NAME

THIRD TERM E–LEARNING NOTES

SUBJECT : CHEMISTRY

SCHEME OF WORK

CLASS: S S 1

TOPIC WEEK

1. **Revision of last term's work**
2. **Acids, Bases and Salts:** Definition and Characteristics of Acids, Preparation of Acids, Reactions of Acids, Uses of Acids
3. **Acids, Bases and Salts:** Definition, Characteristics and Preparation of bases Reactions and Uses of bases, Relative acidity and alkalinity (the pH scale)
4. **Acids Bases and Salts:** definition and characteristics of salts, preparation of salts and, types of salts, uses and hydrolysis of salt in water
5. **Water:** source of water, types of water (soft and hard),water pollutants, uses of water and laboratory preparation of water
6. **Carbon and Its Compounds:** Carbon, allotropes and their structures, properties, difference between diamond and graphite, chemical properties of carbon, coal and types of coal
7. **Mid –Term Break and Holiday Assignment**
8. **Carbon and its Compounds:** carbon(IV) oxide, CO_2, preparations, properties and uses, carbon(II) oxide, CO, preparations, properties and uses. Synthetic gases, metallic trioxocarbonates; occurrences, preparation and uses, test for carbon ion

9. **Carbon and its Compounds:** hydrocarbon and its main classes, crude oil and natural gas- fractional distillation of crude oil and uses of petroleum fractions, cracking of petroleum fractions, reforming, octane number and knocking, importance of crude oil and petrochemicals

10. **Revision**

11. **Examination.**

REFERENCE TEXTS:

1 .Comprehensive Certificate Chemistry for Senior Secondary Schools by G N C Ohia et al

2. New School Chemistry for Senior Secondary Schools by Osei Yaw Ababio

3. Chemistry for Senior Secondary Schools 1 by Magbagbeola O, et al; Melrose Books and Publishers

4. **Revised edition understanding chemistry for schools and colleges by Godwin O. Ojokuku.**

WEEK 1

1. Revision of last term's work

WEEK 2

TOPIC: ACIDS, BASES AND SALTS

CONTENTS:

ACIDS

1. DEFINITION AND CHARACTERISTICS OF ACIDS
2. PREPARATION OF ACIDS
3. REACTIONS OF ACIDS
4. USES OF ACIDS

PERIOD 1: DEFINITION AND CHARACTERISTICS OF ACID

Acids are associated with the sour taste we feel when we take fruits such as lemon, lime and oranges especially when they are not ripe. Palm wine left open in the air becomes sour because of the formation of an acid.

(i) **Definition of acid**: An acid is a substance which produces hydrogen ions (or protons) as the only positive ion when dissolved in water. For example, hydrochloric acid (HCl) dissolves in water to form hydrogen ion (H^+) and hydroxyl ion (OH^-). This process is known as ionization. There are two main classes of acids: ***Organic acids and mineral or inorganic acids***. The former occur as natural products in plants or animal materials while the later can be prepared from mineral elements or inorganic matter. Acids can also be grouped into ***Strong acids (ionizes completely) and Weak acids (ionizes partially).***

Some organic and Inorganic acids

Organic acids	**Source**	**Inorganic acids**	**Constituents**
Ethanoic acids	Vinegar	Hydrochloric acid	Hydrogen, Chlorine
Citric acids	Lime, Lemon	Tetraoxosulphate (vi) acid	Hydrogen ,Chlorine, Sulphur, Oxygen
Fatty acids	Fats and Oil	Trioxonitrate (v) acid	Hydrogen, Nitrogen, Oxygen

STRENGTH OF AN ACID

Strength of an acid is defined as the degree or the extent to which an acid ionizes in water. Based on this fact, acids can be weak or strong.

Strong acids are those that ionize completely in water. Examples of strong acids are H_2SO_4, HCl, HNO_3, HBr, HI etc. For example HCl ionizes completely according to the equation below:

$HCl \rightarrow H^+ + Cl^-$ (100% ionization)

Strong acids are also strong electrolytes i.e. they have high electrical conductivity.

Weak acids are those that ionize partially in water. Examples are organic acids, such as (Ethanoic acids, Citric acids, amino acids) and some inorganic acids such as HNO_2,H_2CO_3,H_3PO_4,HF etc. For example ethanoic acid, CH_3COOH, ionizes partially in water according to the equation below:

$CH_3COOH \leftrightharpoons CH_3COO^- + H^+$

Weak acids are also weak electrolyte because they are poor conductor of electricity.

BASICITY OF AN ACID

All acids in an aqueous solution yield hydrogen ions which can be replaced by metallic ion.

The **basicity** of an acid is the number of replaceable hydrogen ions, H^+, in one molecule of the acid.

ACIDS	BASICITY
HCl	1
H_2SO_4	2
H_3PO_4	3
H_2CO_3	2
CH_3COOH	1

Characteristics of acids (Physical Properties)

1. Acids turn blue litmus paper red.
2. They have sour taste; e.g. sour taste of unripe fruits.
3. Strong acids are corrosive in concentrated form; e.g. HCl, H_2SO_4

EVALUATION

1. Define an acid and give two examples each of organic acid and inorganic acid

2. Differentiate between a strong acid and a weak acid. Give two examples of each.

3. (a) What is basicity of an acid? (b). Mention four physical properties of an acid.

4. Compare and contrast the electrical conductivity of HCl and CH_3COOH

PERIOD 2: PREPARATION OF ACIDS

1. Dissolving non-metallic oxide (acid anhydride) in water.

- Carbon (iv) oxide dissolves in water to form weak acid, trioxocarbonate (iv) acid.

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

2. Direct combination of constituent elements.

- Hydrogen reacts directly with Halogens in the presence of catalyst to form halogen acids gas which dissolves readily in water to form acid.

$$H_{2(g)} + Cl_{2(g)} \xrightarrow[heat]{Activated\ charcoal} 2HCl_{(g)}$$

3. Heating Hydrogen gas and bromine vapour, in the presence of platinum as the catalyst, produces hydrogen bromide gas, which dissolves readily in water to form hydrobromic acid.

$$H_{2(g)} + Br_{2(g)} \xrightarrow[heat]{Platinum} 2HBr_{(g)}$$

4. Displacement of weak or volatile acid from its salt by a strong acid.

- Concentrated H_2SO_4 is stronger but less volatile than HCl and, H_2SO_4 can therefore be used to displace the weaker HCl acid from its salt (NaCl).

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

  The hydrogen chloride gas formed dissolved in water readily to produce hydrogen chloride acid.

EVALUATION

Mention the methods of preparing acids

PERIOD 3: REACTION OF ACIDS (CHEMICAL PROPERTIES)

1. **Reaction of acid with metals**

Acid react with some metals to liberate hydrogen gas.

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

$Mg_{(s)} + H_2SO_{4\,(aq)} \longrightarrow MgSO_4 + H_{2(g)}$

NOTE: Dilute HNO_3 does not react with metals to produce hydrogen gas.

2. **Reaction of acids with Base and Alkalis**

Dilute acids react with bases and alkalis to form salts and water (known as ***neutralization reaction***)

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

$H_2SO_{4(aq)} + CaO_{(aq)} \longrightarrow CaSO_{4(aq)} + H_2O_{(l)}$

3. Reaction of acids with Trioxocarbonate (iv) and hydrogen trioxocarbonate (iv).

- Acid reacts with CO_3^{2-}or HCO_3^- to liberate carbon (iv) oxide (CO_2).

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

$NaHCO_3 + HCl_{(aq)} \longrightarrow NaHCl_{l(aq)} + H_2O_{(l)} + CO_{2(g)}$

EVALUATION

1. What is neutralization?

2. State three chemical properties of acids

PERIOD 4: USES OF ACIDS

Name	***Uses***
Hydrochloric acid	• in industries to make chemicals • to remove rust

Tetraoxosulphate (vi) acid	• to make chemicals • as drying and dehydrating agent • as electrolyte in lead-acid accumulators
trrioxonitrate (v) acid	• for making fertilizers, explosives, etc.
Acetic acid (ethanoic)	• In preserving food • In dyeing silk and other textiles.
Tartaric	• In making baking soda, soft drinks and health salt
Citric acid	• In making fruit juice
Fatty acids (e.g. palmitic and stearic acids)	• In manufacturing soap. (A process known as ***Saponification****)*

EVALUATION

Give three (3) uses of each of the following acids:

HCl, H_2SO_4, HNO_3, Citric acid

GENERAL EVALUATION

OBJECTIVE TEST:

1. A weak acid is one which A. is not corrosive B. is slightly ionized in water. C. does not produce salts with alkalis. D. form acid salt with water
2. The number of replaceable hydrogen ions in one molecule of an acid indicates its

A. basicity B. acidity C. alkalinity D. reactivity

3. Which gas is liberated when acid react with metals.

A.O_2 B. H_2 C. CO_2 D.NO_2

4. Reaction of acid and base to produce salt and water is

A. precipitation B. neutralization C. evaporation D. decantation

5. $H_{2(g)} + Cl_{2(g)} \xrightarrow[heat]{} 2HCl_{(g)}$. The catalyst in this reaction is

A. activated charcoal B. platinum C. yeast D. heat

ESSAY QUESTIONS:

1. Give three physical properties of an acid.

2. Write an equation for the reaction between iron fillings and tetraoxosulphate(vi) acid.

3. State how hydrogen chloride gas can be obtained from tetraoxosulphate (vi) acid

4. (a) What is basicity? (b). State the basicity of the following acids: i. HNO_3 ii. H_2SO_4 iii. CH_3COOH.

