   $CO_2 + C \longrightarrow 2CO$

PHYSICAL PROPERTIES OF CO (Carbon II Oxide)

a. It is a colourless gas
b. It is odourless
c. It is sparingly soluble in water
d. It is slightly less dense than air and has no effect on damp litmus paper and hence a neutral oxide
e. It is poisonous

CHEMICAL PROPERTIES OF CO

(a) Reaction with air or oxygen
   Carbon II oxide burns in air with a blue flame to form carbon IV oxide
   $2CO + O_2 \longrightarrow 2CO_2$

(b) Reducing property of CO

It is a strong educing agent

$Fe_2O_3 + CO \longrightarrow 2Fe + 3CO_2$

$PbO + CO \longrightarrow Pb + CO_2$

(c) Reaction with steam

Under standard condition, carbon II oxide reacts with steam thereby reducing it to hydrogen

$CO_2 + H_2O \longrightarrow CO_2 + H_2$

(d) Reaction with transition metals

It reacts with certain transition metals to form carbonyl

$Ni + 4CO \longrightarrow Ni(CO)_4$ (NICKEL TETRACARBONYL)

It acts as ligands in complex ions.

(e) Reaction with haemoglobin

It is an extremely poisonous. Due to this, whenever it reacts or infect the red blood cells, it prevents the circulation of oxygen to essential body parts. This often lead to suffocation and in worst instances, to death.

USES OF CARBON II OXIDE

(a. Carbon II Oxide serves as a reducing agent in the extraction of metals from their ores

(b. It serves as a fuel and an essential constituent of water gas and producer gas

(c. It is used in the preparation of methanol