SS1 CHEMISTRY: 3RD TERM

SCHEME OF WORK

SCHEME OF WORK FOR THIRD TERM

WEEK	TOPIC
1.	Acids
2.	Concentrated and Dilute acids
3.	Bases
4 - 5	Salts
6 - 8	Carbon and its compounds
9 - 10	Chemical Industry
11 - 13	Revisions and Examination

ACIDS

- **Definitions of acid**:

An acid is a substance, which produces hydrogen ions, H^+ or hydroxonium ions, H_3O^+ as the only positive ions in aqueous solution. (**Arrhenius definition of an acid**)

  - $HCl_{(g)} + H_2O_{(l)} \longrightarrow H_3O^+_{(aq)} + Cl^-_{(aq)}$
  - $HNO_{3(aq)} \longrightarrow H^+ + NO_3^-{}_{(aq)}$

- When an acid is dissolved in water, it dissociates first, to produce hydrogen ion, H+, a proton, which then combines with water readily to form hydroxonium (oxonium) ion, H_3O^+.

Lewis concept of Acids: *An acid is an electron-pair acceptor*. This is a more general definition. Lewis acids do not contain protons but have empty orbital on their central atoms. For example: BF_3, $AlCl_3$ and $FeCl_3$.

Bronsted-Lowry concept of Acids: *An acid is a proton donor*.

e.g. HCl, HNO_3.

Classes OF ACIDS

- **Organic acids:** these are acids obtained from natural plant and animal products. E.g. Ethanoic acid (CH_3COOH), Lactic acid, amino acid, ascorbic acid.
- **Inorganic acids:** these are prepared from inorganic matter or mineral elements. E.g. HCl, HNO_3, H_2SO_4

STRENGTHS OF AN ACID:

The strength of an acid is determined by the hydrogen ion concentrations in the acid solution

Acids are classified into strong and weak acids in terms of their strengths.

- **Strong Acids**: *These are acids that ionize or dissociate completely in aqueous solutions*. They are strong electrolytes. E.g. HCl, HNO_3, H_2SO_4
- **Weak Acids**: *These are acids that only ionize slightly or partially in aqueous solution with low hydrogen ion concentration*. They are weak electrolytes. Organic acids e.g., Ethanoic acid(CH_3COOH), H_2CO_3, H_2SO_3 and H_3PO_4

Assignment 1

What is an acid?

State the difference between the following

- Weak acids and strong acids
- Organic acids and inorganic acids

List of common organic acids:

Acid	**Source**
Ethanoic acid	Vinegar
Lactic acid	Sour milk
Tartaric acid	Grape and sour soup
Citric acid	Lemon and orange(unripe)
Ascorbic acid	Lime, grape.
Amino acid	Protein
Methanoic acid	Bees and ants’ stings.

class work 1

State the source of the following acids

1. Amino acid
2. Lactic acid
3. Ethanoic acid
4. Ascorbic acid
5. Citric acid

CLASS WORK 2

State the basicity of the following acids:

1. C_2H_5COOH,
2. H_3PO_4,
3. HNO_2,
4. H_2SO_3

Concentrated and Dilute Acids

Concentrated acid contains more acid molecules than water. The portion of water is much less than that of the acid. Most concentrated acids are corrosive.

Dilute Acids: A dilute acid contains more water than acid.

- **Note**: Acids exhibit acidic properties only when dissolved in water i.e. aqueous solution.

PHYSICAL PROPERTIES.

1. Dilute acids have sour taste
2. Concentrated acids are corrosive, i.e., causes burns.
3. Dilute acids turn blue litmus paper red
4. They are strong electrolytes

PREPARATION OF ACIDS

1. **Action of an acid anhydride on water**:

An acid anhydride is an oxide of a non-metal that dissolves in water to produce an acid. E.g. SO_2, NO_2, CO_2, SO_3

Examples of acid anhydrides are:

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

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

2. **Displacement reaction:** a stronger acid will displace a weaker acid from its salt

$$H_2SO_{4(aq)} + 2NaCl_{(s)} \longrightarrow Na_2SO_{4(aq)} + 2HCl_{(g)}$$

$$H_2SO_{4(aq)} + 2NaNO_{3(s)} \longrightarrow Na_2SO_{4(aq)} + 2HNO_{3(aq)}$$

3. **Direct Combination of Elements:**

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

- **<u>Assignment</u>**

1. What is the difference between dilute and concentrated acid.
2. Explain what is meant by the strength of an acid. Why is Ethanoic acid regarded as a weak acid?

BASICITY OF AN ACID

- The basicity of an acid *is the number of hydrogen atoms that can be ionized in water by ONE molecule of the acid i.e. the number of ionizable or replaceable hydrogen atoms in a molecule of the acid*. Examples:

Acid	Basicity
HCl	1 monobasic
HNO_3	1 monobasic
H_2SO_4	2 dibasic
H_3PO_4	3 tribasic
CH_3COOH	1 monobasic

Class work

State the basicity of the following acids:

1. C_2H_5COOH,
2. H_3PO_4,
3. HNO_2,
4. H_2SO_3

CHEMICAL PROPERTIES OF ACIDS

1. An acids reacts with a base to produce a salt and water only (neutralization).

$HNO_{3(aq)} + NaOH_{(aq)} \longrightarrow NaNO_{3(aq)} + H_2O_{(l)}$.

2. Dilute acids react with metals (more reactive than hydrogen) to liberate hydrogen gas. $2HCl_{(aq)} + Zn_{(s)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}$

Note: HNO_3 *does not liberate hydrogen gas with metals because, it is a very strong oxidizing agent. Any hydrogen gas formed is quickly oxidized to water (except when it is extremely dilute)*.

3. . An acid reacts with trioxocarbonates(IV) to liberate carbon(IV) oxide. Salts and water are also produced.

$Na_2CO_{3(aq)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} + CO_{2(g)}$

ASSIGNMENT

1. state two physical properties of an acid

2 Using balance chemical equation, write an equation to show the reaction between Sodium hydroxide (NaOH) and dilute hydrochloric acid (HCl) to form salt and water

USES OF ACIDS

Acids are used

1. in the production of salts, dyes, detergents, paints and explosives, soaps e.t.c.
2. in the dissolution metals or to remove dust,
3. as electrolytes in lead acid accumulator,
4. as food preservatives and mild antiseptic
5. as drying agents, dehydrating agents and oxidizing agents

BASES

A base is either an oxide or hydroxide of a metal. They exists as solids.

A base is a substance which reacts with hydroxonium ion, H_3O^+, or hydrogen ion, H^+ to produce water. **(Arrhenius definition of a Base)**

$OH^- + H^+ \longrightarrow H_2O_{(l)}$

Examples of basic oxides are: CaO, MgO, Na_2O, K_2O e.t.c.

Basic oxides dissolve in water to form hydroxides: $Na_2O + H_2O \longrightarrow 2NaOH$

An alkali is a soluble base, i.e., a base that dissolves in water to produce hydroxide ions, OH^-. $NaOH + H_2O \longrightarrow Na^+ + OH^-$

Alkalis are classified into strong and weak bases.

Strong Alkalis: *These are bases that ionize completely in water*. They are strong electrolytes, e.g., KOH, $NaOH$ and $Ba(OH)_2$.

Weak Alkalis: These are those that are slightly ionized in water, e.g., $Ca(OH)_2$, $Mg(OH)_2$ and ammonia solution.

Class work

- Define **basic oxide**
- Give **two** examples of basic oxide
- What is the difference between a base and an alkali

Bronsted-Lowry Concept of Bases:

A base is a proton acceptor, e.g.,

BASE ACID

$NH_3 + HCl \longrightarrow NH_4^+ + Cl^-$

$H_2O + H_2O \longrightarrow H_3O^+ + OH^-$

From above example, water can act as weak acid and weak base.

It is amphoteric.