5. State the natural source of i. ethanoic acid ii. Citric acid iii. Amino acid

6. (a) Why is ethanoic acid regarded as weak acid? (b). Hydrochloric acid is regarded as a strong acid. Why?

WEEKEND ASSIGNMENT:

New School Chemistry for Senior Secondary Schools by Osei Yaw Ababio; pages 97 - 100

PRE–READING ASSIGNMENT:

Read about Bases and Alkalis

WEEKEND ACTIVITY:

How are bases prepared and, what are their characteristics?

WEEK 3

TOPIC: ACIDS, BASES AND SALTS

CONTENTS:

BASES

1. **Definition , Characteristics and Preparation of bases**
2. **Reactions and Uses of bases**
3. **Relative acidity and alkalinity (the pH scale)**

PERIOD 1: BASES

DEFINITION OF BASES

A base is a substance which will neutralize an acid to yield salt and water only. It is either an oxide or hydroxide of a metal, e.g sodium oxide, magnesium hydroxide, etc, while; an **alkaline** is a basic hydroxide which is soluble in water. Bases that are soluble in water are referred to as **alkalis.** Examples are sodium hydroxide ($NaOH$), potassium hydroxide (KOH), calcium hydroxide ($Ca(OH)_2$)

Oxides of heavy metals like PbO, ZnO and CuO are insoluble in water and are therefore bases not alkalis. CaO and MgO are slightly soluble and are alkalis. Like acids, **alkalis may be strong or weak.**

STRENGTH OF AN ALKALIS:

The strength of an alkali is the degree of its ionization in water. **Strong alkalis** are completely ionized in water. Examples of strong alkalis are potassium hydroxide, sodium hydroxide, calcium hydroxide, strontium hydroxide etc. **Weak alkalis** are partially ionized in water . example of a weak alkali is aqueous ammonia,.

CHARACTERISTICS OF BASES

1. Bases are soapy to touch, e.g. $NaOH$
2. They have bitter taste, e.g. lime water
3. They turn red litmus blue
4. Concentrated form of the caustic alkalis, $NaOH$ and KOH are corrosive
5. They are electrolytes

PREPARATION OF BASES

1. Combustion of a reactive metal in air. When electropositive metals are heated in oxygen, they form metallic oxides.

$$2Ca + O_2 \rightarrow CaO_{(s)}$$

2. By reaction of metals with water (steam)

$$Ca + H_2O \rightarrow Ca(OH)_2 + H_2$$

3. Decomposition of metal hydroxides by heating

$$Ca(OH)_2 \xrightarrow[\text{heat}]{\text{heat}} CaO + H_2O$$

$$Cu(OH)_2 \longrightarrow CuO + H_2O$$

4. Precipitation or double decomposition reaction

$$CuSO_4 + 2NaOH \longrightarrow Cu(OH)_2 + Na_2SO_4$$

5. Dissolution of metallic oxides in water

$$Na_2O + H_2O \longrightarrow NaOH$$

$$K_2O + H_2O \longrightarrow 2KOH$$

EVALUATION

1. What is a base? Give three examples.

2. (a) Differentiate between a base and an alkaline. (b) Give three uses of base

3. State three properties of bases and, mention four methods of their preparation with examples.

PERIOD 2: REACTION OF BASES

1. Reaction with acid: all bases react with acids to form salt and water only

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

2. Reaction of metallic hydroxide with heat

$$Zn(OH)_2 \xrightarrow{heat} ZnO + H_2O$$

3. Reaction with ammonium salts: alkali reacts with ammonium salts in the presence of heat to liberate ammonia gas.

$$2NH_4Cl + Ca(OH)_2 \longrightarrow CaCl_2 + 2NH_3 + 2H_2O$$

$$NaOH + NH_4NO_3 \longrightarrow NaHNO_3 + H_2O + NH_3$$

USES OF BASES

1. NaOH is the most common base and is very soluble, hence its used as a drying agent.

2. Bases are used in the making of soap.

3. $Ca(OH)_2$ is used in the neutralization of soil acidity.

4. $Mg(OH)_2$ is used in the production of toothpaste.

5. $Ca(OH)_2$ is used in the making of mortar, plaster of Paris, white wash and cement and sugar refining.

6. NH_4OH is used in weak solution as a common cleanser and grease solvent.

7. NH_3 is used in making fertilizers and detergents.

EVALUATION:

1. Describe two chemical properties of bases with examples.

2. Give 5 uses of bases with one example each.

PERIOD 3 & 4: RELATIVE ACIDITY AND ALKALINITY (THE PH SCALE)

The term pH denotes hydrogen ion index. **It is a number-scale used to express the degree of acidity or alkalinity of a solution and, the number ranges from 0 to 14.** A solution with pH value of less than 7 is acidic while that with a value greater than 7 is alkaline. A solution with pH of 7 is neutral i.e. it is neither acidic nor alkaline. The pH of a solution can be measured with an instrument called **pH meter.**

Colour	**pH number**	**Acid / Base**
Red	1 – 3	Very acidic
Orange	4 – 5	Weak acid
Yellow	6	Very weak acid
Green	7	Neutral
Blue	8	Very weak base
Indigo	9 – 10	Weak base
Violet	11 – 14	Very basic

pH range and colour changes of universal indicator

Logarithmic pH scale: Sorensen, in 1909, introduced the logarithmic pH scale to eliminate the inconvenience encountered when using negative indices and to give room for wide range of $[H^+]$and $[OH^-]$ concentrations that we do come across in acid-base reactions. **He defined pH as the negative logarithm of the hydrogen ion concentration to the base 10.** For example, if the hydrogen ion concentration of an aqueous medium is 10^{-5} mol dm^{-3}, the acidity of the solution could be written in terms of pH as follows:

$[H^+] = 10^{-5}$

Log $[H^+] = \log 10^{-5} = -5$

$pH = -\log [H^+] = -(-5) = 5$

Thus, if $[H^+]$ is 10^{-x}, then pH = x

Proportional to each other:

$[H^+] [OH^-] = 10^{-14}$

$P^H + P^{OH} = 14$, where P^{OH} is the hydrogen ion index

pOH = 14 – pH

Note: A high pH value indicates low H^+ concentration (weak acidity) and a high OH^- concentration (strong alkalinity). At neutrality, $[H^+] = [OH^-] = 10^{-7}$

Worked Example

1. Calculate the pH of 0.005 moldm^{-3} tetraoxosulphate (vi).

Solution

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$$

$H^+ = [2 \times 0.005]$ moldm^{-3}

$= 0.001 = 1 \times 10^{-2}$

pH = -log $[H^+]$

pH = -log $[1 \times 10^{-2}]$

pH = 2

EVALUATION

1) (a) Define the term P^H. (b) Calculate the pH of 0.01 M tetraoxosulphate (VI) acid solution.

GENERAL EVALUATION

OBJECTIVE TEST:

1. pH of 0.001 M acid is A. 2 B. 3 C. 4 D. 1

2. Which pH value indicates a basic solution? A.-1 B. 7 C. 9 D. 3

3. A solution of pH 7 is A. acidic B. basic C. neutral D. alkaline

4. Bases can be prepared by the following method except: A. Combustion of a reactive metal in air. B. Dissolution of metallic oxides in water. C. By reaction of metals with water (steam). D. Precipitation or double decomposition reaction.

5. Which is correct? $Zn(OH)_2 + \text{Heat} \longrightarrow H_2O + ?$ A. ZnO B. ZnO_2 C. H_2 D. $ZnCl_2$

ESSAY QUESTIONS

1. Mention 3 different methods by which you could prepare bases in the laboratory. Write an equation to illustrate each method.

2. (a). Define pH and P^{OH}. (b) What is the relation pH and P^{OH} of an aqueous solution? (c) Determine the pH of a solution containing $0.05moldm_{-3}$ $NaCO_3$.

3. Distinguish between (i) a strong base and a week base. (ii) a Base and an Alkaline.

4. A glass cup of orange juice is found to have P^{OH} of 11.40. Calculate the concentration of the hydrogen ions in the juice.

5. Find the hydrogen ion, H^+ and hydroxide ion, OH^- concentration in 0.02M solution of H_2SO_4.

WEEKEND ASSIGNMENT:

New School Chemistry for Senior Secondary Schools by Osei Yaw Ababio;

WEEKEND ACTIVITY

1. List three Deliquescent and Hygroscopic substances each.

2. Mention five types of salts.

WEEK 4

TOPIC: ACIDS, BASES AND SALTS

CONTENTS:

SALTS

1. definition and characteristics of salts
2. preparation of salts and
3. types of salts
4. uses and hydrolysis of salt in water

PERIOD 1: SALTS

Definition of salts

A salt is formed when all or part of the ionizable hydrogen of an acid is replaced by metallic or ammonium ions. It consists of all aggregation of positively charged metallic ion and negatively charged acid ions.

Characteristics of salts

1. Water of crystallization: This can be defined as the definite amount of water that some substances chemically combine with when they form salt and such salts are referred to as **hydrated** salts. When heated, they give off their respective water of crystallization and by so doing become **anhydrous** salt. When hydrated, they are crystalline in shape but when heated and the water of crystallization is released, there's a loss of crystalline shape. Examples of salt with water of crystallization are sodium trioxosulphate(IV) decahydrate, $Na_2SO_3 .10H_2O$, Iron(II) tetraoxosulphate(VI) heptahydrate, $FeSO_4.7H_2O$, sodium trioxocarbonate(IV) decahydrate, $Na_2CO_3.10H_2O$ etc.

2. **Efflorescence:** This is the loss of part or all of the water of crystallization from a crystalline salt when exposed to the atmosphere to form a lower dehydrate or the anhydrous salt; e.g. Na_2CO_3 $10H_2O$ (washing soda).

3. **Deliquescence:** This is a phenomenon in which a substance absorbed moisture (water) from the atmosphere when exposed and turn into solution; e.g. $CaCl_2$, $FeCl_3$, , $CuCl_2$, $ZnCl_2$ etc.

4. **Hygroscopic:** This is a phenomenon in which a substance absorbed moisture (water) from the atmosphere when exposed and does not turn into solution but merely become sticky or moist; e.g. sodium trioxonitrate(V), potassium trioxonitrate(V). Hygroscopic substances are commonly employed as drying agents or desiccants.

Drying agents or desiccants are substances that have strong tendency to absorb moisture or water. They are used to dry gases in the laboratory. A drying agent cannot be used if it reacts with the substance to be dried;, that is why H_2SO_4 cannot be used to dry ammonia gas because they will react to form ammonium tetraoxosulphate (vi).

$$\mathbf{2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4}$$

EVALUATION:

State three properties of salts with two examples each.

PERIOD 2: PREPARATION OF SALTS

The method chosen to prepare a salt depends largely on (a) its solubility in water (b) its stability to heat.

A. Preparation of soluble salts

1. Reaction of acid and metal: Here, the more reactive metal (Ca, Mg, Zn, Fe), directly displaces the hydrogen ion in the acid; e.g.

$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$

2. Reaction of alkaline and acid: Salts are formed when acid reacts with alkaline; e.g.

$KOH + HNO_3 \longrightarrow KNO_3 + H_2O$

3. Dilute acid and insoluble base: A salt is formed when a dilute acid is heated and the insoluble base is added to the acid until no more bases can dissolve in the acid. E.g $2HCl + CuO \rightarrow CuCl_2 + H_2O$

B. Preparation of insoluble salts

1. Double decomposition: This is done by missing two compounds, one containing the metallic radical and the other the acidic radical of the required insoluble salt; e.g. $H_2SO_4 + CuO \longrightarrow CuSO_4 + H_2O$

2. Combination of constituent elements: This involves the combination of the elements that make up the insoluble salt; e.g.

$Fe + S \longrightarrow FeS$

$2Fe + 3Cl_2 \longrightarrow 2FeCl_3$

EVALU ATION

1. Name two salts which can be prepared by titration and, describe two methods of preparing soluble salts.
2. Explain with two examples the term efflorescence
3. When is a substance said to be deliquescence. Explain with examples.
4. Common salt (NaCl) becomes wet on exposure to air. Explain.
5. What are dehydrating agents? Explain the function of fused calcium (II) chloride in the desiccator.

PERIOD 3: TYPES OF SALTS

There are five main types of salts. They are: normal salts, acid salts, basic salts, double salts and complex salts.

1. Normal salt: Formed when all the replaceable hydrogen ions in the acid have been completely replaced by metallic ions.

$$H_2SO_4 + ZnO \longrightarrow H_2O + ZnSO_4$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

2. Acid salt: Formed when the replaceable hydrogen ions in acids are only partially replaced by a metal and are acidic to litmus paper; e.g.

$$H_2SO_4 + NaOH \longrightarrow NaHSO_4 + H_2O$$

3. Basic salt: Formed when there is an insufficient acid to neutralize a base; e.g.

$$Ca(OH)_2 + HCl \longrightarrow Ca(OH)Cl + H_2O$$

$$Zn(OH)_2 + HCl \longrightarrow Zn(OH)Cl + H_2O$$

4. Double salt: Ionizes to produce three different types of ions in solution. Usually two of these are positive charged, while the other is negatively charged; e.g. potash alum or aluminum potassium tetraoxosulphate(vi)duodecahydrate, $KAl(SO_4)_2.\ 12H_2O$

$$KAl(SO_4)_2.12H_2O \rightarrow K^+ + Al^{3+} + 2\,SO_4^{2-} + 12H_2O$$

5. Complex salts : Complex salts ionize in water to complex ions; e.g. sodium tetrahydroxozincate (II), $Na_2Zn(OH)_4$ and potassium hexacyanoferrate (II), $K_4Fe(CN)_6$.

$K_3[Fe(CN)_6] \rightarrow 3K^+ + [Fe(CN)_6]^{3-}$

PERIOD 4: USES AND HYDROLYSIS OF SALTS

USES OF SALTS

1. Sodium chloride is used in preserving food

2. Salt are used as drying agents and antifreeze

3. Salt is used in soap making process to separate soap from glycerin

4. It is used in softening of water e.g. Na_2CO_3 $10H_2O$

5. Used in Stabilizing dirty roads

6. Used in the production of toothpaste.

HYDROLYSIS OF SALTS

When salt is dissolved in water a solution which is either acidic or basic is formed. The reaction of a salt with water to form acidic or basic solution is known as **Hydrolysis.** . However, when other salts are dissolved in water solutions that are not neutral are formed. These solutions may either be acidic or alkaline.

The solution of a salt of strong acid and a weak base will be acidic while a salt of a weak acid and a strong base will be alkaline.

. **Examples:** $NH_4Cl + H_2O \longrightarrow NH_4OH + HCl$

$CuSO_4 + 2H_2O \longrightarrow Cu(OH)_2 + H_2SO_4$

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

$K_2CO_3 + 2H_2O \longrightarrow 2KOH + H_2CO_3$

EVALUATION

1) Give five types of salts with examples.
2) What are the uses of salts? Define hydrolysis.
3) Differentiate between a normal salt and acidic
4) What is salt? Give five examples.

GENERAL EVALUATION

OBJECTIVE TEST :

1. An example efflorescence compound is A. BaCl B. KOH C. $CaCl_2$ D. $Na_2CO.10H_2O$
2. Which of the following compounds will form solution when exposed to air? A. $Na_2CO.10H_2O$ B.$NaNO_3$ C. $CuSO_4$D. $CaCl_2$

3. The following salts dissolve readily in water **except** A.$CaCl_2$ B. Na_2SO_4 C. $(NH_4)_2SO_4$ D. $PbSO_4$

4. Alums are classified as A. Normal salt B. basic salt C. Double salt D. Simple salt

5. Water in crystalline salts provides A. hydrated bonds and colour B. colour and shape C. Colour and solubility base

D. Shape and crystal lattice

ESSAY QUESTIONS

1. Explain and give an example each of (a) deliquescent substance (b) hygroscopic substance (c) efflorescent substance.
2. Give three general methods of preparing salts. Give equations for the examples.

How would you prepare pure dry potassium trioxonitrate(V). (b) What product is always is obtained in the neutralization reaction?

3. Define is water of crystallization? Give two examples of salts that possess this water.

(a) What is salt? Give four examples. (b) What is obtained when water is driven out from a hydrated salt by heat?

WEEK 5

TOPIC: WATER

CONTENTS:

1. SOURCE OF WATER
2. TYPES OF WATER (SOFT AND HARD)
3. WATER POLLUTANTS
4. USES OF WATER AND LABORATORY PREPARATION OF WATER

WATER

"Water is Life". It is the most important and the most abundant on earth. It is of great importance to all plants and animals. The human body is over 6o percent water and it is present in equally the same amount in plants. It should however be noted that water is not available everywhere and its availability at certain parts of the world has led to the influx of man to those areas to set up villages and towns.