Lewis Concept of Bases: *A base is an electron pair donor*. They possess lone pairs of electrons. Examples:

BASE ACID

$NH_3 + H_3O^+ \longrightarrow NH_4+ + H_2O$

Physical Properties of Bases.

1. Alkalis have bitter taste;
2. Their solutions are slippery, i.e., have soapy feel to touch.
3. They turn red litmus paper blue;
4. Concentrated forms of caustic alkalis (KOH and NaOH) are corrosive.

- **Chemical Properties of Bases**

A base reacts with an acid to produce salt and water only (neutralization), e.g.,

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

Base + *Acid* ⟶ *Salt* + *Water* [***Neutralization Reaction***]

2. *An alkali reacts with acid anhydride to form salt and water only*.

$$2KOH_{(aq)} + CO_{2(g)} \longrightarrow Na_2CO_{3(aq)} + H_2O_{(l)}$$

3. *Alkalis react with ammonium salts to liberate ammonia gas*.

$$KOH_{(aq)} + NH_4Cl_{(aq)} \xrightarrow{\text{Heat}} KCl_{(aq)} + H_2O_{(l)} + NH_{3(g)}$$

Assignment 4

1. Define neutralization reaction.
2. Using a balanced chemical reaction, show the neutralization reaction between an acid and a known base

Assignment 5

- Define **basic oxide**
- Give **two** examples of basic oxide
- What is the difference between a base and an alkali

Assignment 6

Find the pH in which the hydrogen ion, H^+ concentration is 6.38×10^{-6} $moldm^{-3}$.

Preparation of Bases

1. *Combustion of a reactive metal in air*.

A reactive metal burns in air to give the corresponding oxide, e.g.,

$4Na_{(s)} + O_{2(g)} \longrightarrow 2Na_2O_{(s)}$

Action of a soluble base on water:

Soluble bases react with water to give the corresponding hydroxides, e.g.,

$CaO_{(s)} + 2H_2O_{(l)} \longrightarrow Ca(OH)_{2(aq)}$

3. **Action of a reactive metal on cold water**:

Soluble bases(alkalis) are prepared by action of reactive metals on cold water.

$2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2(g)}$

4. **Precipitation Method**:

Insoluble hydroxides are precipitated by action sodium hydroxide on aqueous solution of their salts.

$2NaOH_{(aq)} + CuSO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + Cu(OH)_{2(s)}$

Uses of Alkalis:

1. They are used in the production of soaps, papers, glass, etc.,e.g. NaOH

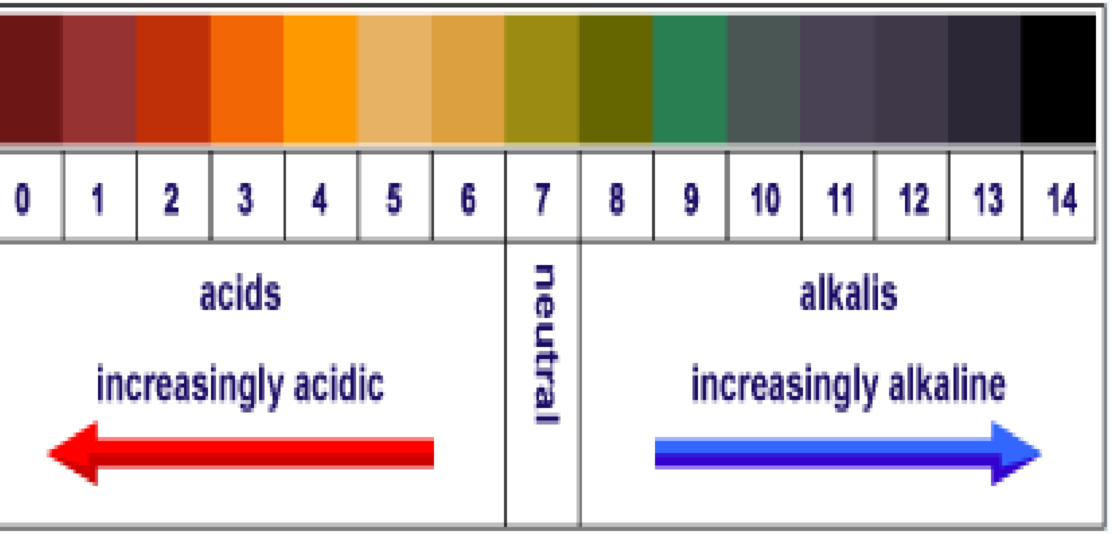
2. Slaked lime, $Ca(OH)_2$, is used as fertilizer

3. Some are used as a laxative (reduction of excess acidity in the stomach, e.g., $Mg(OH)_2$.

4. Ammonia is used in laundry.

Acidity and alkalinity of solutions

- *The pH of a solution is a measure of the degree of acidity or alkalinity of the solution*. [pH = power of hydrogen]
- The pH of a solution can be measured accurately by an instrument or device called ***pH meter***. It can also be determined roughly by a substance called ***universal indicator***.
- **pH Scale**: The pH scale ranges from 0 to 14 as the lower and upper limit respectively.