PERIOD 1: SOURCE OF WATER: Water can either be found as a natural source or as treated water. There are many sources of water found on the earth's surface, they include rain water, spring water, well-water, river water, lake water and sea-water. Rain water is the purest form of natural water because it is formed as a result condensation of water in the atmosphere. Spring water contains a considerable amount of mineral salt; but very little suspended impurities such as dust and bacteria. Well-water contains a lot or clay and other mineral salts. Deep well-water tends to be less polluted than surface well-water. River water, Lake water and Sea-water contain a lot of dissolved air, mineral salts, bacteria and organic remains.

All these waters have to be purified before they can be used for drinking. And all the type of natural water are in constant circulation, forming a gigantic water cycle.

TREATED WATER

Treated water are usually prepared for special purposes. Examples are distilled water, pipe-borne water for townships and chlorinated water used in swimming pool.

DISTILLED WATER

Distilled water is chemically pure water prepared by condensing steam using Lie big condenser. If ion exchange resin is used in preparing the water, it is called ionized water.

EVALUATION

1. (a) List four sources of water. (b) Which of the listed source of water in (a) is the purest? Give reason.

2. Explain the how distilled water is obtained.

PERIOD 2: TYPES OF WATER (SOFT AND HARD)

Water is of two types namely: Soft water and Hard water.

1. Soft water: Water is said to be soft if it readily forms lather with soap. Examples are rain water, tap water.

2. Hard water: Hard water is water which will not form lather with soap. Examples are river water, lake water, stream water and sea water.

Types of hard water

There are two types of hard water namely:

1.. Temporary hard water: This the hardness caused by the presence of dissolved $Ca(HCO_3)$ and $MgCO_3$ in water and can be removed by boiling.

2. Permanent hardness: This is the hardness caused by the presence of $CaSO_4$, $MgSO_4$ and chlorides which cannot be removed by boiling but by addition of washing soda, caustic soda and ion exchange method.

Advantages of hard water

1. It has pleasant taste than soft water and tasteless water.

2. It does not dissolve lead pipes of pots unlike soft water which dissolves led pipes.

3. It is good for healthy teeth and bones because it contains calcium which is an important element in formation of teeth and bones of animals.

4. Animals like snail and crabs are able to make their shell with the help of hard water.

Disadvantages of hard water

1. It causes furring of kettle and boilers unlike soft water.
2. It infers with processes used to dye materials and tan hides.
3. It forms scum with soap thus, wasting soap unlike soft water.

EVALUATION

1. What are the natural sources of water
2. Differentiate between soft water and hard water
3. Mention three (3) advantages and two (2) disadvantages of hard water

PERIOD 3: WATER POLLUTANTS

The common pollutants are as follows:

(a). Crude oil spill: Accidents and carelessness in oil rigs and tankers cause oil spills mainly in the coaster waters. The oil floats on water and kills most of the marine life in the affected areas. The oil is then washed up on the beach, temporarily preventing people from using the water for recreation.

(b). Industrial and agricultural waste: Chemical wastes from industries and agriculture; such as acids, organic solvents, mercury compounds, fertilizers, insecticides, etc that are emptied directly into rivers untreated causes water pollution and endangers aquatic life. For instance, mercury compounds accumulate in the body of the aquatic organism like fish and this eventually causes food poison in the animal that feeds on such fish.

(c) Refuge and sewage: It is common practice to see people dump refuse and human wastes into a nearby river. Most of these refuge and sewage are pollutants which are biodegradable i.e. they can decomposed by decomposers such as bacteria which uses up the oxygen present in the water.

EVALUATION

1. Mention two sources of water pollution.
2. Briefly discuss how polluted water can be treated.

PROPERTIES OF WATER

Physical Properties of Water

1. Pure water is colourless, odourless and tasteless.
2. It is a liquid at room temperature.
3. It boils at 100^oC and freezes at 0^OC.
4. It has a density of 1 gcm^{-3} at 4^Oc.
5. It is neutral to litmus.

Chemical Properties of Water

1. Water reacts with metals such as Sodium, potassium, calcium etc forming alkalis with the liberation of hydrogen gas.
2. Water reacts with non- metals e.g carbon with the liberation of Carbon(II) oxide and hydrogen gas.
3. Water reacts with sodium oxide and potassium oxide with the formation of strong alkalis such as sodium hydroxide and potassium hydroxide.

PERIOD 4: USES OF WATER AND LABORATORY PREPARATION OF WATER

1. Water is used for cooking and drinking.
2. It is used as a means of transport.
3. It is used in the manufacturing of drugs.
4. It is also used in car batteries
5. It is used in the laboratory for preparing reagents and for carrying out analysis.

LABORATORY PREPARATION OF WATER

Water is prepared from its constituent elements, i.e. hydrogen and oxygen. Hydrogen is generated by the action of fairly concentrated hydrochloric acid on zinc. The gas then passed through a U-tube containing anhydrous calcium chloride gas, the hydrogen is burnt at a jet and the vapours are 'cooled' when they come in contact with a clean can kept cool by water. A test tube is placed over the jet to collect hydrogen gas by displacement of air. When the test tube is full of gas, it burns on the application of to it, light the jet and allow the flame to burn very close to the can. Moisture will condense on the can and will drop into a dish which is placed below the liquid.

The liquid can be shown as water using:

- Action of the liquid on anhydrous copper(II) tetraoxosulphate (VI) and cobalt(II) chloride salt.
- Boiling point of the water.

EVALUATION

1. What are the pollutants that can be present in water
2. (a) Give four uses of water. (b) How can water be prepared in the laboratory?
3. Distinguish distilled water from treated water.

GENERAL EVALUATION

OBJECTIVE TEST

1. One of these is not a water pollutant: A. petroleum B. industrial effluents C. biodegradable chemicals D. domestic liquid and solid water

2. Temporal hardness of water is removed by the use of the following except: A. boiling B. use of Na_2CO_3 C. use of $Ca(OH)_2$ D. $MgSO_4$

3. Water is temporarily hard because it contains A. $CaSO_4$ B. $MgSO_4$ C. Chlorine D. $Ca(HCO_3)_2$

4. Natural water collected from rivers and ponds contain oxygen, CO_2 and A. hydrogen B. nitrogen C. SO_2 D. Chlorine

5. A sample of water which has passed through a de-ionizer may contain A. temporal hardness B. permanent hardness C. Heavy metal ions D. organic impurities.

ESSAY QUESTIONS

1(a). Mention two types of hardness of water

(b). List two salts that cause each of them.

2. Describe an experiment to show that contains hydrogen and oxygen only

3. What term is used to describe water sample that: (a) produce lather with soap (b) does not produce lather with soap.

4. State two advantages of soft water over hard water. (b) List two advantages of hard water.

5. Enumerate three water pollutants you know.

WEEKEND ASSIGNMENT:

Read New School Chemistry for Senior Secondary Schools by Osei Yaw Ababio; pages 298 - 302

PRE–READING ASSIGNMENT:

Read about carbon and its compounds.

WEEKEND ACTIVITY

(a)Describe the structure of carbon atom and its properties.(b) What are the allotropes of carbon.

WEEK 6

TOPICS: CARBON AND ITS COMPOUNDS

CONTENT:

1. CARBON, ALLOTROPES AND THEIR STRUCTURES,

2. PROPERTIES, DIFFERENCE BETWEEN DIAMOND AND GRAPHITE

3. CHEMICAL PROPERTIES OF CARBON

4. COAL AND TYPES OF COAL

PERIOD 1: CARBON, ALLOTROPES AND THEIR STRUCTURES

Carbon is a non -metal found in group 4 of the periodic table. It occurs naturally as diamond and graphite. These physically different forms of the same chemical element are known as **allotropes.** Other elements that exist in different forms in their free states include tin, Sulphur and phosphorus. Also, it occurs in an impure form as coal and in the combine state as petroleum, wood and natural gases.

Atomic structure of carbon

Carbon is the sixth element in the periodic table. the nucleus its atom it composed of six proton and six neutron and surrounded by six electron;2 in the first energy level (k-shell) and four in the 2nd energy level (L-shell).its orbital configuration is $1S^2 2S^2 2P^{2.}$Carbonatom has four valency electrons. Carbon atoms are able to catenate, i.e. join to one another by covalent bonds in a continuous fashion. The phenomenon is called catenation.