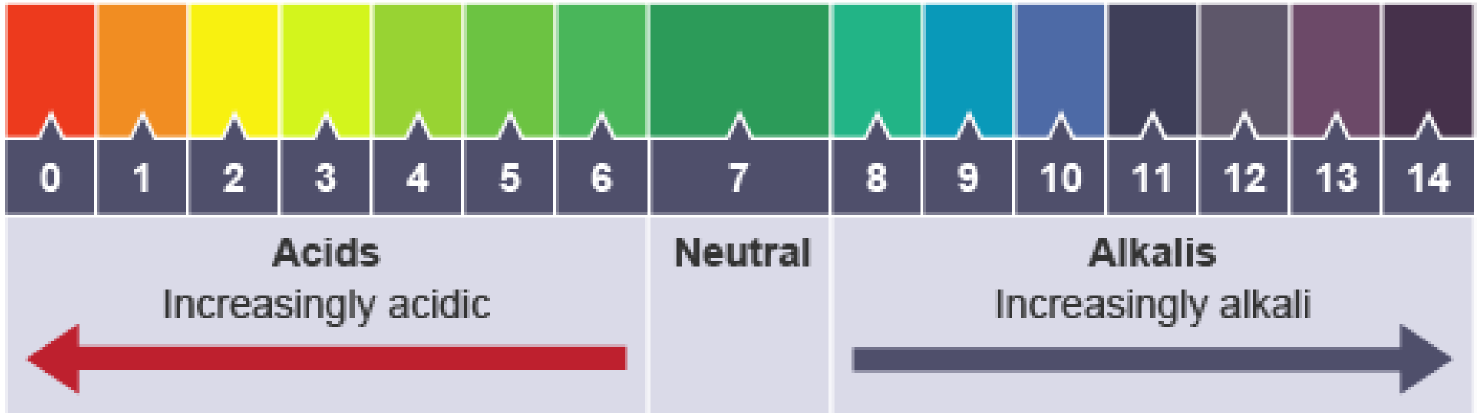


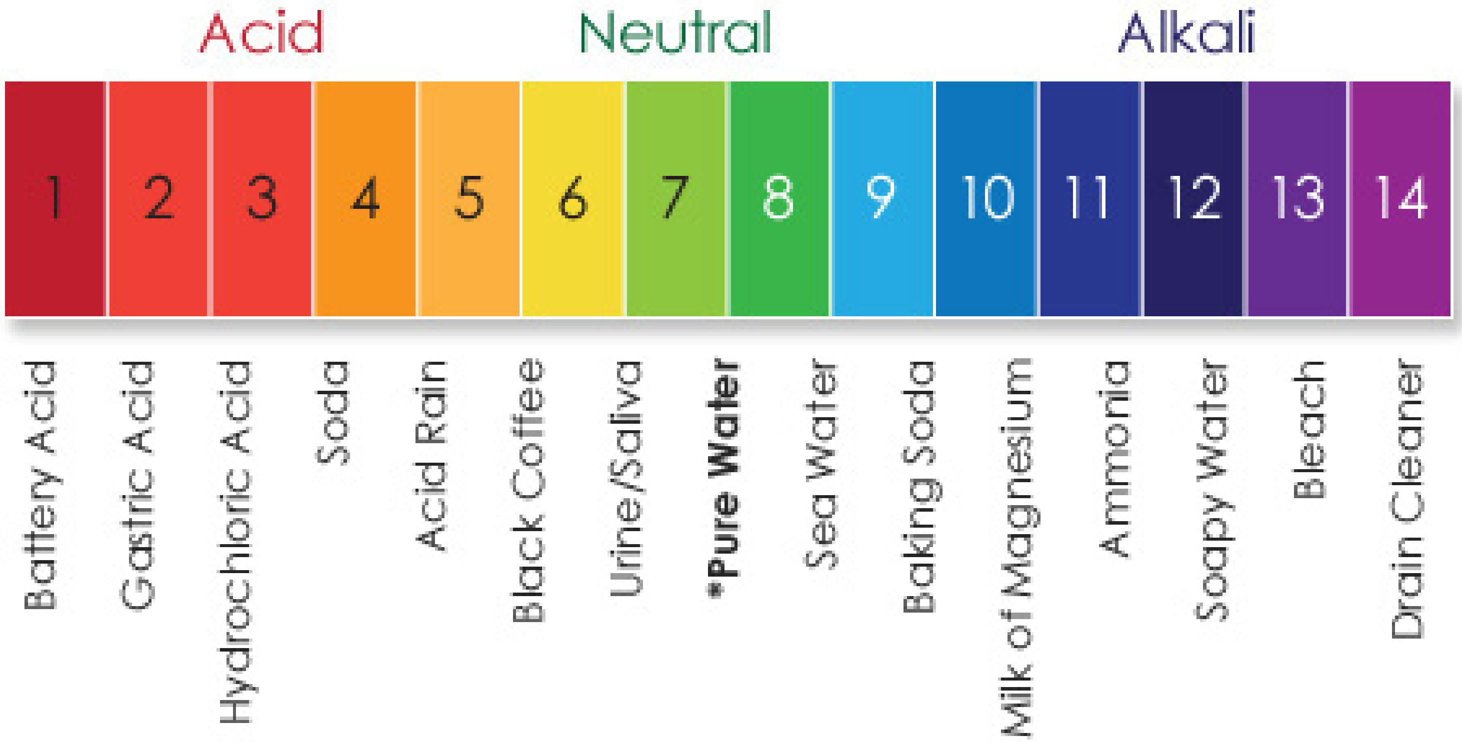
The pH of a solution can also be defined as:

- *Concentration of hydroxonium or hydrogen ions in a solution.[H^+]*
- *The negative logarithm to base ten of the hydroxonium concentration*.

Mathematically, $pH = -\log_{10}[H^+]$ or

$$pH = \log_{10} 1/[H^+]$$


0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Acids
Increasingly acidic
Neutral
Alkalis
Increasingly alkali


Acid
Neutral
Alkali
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Battery Acid
Gastric Acid
Hydrochloric Acid
Soda
Acid Rain
Black Coffee
Urine/Saliva
*Pure Water
Sea Water
Baking Soda
Milk of Magnesium
Ammonia
Soapy Water
Bleach
Drain Cleaner

Calculations of pH

- **Worked examples**:
- 1. The concentration of H^+ in two solutions are (a) 1×10^{-14} mol. dm^{-3}, and (b). 5×10^{-9} mol. dm^{-3}. What is the pH of each solution?.

- (a). $[H^+] = 10^{-14}$ mol.dm^{-3},
- So, pH = $-\log_{10}(10^{-14}) = -(-14) = 14$.

- (b). $[H^+] = 5 \times 10^{-9}$ mol. dm^{-3}
- So, pH = $-\log_{10}(5 \times 10^{-9})$
- $= -(\log_{10}5 + \log_{10}10^{-9})$
- $= -(\log_{10}5 + -9\log_{10}10)$
- $= -0.70 + 9$
- $= 8.30$

2. A solution has a pH of 3.4. What is its hydrogen concentration?

3. *Calculate the pH of 0.005 mol. dm^{-3} tetraoxoslphate(VI)*.

Solution:

$\longrightarrow$

pH + pOH = 14

- 4. *A glass cup of orange juice is found to have pOH of 11.40. Calculate the concentration of the hydrogen ions in the juice*.
- **Solution**:
- **pH + pOH = 14**
- pH = 14 – pOH, = 14-11.4 = 2.60.
- pH = $-\log_{10}[H^+]$ =
- $-\log_{10}[H^+] = 2.60$
- $\log_{10}[H^+] = -2.60$, Antilog of -2.60 = 2.51×10^{-3} $moldm^{-3}$

- **Assignment**:
- *Find the pH in which the hydrogen ion, H^+ concentration is 6.38×10^{-6} Mol. dm^{-3}.*

Indicators:

Indicators are weak acids or bases which will produce different colors in solution according to hydrogen ions concentration, H^+.

<u>Suitability of Acid-Base Indicators</u>:

Indicators are used in titrations and their suitability is as shown:

<u>Titrations</u>.	**<u>Suitable indicator</u>**.
Strong acid vs Strong base.	Any indicator
Weak acid vs strong base	Phenolphthalein
Strong acid vs weak base	Methyl orange
Weak acid vs Weak base	no suitable indicator

Practical 1

Chemistry Practical for third term

Instruction :

You are provided with solutions of three compounds labelled A,B,C, carefully carry out the following exercises, write your observation and state the conclusion.

(i) Test solution A with a litmus paper { Blue and Red }

Observation……………………………………………………………………………….

Conclusion ……………………………………………………

(ii) Test solution B with a litmus paper { Blue and Red }

Observation………………………………………………………………………………

Conclusion ……………………………………………………

(iii) Test solution C with a litmus paper { Blue and Red }

Observation……………………………………………………………………………….

Conclusion ……………………………………………………

Practical 2

Chemistry Practical for third term

Instruction :

You are provided with an acid solution labelled A and an alkali solution labelled B, a measuring cylinder and a test tube

a. Using a measuring cylinder, take 10 cm^3 of **A** and Put it into a test tube, Add 2 or 3 drops of the following indicators and state your observation (colour change).

b. Using a measuring cylinder, take 10 cm^3 of **B** and Put it into a test tube, Add 2 or 3 drops of the following indicators and state your observation (colour change).

c. Using a measuring cylinder, take 10 cm^3 of **A** and Put it into a test tube, measure 10 cm^3 of **B** and add it to the same test tube above, then add 2 or 3 drops of the following indicators and state your observation (colour change).

Present your report using the table format below

Test	Colour of A in Methyl orange	Colour of A in phenolphthalein	
10cm^3 of solution A			
10 cm^3 of solution B			
Mixture of 10 cm^3 of solution A + 10 cm^3 of solution B			

Practical 3

TITRATION EXPERIMENT

Instruction :

A is a solution of 0.1 moldm^{-3} HCl. **B** is a solution containing of 0.1 moldm^{-3} NaOH.

(a) Put **A** into the burette

(b) Using a pipette, measure 25.00 cm^3 portions of **B** and put it into the conical flask

(c) Add 2-3 drops of methyl orange indicator into the conical flask containing **B**.

(d) Read and record the initial volume of acid

(e) Titrate solution **B** in conical flask against **A** in the burette until you observe the first colour change.

(f) Read and record the new volume of acid.

Repeat the procedure 3 times.

Tabulate your burette readings and calculate the average volume of **A** used.

Presentation of Report

Volume of Pipette used ……………cm^3

	Rough	1st	2nd	3rd
Final burette reading(cm^3)				
initial burette reading(cm^3)				
Volume of acid used (cm^3)				

Average volume of acid used: $\frac{1st+2nd+3rd}{3}$ cm^3

NB: USE OF PENCIL IS NOT ALLOWED

- **Colours of Indicators**:
- Indicators change colors depending on the pH of the solution concerned. Colors of some indicators in different media are:

Indicator	pH range	Acid medium	Alkaline medium
Methyl orange	3.1 – 4.6	red	yellow
Phenolphthalein	8.3 – 10.0	colorless	pink
Litmus	5.0 – 8.0	red	blue

- **Buffer solutions**:
- *A buffer solution is one which resists changes in pH on dilution or addition of small amounts of acids or alkalis*

- Revision Exercise:
- 1. *What is buffer solution? Calculate the pH of a solution containing 4.0 x* 10^{-4} *moldm*$^{-3}$ *hydrogen ions*.

SALTS

- *A salt is formed, when all or part of the ionizable hydrogen ions in an acid are replaced by metallic or ammonium ions*.
- **Types of Salts**.
- There are five types of salts: *normal salts, acid salts, basic salts, double salts and complex salts*.
- 1. **Normal Salts**: Normal salts are formed when all the replaceable hydrogen ions are completely replaced by metallic ions.
- $HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$
- $H_2SO_4(aq) + ZnO(s) \longrightarrow ZnSO_4(aq) + H_2O(l)$

- **Acid Salts**: *Acid salt is formed when the replaceable hydrogen ions in an acid are only partially replaced by a metal or ammonium ion*. They are produced by acids that contain more than one replaceable hydrogen ion.
- $H_2SO_4(aq) + KOH(aq) \longrightarrow KHSO_4(aq) + H_2O(l)$. *Acid salt can still behave as an acid because of the presence of replaceable hydrogen ions*.
- $KHSO_4(aq) + KOH(aq) \longrightarrow K_2SO_4(aq) + H_2O(l)$
- **Basic Salts**: *Basic salts are those that contain hydroxide ions, OH^-*. They have properties of a base because of the presence of the hydroxide ions.
- $Ca(OH)_2(aq) + HCl_{(aq)} \longrightarrow Ca(OH)Cl_{(aq)} + H_2O(l)$
- *Basic salts are formed by hydroxides that contain more than one hydroxide ion*. Another example is Mg(OH)Cl.
- **Double Salts**: *These are salts that ionize to produce three types of ions in solution, usually, two of which are positively charged*.
- Double salts are also known generally as **alums**. They have distinct

crystals that differ from either those salts from which they are formed. Examples are:

- Ammonium iron(II) tetraoxosulphate(VI)-hexahydrate. $(NH_4)_2Fe(SO_4)_2.6H_2O$.

- Aluminum potassium tetraoxosulphate(VI) duodecahydrate. $KAl(SO_4)_2.12H_2O$

Complex Salts: *These are salts that contain a central ion which are surrounded by other ions called **ligands***.

Examples are: Copper(II) tetraamine, $Cu(NH_3)_4^{2+}$ · Potassium hexacyanoferrate(II), $K_4Fe(CN)_6$.

PREPARATION OF SALTS

The method chosen for preparing a particular salt depends on:

- *its solubility in water,*

- *its stability to heat*.

Soluble Salts: Soluble salts are prepared by the following methods:

1. **Action of dilute acids on metals**: Metals that are ***more reactive*** than hydrogen displace hydrogen from dilute acids to form salt.

$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$

$Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$

2. **Neutralization method**: A salt may be prepared by titrating an acid against appropriate alkali. A suitable indicator is used to determine the end point. Salt and water are produced.

$KOH(aq) + HNO_3(aq) \longrightarrow KNO_3(aq) + H_2O(l)$

3. **Action of dilute acid on insoluble base**: Dilute acids react with insoluble bases to form salts and water only.

$H_2SO_4(aq) + CuO(s) \longrightarrow CuSO_4(aq) + H_2O(l)$

4. **Action of dilute acid on trioxocarbontates(IV)**: dilute acids react with trioxocarbonates(V) to produce salt, water and carbon(IV) oxide.

$H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_4(aq) + H_2O(l) + CO_2(g)$

Recovering Soluble Salts from Solution: Soluble salts are recovered from solution by :

- *Heating to dryness (evaporation),*

- *Crystallization*.

Preparation of Insoluble Salts: Salts that are not soluble in water can be prepared by the following methods:

: **Double decomposition:** *This is a reaction in which two soluble compounds react with exchange of radicals to form two other compounds, of which one is insoluble*. The insoluble one is the required salt and it is removed by filtration.

$AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$

2. **Combination of constituent elements**: Some salts, especially, binary salts such as chlorides and sulphides may be prepared by directly heating together the two elements that make up the salt.

$Fe(s) + S(s) \longrightarrow FeS(s)$

Properties of Salts:

- **Efflorescent, Deliquescent and Hygroscopic Substances**:
- **Efflorescence**: *This is a phenomenon whereby a compound loses part or all of its water of crystallization when exposed to the atmosphere*. Such compounds are said to be efflorescent. Examples are: $Na_2CO_3.10H_2O$ and $Na_2SO_4.10H_2O$.
- **Deliquescence**: *This is a phenomenon where some compounds absorb so much water from the atmosphere when exposed to form aqueous solution*. Such compounds are deliquescent. Examples are: NaOH, KOH, $FeCl_3$, $CaCl_2$, P_2O_5 and silica gel.

- **Hygroscopy**: *This is a phenomenon in which a compound absorbs water from the atmosphere when exposed, but not enough to form solution*. The compound if solid, becomes sticky and if liquid, more dilute. Examples are: $NaNO_3$, CuO, CaO and concentrated H_2SO_4.

- **<u>Water of Crystallization</u>**: *This the definite amount of water molecules that crystals chemically combined with as they crystallize out of water*. Such salts are known as hydrated salts. Examples are $CuSO_4.5H_2O$, $FeSO_4.7H_2O$, $Na_2CO_3.10H_2O$. (Anhydrous salts do not contain water of crystallization)
- Drying agents: these are substances that have strong affinity for moisture or water. They are either hygroscopic or deliquescent. In chemical process(reaction) they are called dehydrating agents.
- A drying agent cannot be used to dry a substance if it reacts with the substance to be dried.

Drying agent	Gases
Concentrated H_2S0_4	All gases except ammonia and hydrogen sulphide.
Fused $CaCl_2$	All gases except ammonia.
P_20_5(Phoshorus(v)oxide)	All gases except ammonia
Ca0 (quicklime)	Suitable for ammonia
Silica gel	All gases

Drying Agent are commonly used in desiccators for drying substances

Hydrolysis of Salts

Hydrolysis is the term used to describe the chemical reaction between water and certain salts. it is the reverse of neutralization.

Salts are hydrolyzed to give acidic or alkaline or neutral solutions

- **NATURE OF SALTS**:

i. Neutral Salts Solutions: Formed between strong acid and strong base e.g $NaCl$, KCl, $NaNO_3$, Na_2SO_4

ii. Acidic salt solutions: formed between strong acid and weak base e.g NH_4NO_4, $CaCl_2$, $AlCl_3$, NH_4Cl

iii. Alkaline salt solution: Formed between a weak acid and a strong base e.g K_2CO_3, Na_2CO_3, $KHCO_3$, Na_2S, $NaCN$

iv. Salt or weak acid and weak base also give a neutral pH e.g CH_3COONH_4, $(NH_4)_2CO_3$

CARBON AND ITS COMPOUND

Carbon occurs naturally as diamond and graphite. It occurs in an impure form as coal and in the combined state as carbon(iv),natural gas, petroleum and wood.

One of the unique characteristics of carbon is that it forms bonds with other carbon atoms to form branched, straight chain and cyclic compounds. This property is called catenation.