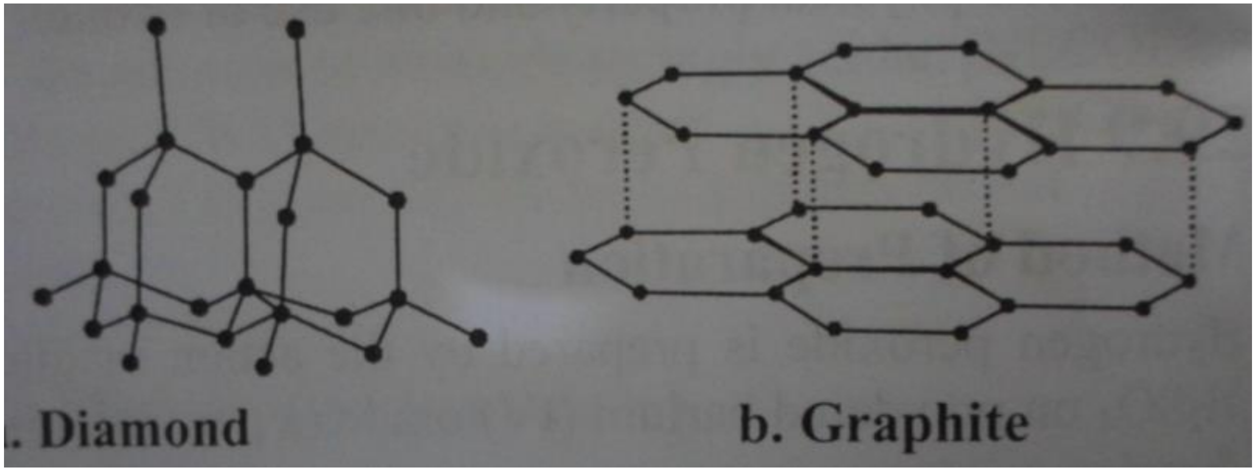
Allotropes of carbon

Allotropy is the existence of an element in the same physical state but indifferent forms. The various forms are called ***allotropes.*** Carbon exhibits allotropy. Other elements that also exhibit allotropy are sulphur, Tin, Oxygen and Phosphorus. The two crystalline allotropes of carbon are: Diamond and graphite. Charcoal is amorphous. allotrope of carbon.

Diamond

Structure and Bonding

In diamond, each carbon atom is at the center of a regular tetrahedron and covalently bonded to four other atoms in a strong compact fashion. The covalent linking between the atoms is continuous to produce a single infinite tightly locked 3-dimensional giant (macro) molecule, which has a network octahedral structure see the diagram below:



The rigidity of the structure is responsible for the hardness of diamond; it is the hardest known substance. Since the covalent bonds are strong and the molecule is compact, the melting point of diamond is very high.

PHYSICAL PROPERTIES OF DIAMOND

1. Pure diamond is hard, colourless and transparent.

2. Forms octahedral crystals with high refractive index.

3. It is very hard; it has a density of 3.5gcm^{-3}, and melting point of 3600^{0}C.

4. It does not conduct electricity, because all the four valence electrons per carbon atom are used in bonding i.e.no mobile electrons.

5. It is insoluble in any solvent.

USES OF DIAMOND

1. Because of its high refractive index and amazing metallic luster when cut, it is used in jewelries.

2. Because of its hardness, diamond is used in cutting glasses, in drilling rocks; in boring of holes; in making bearings in engines; and as an abrasive, i.e.to smoothen rough surfaces.

GRAPHITE

Structure and Bonding

In graphite, each carbon atom is covalently bonded to three other atoms to produce an infinite two-dimensional flat hexagonal layer structure, which is strong and hard. See the diagram above. The flat hexagonal layers in graphite are held together by the weak van der Waals attractive forces, which allow movement of the planes parallel to each other, and make the graphite to be soft and slippery. The fourth electron in the valence shell of each carbon atom in graphite is mobile, because it is not used in bonding, and account for its electrical conductivity.

EVALUATION

1. Define the term allotropy.

2. What is the structure of? (a) diamond (b) graphite.

3. Give the reason why diamond is hard, while graphite is soft.

PERIOD 2: PROPERTIES, DIFFERENCE BETWEEN DIAMON AND GRAPHITE

Physical properties of graphite

1. Graphite form soft, black and opaque hexagonal crystals, which are greasy to feel. The softness is due to the ability of the adjacent layers to slide over one another.
2. It is hard. Its density is 2.3gcm^{-3}, and melts at about 3500^{0}c.
3. It is good conductor of heat and electricity-due to the presence of a mobile electron per carbon atom.
4. It is soluble in any solvent. Graphite is an example of a non –metallic conductor.it is a metalloid.

USES OF GRAPHITE

1. Graphite is used as a lubricant, because of its flat hexagonal layer which can slide over one another.

2. Used as inert electrodes during electrolysis and for brushes of electric motors been a good conductor of electric current.

3. When mixed with clay, graphite forms lead, which is used in making lead pencils. The hardness of a pencil depends on the amount of clay in the mixture. Soft pencils contain more of graphite, while hard pencils contain more of clay.

4. Used in making crucible, because of its high melting point.

5. Used in nuclear reactors; being soft and with a high melting point.

DIFFERENCE BETWEEN DIAMOND AND GRAPHITE

DIAMOND PROPERTIES	GRAPHITE PROPERTIES
1. Diamond is a transparent solid that sparkles when cut and polished	Graphite is an opaque solid, with a metallic luster

2. It is octahedral in shape	It is hexagonal in shape
3. Its density is 3.53.5gcm^{-3}	Its density is 2.33.5gcm^{-3}
4. It is a poor conductor of electricity	It is a good conductor of electricity
5. It is an inert substance but at 900^0c, it burns in air to form carbon(iv) oxide and combines with fluorine	It is a more reactive substance burns in air to form carbon (iv) oxide at 7000c, it also reacts with oxidizing agents to form oxides, it also reacts with fluorine and tetraoxosulphate(vi) acid
6. It is the hardest substance known	It is one of the softest minerals known.

EVALUTION

1. List 3 uses of graphite with reasons.

2. Give four differences between diamond and graphite.

PERIOD 3: CHEMICAL PROPERTIES OF CARBON AND TYPES OF COAL

CHEMICAL PROPERTIES OF CARBON

1. Combustion reaction

Carbon burns in limited supply of air to form carbon (II) oxide equation for the reaction is given as

$2C(s) + O_{2(g)} \longrightarrow 2CO(g)$

In excess air, complete combustion takes place and carbon(Iv) oxide is formed. Equation for the reaction is given as.

$C(s) + O_2 \longrightarrow CO_{2(g)}$

When charcoal is used as fuel, it burns released is used for cooking (exothermic reaction)

NOTE: Carbon occurs most abundantly both naturally as diamond and graphite and in numerous compounds including petroleum coal, natural gas among others.

2. Combination reaction:

Carbon combines directly with certain elements such as Sulphur, hydrogen, calcium and aluminium at a very high temperature.

$C + 2S \rightarrow CS_2$

$2C + Ca \rightarrow CaC_2$

3. **As a reducing agent.**

Carbon is a strong reducing agent. It reduces the oxides of a less active metals.

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

4. Reaction with strong oxidizing agent. Trioxonitrate (v) acid oxidizes carbon to carbon (iv) oxide

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

COAL AND TYPES OF COAL

COAL: This is one the two most principal sources of fuel and energy, the other being petroleum. Coal was found as a result of complex chemical and physical changes when the remains of forest were buried under the earth millions of years ago under great pressure in the absence of air.

Coal is found in great abundance in very many parts of the world including Nigeria. Coal is a complex mixture of hydrocarbons (compounds of carbon and hydrogen) and other organic and inorganic compounds containing small amounts of nitrogen, sulphur and phosphorus as impurities.

Types of Coal

Coal is derived from wood; it naturally contains a lot of carbon. There are four main types of coal, arising from the progressive variation in their carbon content. They are:

1. Peat-like coal: contains about 60% of carbon.
2. Lignite coal: contains about 70% of carbon.
3. Bituminous coal: contains about 85% of carbon. This is the type that is mostly used for our everyday domestic application.
4. Anthracite coal: contains about 94% of carbon.

The carbon content of each type of coal reflects its rank or degree of classification. Based on carbon content, the different types of coals are put into ranks as follows: Peak → Lignite → Bituminous → Anthracite

Coal is used mainly as a fuel to generate power for station engines, factories and electric parts. It is also used for making various chemicals.