ALLOTROPES OF COMPOUND

Allotropy is the ability of a substance to exist in various forms in the same physical state.

Allotropes of carbon are the various forms in which carbon exists in the same physical state.

Allotropes of carbon

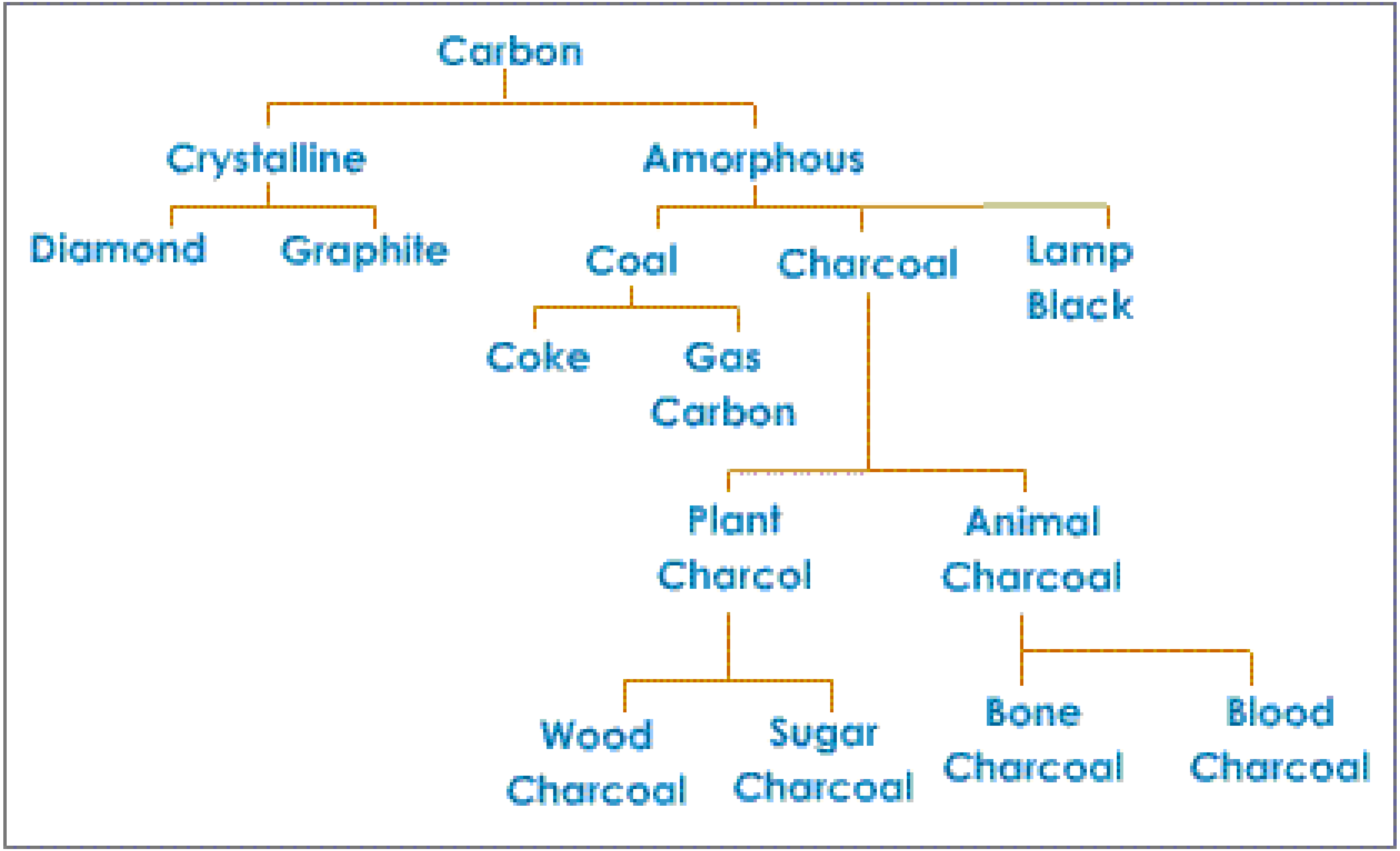
Crystalline allotropes

- Diamond
- Graphite

Amorphous allotropes

- Coke
- charcoal
- soot or lamp black

DO NOT WRITE: JUST EXPLANATION




tinyurl.com/MegaFreeWalls

Diamond is the purest form of carbon obtained naturally.

- **Properties of Diamond**

I. Diamond crystal is octahedral in shape.

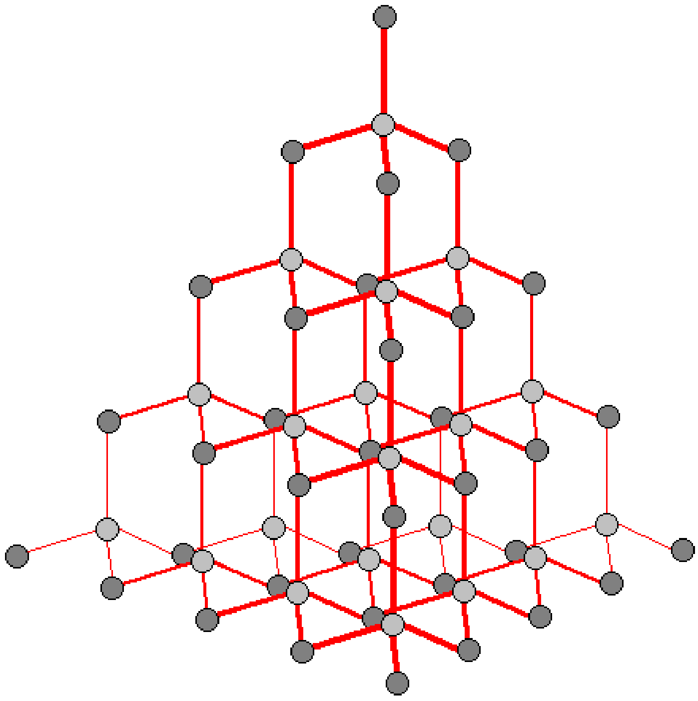
II. It is very hard due to its strong 3-dimensional covalent bonds structure