EVALUATION1. Carbon occurs most abundantly both naturally as _________ and ______

2. With two equations only, describe the combustion of carbon allotropes.

3. Mention four types of coal

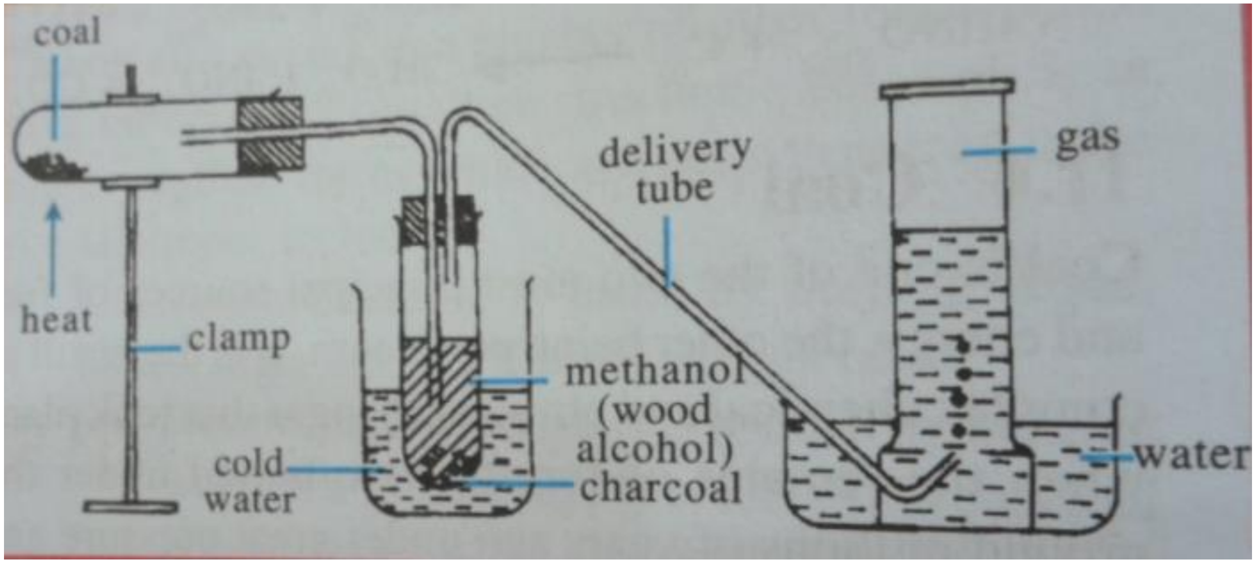
PERIOD 4: DESTRUCTIVE DISTILLATION OF COALAND GASIFICATION OF COAL

DESTRUCTIVE DISTILLATION OF COAL

Destructive distillation of coal involves heating of coal to a very high temperature (600---1200^{o}C) in the absence of air. During the process, coal decomposes to give coal gas, coal tar, ammoniacal liquor and coke as the main products.

Coal + *heat* → coal gas + coal tar + ammoniacal liquor + coke

The process is also known as industrial distillation of coal. The destructive distillation of coal can be carried in the laboratory using the set up below.



Uses of product of destructive distillation of coal

1. Coal gas: Coal gas is a gaseous mixture of hydrogen, methane, carbon (ii) oxide and small amount of ethane, hydrogen sulphide and Sulphur (iv) oxide. The main use of coal gas is as fuel. It is cleaner and more efficient than coal and solid or liquid fuel.

2. Coal tar: Coal tar, a thick brownish-black liquid, is a mixture of many organic chemicals including benzene, toluene, phenol, naphthalene and anthracene. The components can be separated by fractional distillation and are used for the manufacture of commercial products including drugs, dye, paints, insecticides, explosives, etc.

3. Ammoniacal liquor: This an aqueous solution containing mainly ammonia and is used in the manufacture of ammonium tetraoxosulphate(iv), $(NH_4)_2SO_4$.

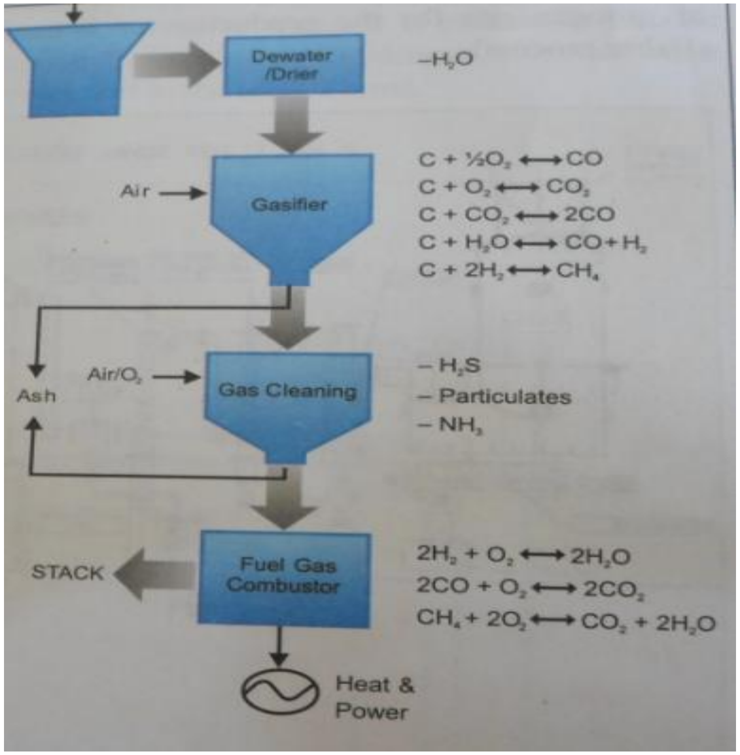
4. Coke: Coke is non-volatile residue which contains about 90% of amorphous carbon and is chemically similar to hard coal. Coke is used in the manufacture of carbide, as a fuel and as a reducing agent in the extracting of metals. Coke is used to make producer gas and water gas through a process called gasification.

Uses of Coke

1. It is used as fuel both industrially and domestically
2. It is used to manufacture carbide used in production of ethyne.
3. It is a reducing agent in the extraction of metals from their ores.
4. It is used in the production of graphite.

GASIFICATION OF COKE:

Gasification of gas is the conversion of coke to combustible gases by incomplete oxidation with steam and air at 1000^oC . Partial oxidation of coke with air and steam gives producer gas and water gas respectively.



GASIFICATION OF COKE

Producer gas: This is a mixture of one-third of carbon(II)oxide and two-thirds nitrogen by volume. It is obtained by heating coke in a furnace in a limited. This is achieved by passing air through red hot coke. During the process, coke is oxidized to carbon (IV) oxide which is subsequently reduced by the hot coke to carbon (II) oxide, a combustible gas. The process can be represented by the following equations.

$$O_2 + 4N_2 + 2C \rightarrow 4N_{2(s)} + 2CO_{(s)} + \text{heat}$$

Uses of producer gas

1. Producer gas is used as fuel in furnaces, retorts and limekilns.
2. It is used as a source of nitrogen for the manufacture of ammonia.

Water gas

Water gas is produced by passing steam through hot coke at 1000°C. This results in reduction of the steam; carbon (II) oxide and hydrogen are formed. Water gas is mixture containing hydrogen and carbon (II) oxide in equal volume.

$C_{(s)} + H_2O_{(l)} \rightarrow CO_{(s)} + H_2$

Water gas has a high calorific value because both carbon (II) 0xide and hydrogen are combustible, whereas the calorific value of producer gas is low because nitrogen which is one of its constituents is not combustible

Uses

1. Water gas is used as a fuel.
2. It is used as a source of hydrogen and other organic compounds.

EVALUATION

1. Differentiate between water gas and producer gas.
2. What is gasification of coke?
3. Highlight 4 main products of destructive distillation of coal. State their uses.
4. Explain briefly, how destructive distillation of coal is obtained.

GENERAL EVALUATION

OBJECTIVE TEST:

1**.** Carbon is often deposited in the exhaust pipes of cars because of the (a) Presence of carbon (b) Incomplete combustion of petrol (c) excessive use of petrol. (d) use of impure fuel.

2. Destructive distillation of coal means --------- (a) heating coal in plentiful supply of air (b) heating coal in the absence of air. (c) conversion of coal to gas (d) destroying coal to produce gas.

3. An aqueous sodium trioxocarbonate(vi) solution is alkaline because the salt is ___________(a) soluble in water (b) a basic salt (c) fully ionized in water (d) hydrolyzed in water

4. The following statements about graphite are correct except that it _____________. (a) has octahedral structure (b) is soft (c) is used as a lubricant (d) has a network structure

5. The following can be obtained directly from the destructive distillation of coal except. (a) ammoniacal liquor (b) producer gas(c) coal gas (d) tar

6. Water gas is a mixture of A. CO_2 and H_2 B. CO_2 and H_2O C. CO_2 D. CO and H_2
7. The liquid product from the destructive distillation of coal is A. ammoniacal liquor B. Coal fume C. Dyestuff D. coal plasma
8. Producer gas is with a low heating power because it contains more A.CO_2 than O_2 B. nitrogen than carbon (II) oxide C. CO_2 than nitrogen D. nitrogen than CO

ESSAY QUESTIONS

1. What do you understand by the term allotropy?

2. Mention two main types of allotropes of carbon.

3. Differentiate the two main types of allotropes of carbon with their diagrams only

4. In a tabular form, differentiate between the two main types of allotropes of carbon.

5. Mention three amorphous or non-crystalline forms of carbon

6. What do you understand by the term gasification of coke?
7. Give the products of gasification of coke..

WEEK 8

TOPIC: CARBON AND ITS COMPOUND

CONTENT:

1. CARBON(IV) OXIDE (CO_2): PREPARATIONS, PROPERTIES AND USES.

2. CARBON(II) OXIDE, CO: PREPARATIONS, PROPERTIES AND USES. SYNTHETIC GASES

3. METALLIC TRIOXOCARBONATES; OCCURRENCES, PREPARATION AND USES.

4. TEST FOR CARBON ION

PERIOD 1: CARBON(IV) OXIDE: PREPARATION AND USES

FORMATION / PREPARATION OF CARBON(IV) OXIDE (CO_2)

In excess air, there is complete combustion; carbon (iv) oxide is produced but in the limited supply of air carbon normally reacts with oxygen to produce carbon(ii) oxide. The equation of reaction is given below for the two reactions.