III. It's density is $3.6 gcm^{-3}$

IV. It has high melting point 3600 ^{O}C.

V. It does not conduct electricity or heat because it has no free valence electrons

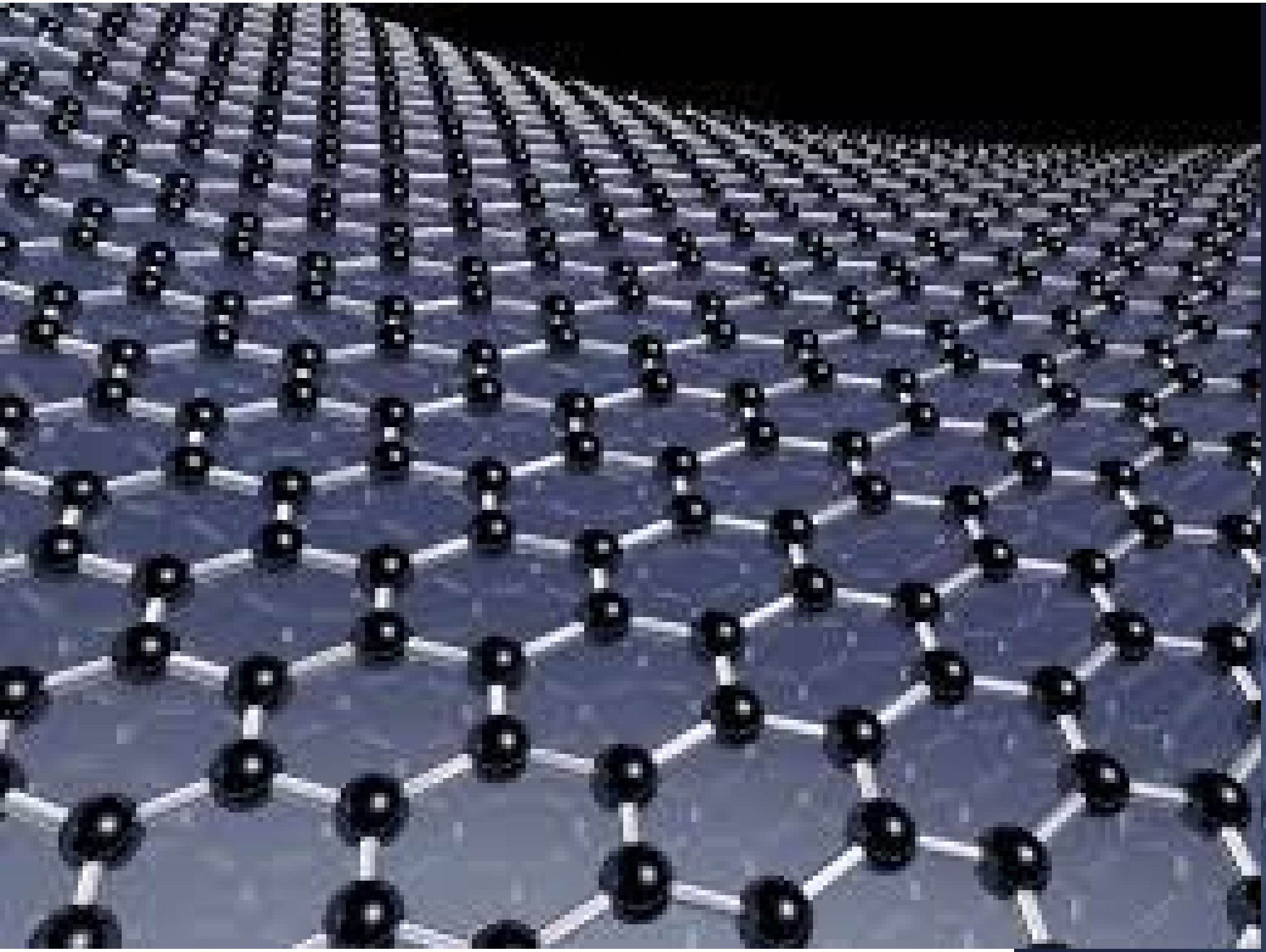
VI. It is insoluble in any solvent



structure of Diamond

Uses of Diamond

1. Due to its density and hardness, it is used in cutting glasses, drilling rocks, as an abrasive e.t.c
2. Because it is lustre and high refractive index, it is used in making jewelries
3. Used as pivot support in precision instruments.



Graphite

It exist as a black, soft and slippery hexagonal crystal

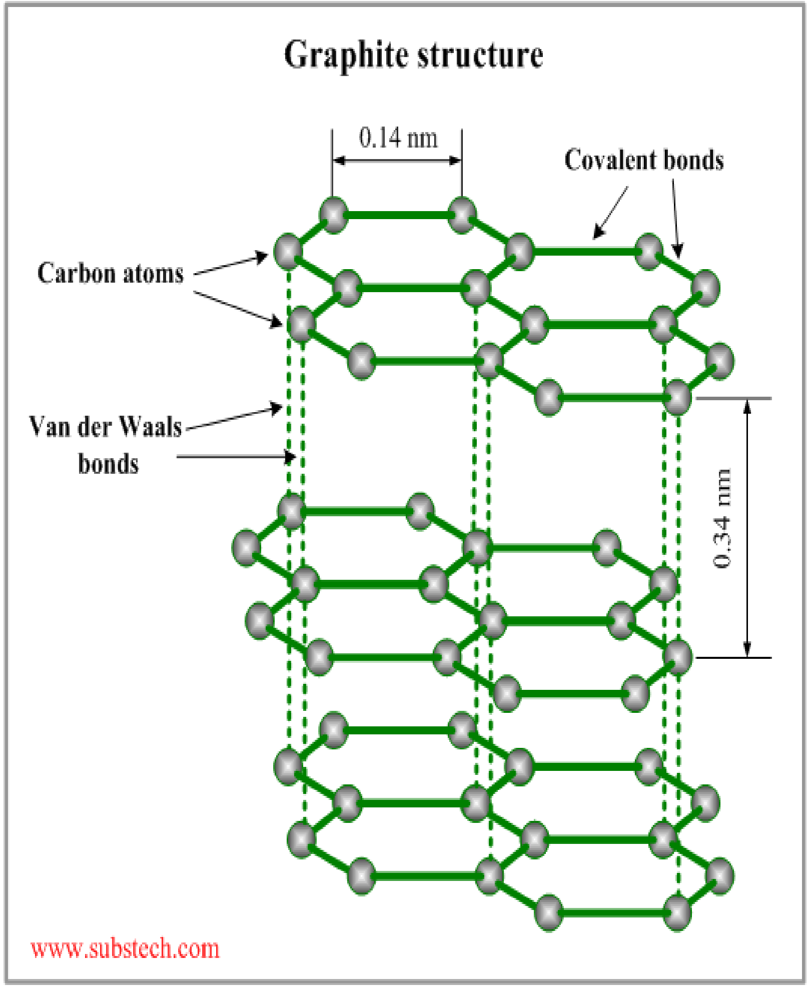
Properties of Graphite

i. It has a flat hexagonal structure held together by weak Van der Waal's forces.

ii. Its melting point is 3500 ^oC and density of 2.3 gcm^{-3}

iii. It is a good conductor of electricity due to presence of mobile electrons

iv. It is soft and flakes easily due to it's layered structure



Uses of Graphite

i. Used as a lubricant due to its layered structure

ii. Used as an electrode because it is relatively inert and conducts electricity

iii. Used to produce lead pencils.

iv. Used in neutron moderator in nuclear reactors because it is soft and its high melting point

Amorphous carbon

These are impure forms of carbon. They are shapeless(non-crystalline)

Coke: A dark-grey residue obtained when coal is heated in the absence of air. It is used as a fuel and production of gaseous fuels

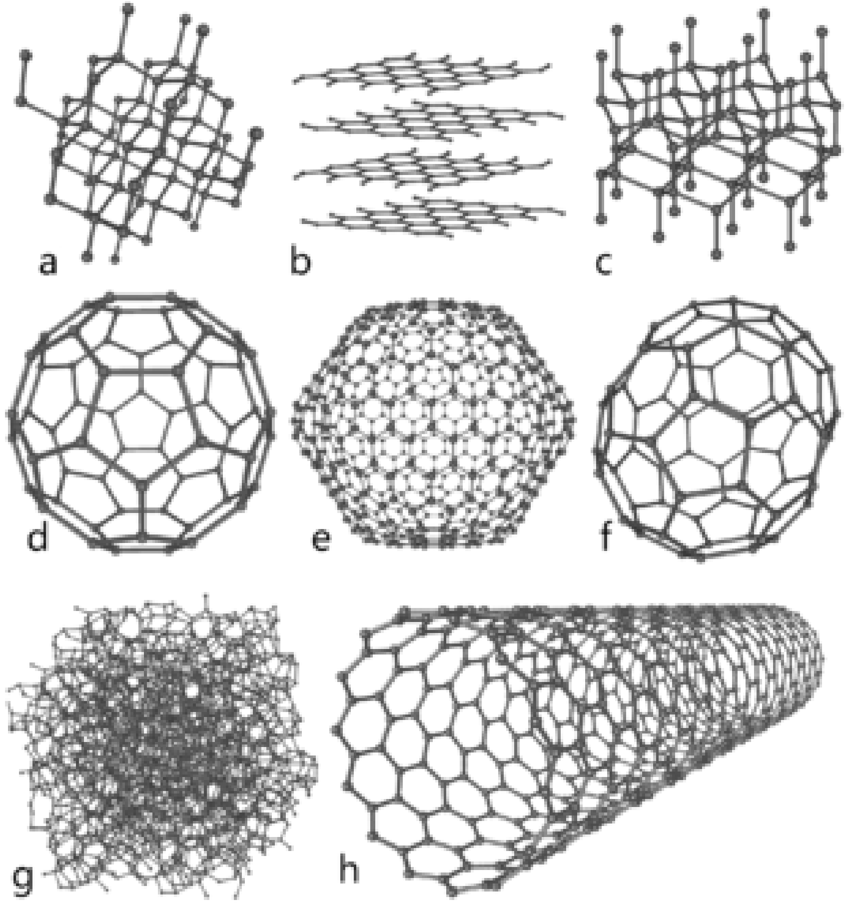
Wood Charcoal: Obtained by burning wood. It is used to adsorb poisonous gases and colours. Activated charcoal (carbon) is used to remove unpleasant taste, odour, colour and whitening of teeth

Sugar Charcoal: It is obtained by dehydrating sugar with concentrated H_2SO_4. it is the purest form of charcoal

$$C_6H_{12}O_6 \xrightarrow{\text{Conc. } H_2SO_4} 6C + 12H_2O$$

Animal Charcoal: Produced by heating bones in limited supply of air. It contains high percentage of Calcium phosphate $Ca_3(PO_4)_2$. it is used in absorbing colouring matter, decolourising crude sugar and petroleum jelly

Soot/Carbon black. Obtained by burning carbonaceous materials. Used in making printer's ink, typewriting ribbons e.t.c.


a
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COAL

It is a black organic rock formed from vegetation of the carboniferous period.

Types of coal

i. Peat
ii. Lignite
iii. Bituminous (soft coal)
iv. Anthracite: hardest form of coal

Coal is widely used as fuel to generate power for steam engines, factories e.t.c.

Destructive Distillation of Coal: this is the process whereby a coal is heated in the absence of air.

The products formed are:

Coal $\longrightarrow$ Coke $\longrightarrow$ ammoniacal liquor $\longrightarrow$ coal tar $\longrightarrow$ coal gas

- Ammoniacal liquor is a solution used to prepare $(NH_4)_2SO_4$ and as a fertilizer
- Coal tar is a semi-liquid used in synthesis of drugs, paints, rubber and road surfacing
- Coal gas is a mixture of H_2, CH_4, CO and C_2H_4.
- Coke is a non-volatile solid residue

Destructive distillation of wood.

Wood $\longrightarrow$ wood charcoal $\longrightarrow$ pyroligneous acid $\longrightarrow$ wood tar $\longrightarrow$ wood gas

Gasification of coke

This involves the conversion of coke(solid) to gases

1. Producer gas: this is formed when coke is heated in air.

$$2C + \underbrace{O_2 + N_2}_{\text{air components}} \longrightarrow \underbrace{2CO + N_2}_{\text{Producer gas}} + \text{heat}$$

It contains 70% N_2 and 30% CO. It has a low heating power. It is used in Lime Kilns, steel and glass furnaces

2. Water Gas. It is formed by heating red hot coke with steam.

$$C + H_2O_{(g)} \longrightarrow CO + H_2 + heat$$

Water gas is used to manufacture hydrogen, methanol and butanol

The production of producer gas is exothermic while water gas is endothermic

Properties of carbon

(i) Combustion: it burns in excess air to form carbon(iv)oxide.

$$C + O_2 \longrightarrow CO_2$$

In limited supply of air CO is formed

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

(ii) Combination reaction

$$C + 2H_2 \longrightarrow CH_4$$

$$C + 2S \longrightarrow CS_2$$

(iii) As reducing agent:

At high temperature it reduces oxides of metals to metal, and steam to hydrogen

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

$$2CuO + C \longrightarrow 2Cu + CO_2$$

Oxides of carbon

An oxide contains only two elements, the element and oxygen

Carbon form two oxides mainly Carbon(iv)oxide and carbon(ii)oxide(co)

Carbon(iv)oxide

Preparation:

carbon(iv)oxide is prepared in the laboratory by the action of acid on trioxocarbonate or hydrogentrioxocarbonate

$$2HCl + CaCO_3 \longrightarrow CaCl_2 + H_2O + CO_2$$

NB:

If the gas is required pure and dry, it is passed through $KHCO_3$ solution to remove any acid fumes and the gas is passed over $CaCl_2$ or Conc. H_2SO_4 to dry the gas

H_2SO_4 is not used in preparing CO_2 because it coat the marble chips with a layer of insoluble $CaSO_4$ which prevent further reaction

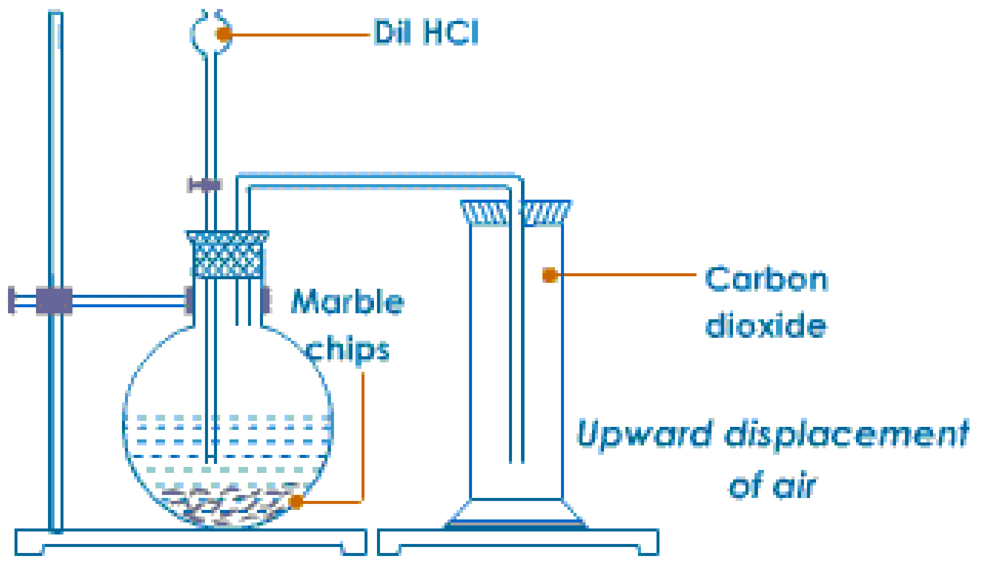

Fig. 11.6 Laboratory Preparation of carbon dioxide

Other method of preparing CO_2 are:

i.Reduction of metal oxide with carbon

$PbO + C \longrightarrow 2Pb + CO$

ii.Complete combustion of hydrocarbon $CH_4 + O_2 \longrightarrow CO_2 + H_2O$

Physical properties of CO_2

i. it is a colourless, odourless and tasteless gas
ii. It is denser than air, it turns moist blue litmus paper red
iii. It readily liquefies and solidifies(78 ^oC) to form a white solid called dry ice.

Chemical properties of CO_2

1) Reaction with burning magnesium to produce white magnesium oxide ash. $2Mg + CO_2 \longrightarrow 2MgO + C$
2) Reaction with water to form a weak trioxocarbonate(iv)acid

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

3) Reaction with alkalis to produce trioxocarbonate(iv)

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

4) Reaction with red hot coke $CO_2 + C \longrightarrow 2CO$

CO_2 is reduced to CO when passed over red hot coke

TEST FOR $C0_2$

When **$C0_2$** is bubbled into lime water $Ca(OH)_2$ the lime water turns milky due to the precipitation of insoluble $CaCO_3$

$$Ca(OH)_2 + C0_2 \longrightarrow CaCO_3 + H_2O$$

- When excess **$C0_2$** is passed into it, the milky colour disappears due to the formation of soluble calcium hydrogen trioxocarbonate $Ca(HCO_3)_2$

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

When heated the clear solution becomes milky again due to the decomposition of $Ca(HCO_3)$.