$C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ + heat (sufficient supply of air)

$2C_{(s)} + O_{2(g)} \longrightarrow 2CO_{(g)}$ + heat (limited supply of air)

Other methods of preparation of CO_2 are:

1. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$
2. The decomposition of trioxocarbonates(IV) salts [except those of Sodium and Potassium] or hydrogen trioxcarbonate(IV) salts, by strong heat e.g

$CaCO_{3(s)} \longrightarrow CaO_{(s)} + CO_2$

$2NaHCO_{3(s)} \longrightarrow Na_2CO_{3(s)} + H_2O + CO_{2(g)}$

3. Action of dilute mineral acid on trioxocarbonate(IV) or hydrogentrioxocarbonate(IV)salt e.g.

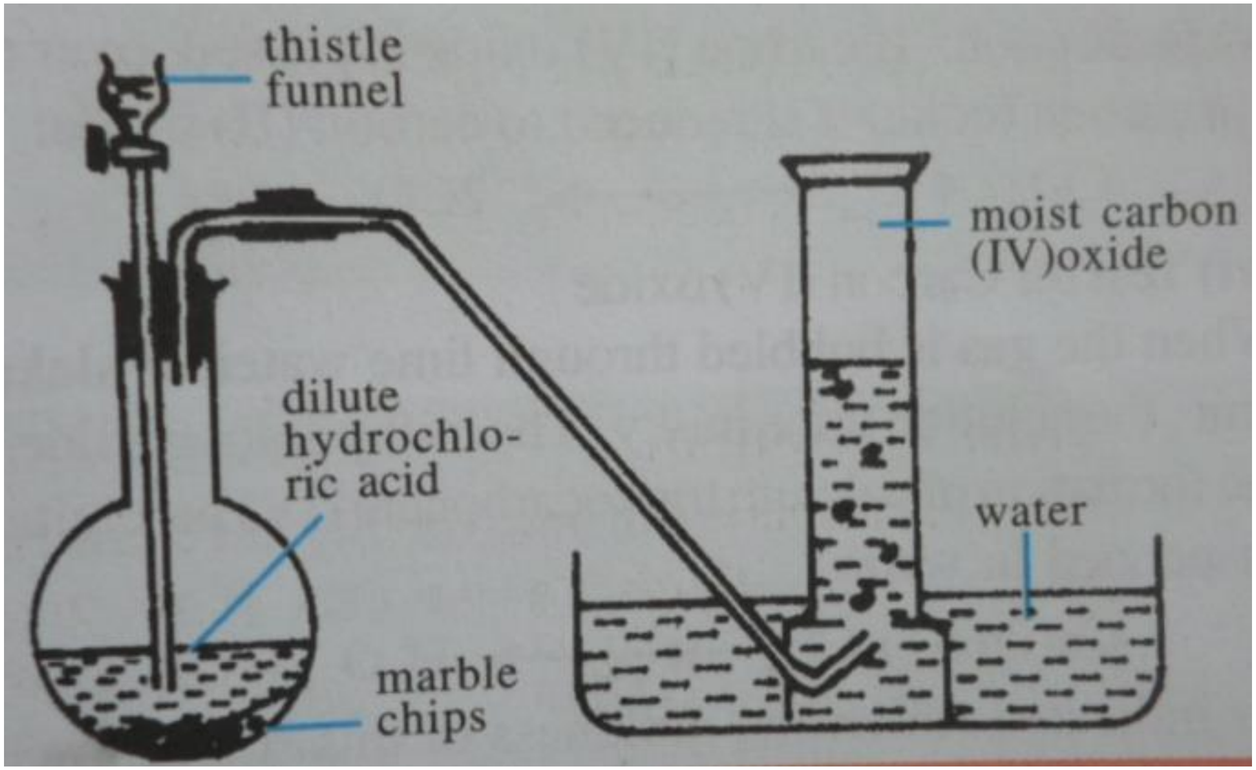
$Na_2CO_{3(s)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

$KHCO_{3(s)} + HNO_{3(aq)} \longrightarrow KNO_{3(aq)} + H_2O_{(l)} + 2CO_{2(g)}$

(iv) The fermentation of glucose by enzyme (zymase)

$C_6H_{12}O_{6(ag)}) \longrightarrow 2C_2H_5OH_{(aq)} + 2CO_{2(g)}$

LABORATORY PREPARATION OF CO_2 GAS



The equation for the reaction is given as shown below

$$CaCO_{3(s)} + HCl_{(aq)} \longrightarrow CaCl_{2(aq)} + H_2O + CO_{2(g)}$$

Pure and dry CO_2 is obtained by passing the gas through a solution of potassium hydrogentrioxocarbonate(IV) [$KHCO_3$] to remove the acid impurities, hydrogen chloride and then, through conc. H_2SO_4 (or fused $CaCl_2$ to dry the gas. It is then collected by downwards delivery, being denser than air as in the diagram above.

PHYSICAL PROPERPIES OF $CO_{2(g)}$

1. It is a colourless and odourless gas.
2. It does not support combustion
3. It is heavier or denser than air.
4. It is easily liquefied at low temperature with pressure higher than 5 atmospheres.

CHEMICAL PROPERTIES OF $CO_{2(g)}$

1. It dissolves in water to give trioxocarbonate(IV) acid, $H_2CO_{3(aq)}$

   $$H_2O + CO_2 \longrightarrow H_2CO_{3(aq)} \rightleftharpoons 2H^+ + CO_3^{2-}{}_{(aq)}$$

   ∴ CO_2 is an acid anhydride of H_2CO_3
2. It turns damp blue litmus paper red
3. It neutralizes the base [NaOH, KOH] to give salt and water only.

   $$CO_2 + 2NaOH_{(aq)} \longrightarrow Na_2CO_{3(aq)} + H_2O$$

   When a large excess of the gas is used an acid salt is formed as shown in the equation above;

$Na_2CO_{3(aq)} + H_2O + CO_{2(ag)} \longrightarrow 2NaHCO_{3(aq)}$

4. It acts as an oxidizing agents as shown in the reaction below.

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

   (b) $2M_{g(s)} + CO_{2(g)} \longrightarrow 2MgO_{(s)} + C_{(s)}$

   In this reaction, magnesium is oxidized to its oxide while CO_2 is reduced to carbon.

5. It reacts with lime water to form $Ca(OH)_2$, the equation is

   $CO_{2(g)} + Ca(OH)_2 \longrightarrow CaCO_{3(s)} + H_2O_{(l)}$

   When it lasted for long inside lime water $Ca(OH)_{2,}$ the equation is

   $CaCO_{3(s)} + H_2O_{(l)} + CO_{2(g)} \longrightarrow Ca(HCO_3)_{2(aq)}$ colourless

These equations above are the laboratory chemical test for the presence of CO_2 gas.

Uses of CO_2

1. It is used in fire extinguishers because it is heavier than air and it does not support combustion.
2. It is used in the production of aerated drinks such as Coca-Cola, 7-Up and Pepsi-Cola.
3. It is used as effervescence in certain health salts such as Andrew Liver salt or Epson salt.
4. It is mixed with tartaric acid and corn starch to form baking powder ($NaHCO_{3)}$; causing bread to rise.
5. It is used in the production of Na_2CO_3 by Solvay process.
6. It is necessary for photosynthesis. The dissolved CO_2 gas in sea-water provides sea plants with food for photosynthesis.
7. Solid CO_2 is called Dry ice. It is used as a refrigerant in preserving food stuff. It is used as a coolant in nuclear reactor. It is called dry ice because it sublimes readily, without forming a liquid.

Dry ice: Advantages over popular ice

Dry ice produces a greater cooling effect than equal mass of the common ice [ice block], because dry ice can provide a temperature of -79^{0}C [194k].

Again, dry ice on warming sublimes [changes from solid to gas] without leaving any liquid; unlike ice which melts to produce water.