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

Uses of CO_2

1. Used in fire extinguishers because it does not support combustion.
2. It is used in the manufacture of soft drink and mineral water as it gives them a pleasant taste.
3. Dry ice is used as cooling agent in refrigerator.
4. It is used in producing baking powder which makes dough to rise.
5. It is used as a coolant in nuclear reaction.

Carbon(II)oxide .

It is a poisonous colourless and odourless gas. It is produced by incomplete combustion of carbon compounds ..

Laboratory preparation

CO is prepared by the action of concentrated H_2SO_4 on methanoic acid [formic acid] or ethane dioc acid [oxalic acid].

$$\begin{array}{l} COOH \\ | \\ COOH \end{array} \xrightarrow{\text{Conc. } H_2SO_4} CO_2 + CO$$

The mixture of gases is allowed to pass over caustic soda (Conc. NaOH) to remove CO_2 impurity

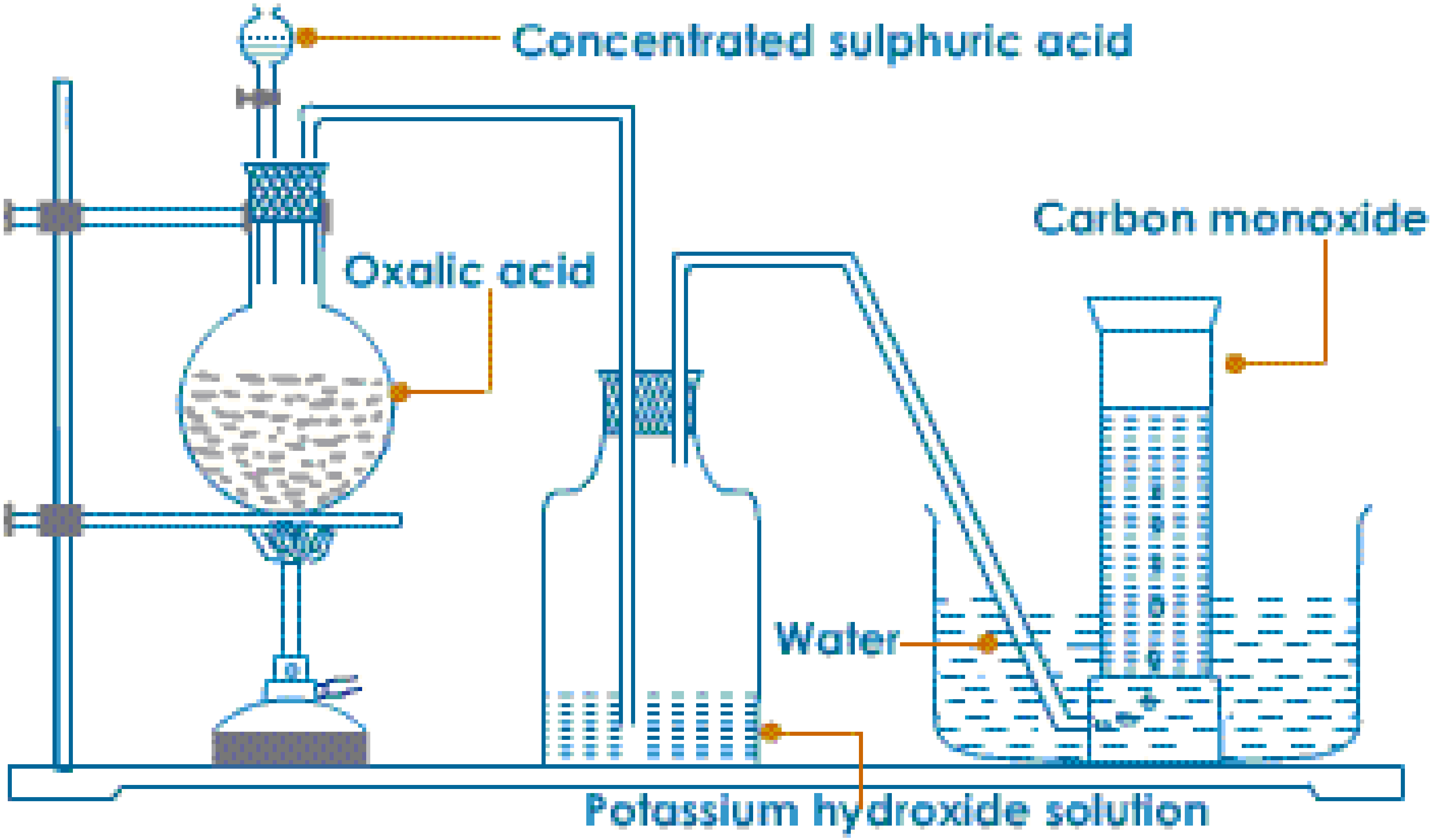

Fig. 11.2 Prepartion of carbon monoxide from oxalic acid

Physical properties of CO

- It is odourless, colourless and tasteless
- It is neutral to litmus
- It is lighter than air.
- It is insoluble in water but dissolves in ammoniacal copper(I) chloride solution

Chemical properties

(i) **As a reducing agent**: It reduces metallic oxides e.g. PbO, Fe_2O_3, CuO to their metals $CuO + CO \longrightarrow Cu + CO_2$

(ii) Combination reaction:

With Oxygen: It burns with a blue flame $2CO + O_2 \longrightarrow CO_2$

With haemoglobin: it combines with haemoglobin to form carboxylhaemoglobin which could lead to suffocation

Test for CO

CO burns in air with a blue flame to give CO_2 which turns lime water milky

Uses of CO

It is used as a reducing agent in the extraction of metals

It is an important constituent of fuel gases (Producer gas and water gas)

Trioxocarbonates (IV) salts

These are salts derived from trioxocarbonates (IV) acid or hydrogen trioxocarbonate (IV) acid, when it reacts with metals, metallic oxides or other dissolved salts.

$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$

Trioxocarbonates (IV) can be identified as Soluble of insoluble.

Trioxocarbonates of Na (Na_2CO_3), K (K_2CO_3) and NH_4^+ $(NH_4)_2CO_3$ are soluble while all others are insoluble in water.

Preparation of Soluble trioxocarbonate(IV)

Soluble trioxocarbonates (IV) are prepared by bubbling carbon (IV) oxide through a corresponding alkali solution

$2KOH + CO_2 \longrightarrow K_2CO_3 + H_2O$

Similarly, hydrogen trioxocarbonate(IV) decompose on heating to yield metallic trioxocarbonate (IV)

$2NaHCO_3 \xrightarrow[\text{HEAT}]{} Na_2CO_3 + CO_2 + H_2O$

PROPERTIES OF TRIOXOCARBONATES (IV)

- All trioxocarbonates (IV) except Na_2CO_3, K_2CO_3 and $(NH_4)_2CO_3$ are insoluble in water. They are hydrolyzed to give their corresponding hydroxide

$$Na_2CO_3 + H_2O \longrightarrow 2NaOH + H_2CO_3$$

2. All trioxocarbonates (IV) react with dilute acids to liberate carbon (IV) oxide

$$2HCl + Na_2CO_3 \longrightarrow NaCl + H_2O + CO_2$$

3. All trioxocarbonates (IV) except Na_2CO_3, K_2CO_3 and $BaCO_3$ decompose on heating to give the oxide of the metal and carbon (IV) oxide

$$CaCO_3 \longrightarrow CaO + CO_2$$

NB: Silver trioxocarbonate (IV) [Ag_2CO_3] decomposes to give metallic silver, oxygen and carbon (IV) oxide

Test for trioxocarbonates (IV)

When warmed with dilute acids, they liberate carbon (IV) oxide