CAUTION: Never handle solid CO_2, dry ice, with bare hands; it causes painful blisters similar to those caused by hot objects.

EVALUATION

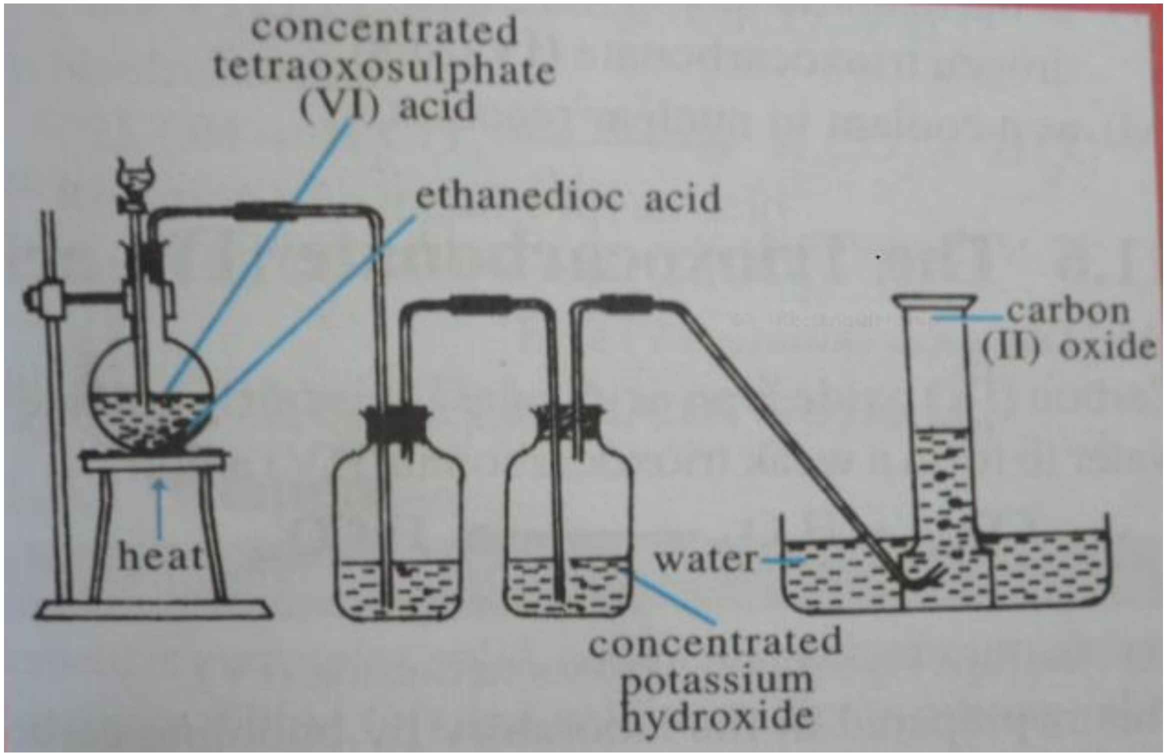
1. List the two reactants for the laboratory preparation of carbon(IV) oxide
2. Draw a labelled diagram for the laboratory preparation of dry sample of Carbon(IV) oxide.
3. Describe the laboratory test for CO_2
4. Describe what will happen when CO_2 is passed into water $Ca(OH)_{2(aq)}$ for a while then in excess

PERIOD 2: CARBON(II) OXIDE

LABORATORY PREPARATION OF CO [in the fume cupboard]

Three methods can be used to prepare CO in the lab and they are as follows;

1. **Ethanedioc acid crystals, [$H_2C_2O_4.2H_2O$]**



The equation for the reaction is given as shown below;

$H_2C_2O_4.2H_2O(s) \xrightarrow{\text{decomposed}} 3H_2O(l) + CO(g) + CO_2(g)$

Note: That conc. H_2SO_4 is a drying agent, it is there to remove the elements of water while KOH removes $CO_{2(g)}$

$CO_{2(g)} + 2KOH_{(aq)} \longrightarrow K_2CO_{3(aq)} + H_2O_{(l)}$

2(a) Sodium Methanoate crystals

$$2HCOONa_{(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O + 2CO_{(g)}$$

b. Methannoic acid

$$HCOOH_{(l)} \xrightarrow[-H2\ O]{H2SO4} CO(g)$$

Show that $\frac{H2SO4}{-H2\ O}$ removes water, a dehydrating agent

3. Reduction of $CO_{2(g)}$ to CO as shown below

$$CO_{2(g)} + C(s) \longrightarrow 2CO(g)$$

PHYSICAL PROPERTIES OF CO

1. It is colourless, odourless and tasteless gas.
2. It is slightly lighter than air.
3. It is only slightly soluble in water, but insoluble in alkalis.
4. It is soluble in ammoniacal solution of copper(I) chloride.
5. It is a poisonous gas, hence, prepared in fume cupboard.
6. It is a neutral gas therefore it does not have any action on the litmus paper.

CHEMICAL PROPERTIES AND USES OF CO

1. It is used as fuel because it supports combustion.

2. It is a useful reducing agent because it is readily reduce to CO_2(g) e.g.

   (i) $CO_{(g)} + H_2O \longrightarrow CO_{2(g)} + H_{2(g)}$

   (ii) $CO_{(g)} + CuO_{(s)} \longrightarrow Cu(s) + CO_2(g)$

   (iii) $3CO(g) + Fe2O_{3(s)}) \longrightarrow 2Fe_{(s)} + 3\ CO_{2(g)}$

   (iv) $CO_{(g)} + PbO_{(s)} \longrightarrow Pb_{(s)} + CO_2(g)$

Note: The product of combustion or oxidation of CO is $CO_{2;}$ confirmed by its ability to turn lime water milky.

3. $Ni_{(s)} + 4CO_{(g)} \longrightarrow Ni(CO)_{4(s)}$

   At 180^0C, nickel carbonyl decomposes to give carbon(II) oxide

   $Ni(CO)_{4(s)} \longrightarrow Ni_{(s)} + 4CO_{(g)}$

   $Ni(CO)_{4(s)}$ nickel carbonyl

4. It combines with chlorine, using finely divided carbon as catalyst to form carbonyl chloride, $COCl_2$[Phosgene]; a poisonous liquid. $CO_{(g)} + Cl_2(g) \longrightarrow COCl_2$

SYNTHETIC GAS

Like water gas, synthetic gas is a mixture of CO and hydrogen. It is obtained by passing natural gas **[Methane**] over steam or air in the presence of Nickels as the catalysts to give a mixture of CO and hydrogen

$$CH_{2(g)} + H_2O_{(g)} \xrightarrow{Ni.900^oC} CO_{(g)} + 3H_{2(g)}$$

$$2CH_{4(g)} + O_{2(g)} \xrightarrow{Ni.900^oC} 2Co_{(g)} + 4H_{2(g)}$$

SEPARATION OF THE CONSTITUENTS OF PRODUCER GAS AND WATER

Producer gas is a mixture of CO and Nitrogen, while water gas is a mixture of CO and hydrogen.

Note: A fuel is any substance that burns in air or oxygen to produce heat and light. Producer gas and water gas are examples of gaseous fuels. Examples of solid fuels are wood, coal and coke

1. Liquid fuels e.g. producer gas, kerosene, alcohol or methylated spirit.
2. Gaseous fuels- e.g. producer gas, water gas, coal gas, natural gas paraffin gas and synthetic gas.
3. Human fuels e.g. food items in the form of fat and oil, protein, starch and sugar
4. Atomic fuel e.g. uranium

EVALUATION QUESTIONS

1. Describe 2 methods of laboratory preparation of $CO_{(g)}$

2. What is meant by fuel?

3. State the components of each of the following (a) water gas (b) Producer gas (c) coal gas (d) synthesis gas.

PERIOD 3: METALLIC TRIOXOCARBONATES, OCCURRENCES, PREPARATION AND USES METALLIC

All trioxocarbonate(IV) salts are insoluble in water except soluble. Hence, they are prepared by double decomposition method, using aqueous Na_2CO_3 e.g.

$Na_2CO_{3(aq)} + CuSO_{4(aq)(} \longrightarrow CuCO_{3(s)} + Na_2SO_{4(aq)}$

$Na_2CO_{3(aq)} + ZnCl_{2(aq)} \longrightarrow ZnCO_{3(s)} + 2NaCl_{(aq}$

White

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

PROPERTIES OF SALTS

1. All trioxocarbonate(IV) salts are insoluble in water, except those of Na, K and NH_4 which are soluble.
2. They dissolve in water to produce alkaline solutions. This is because they are salts of strong bases and weak acid, hence, they hydrolysed in water to produce alkaline
   Solutions'
   e.g $K_2CO_{3(s)} + 2H_2O \longrightarrow 2KOH_{(aq)} + H_2CO_{3(aq)}$

3. All trioxocarbonate(IV) salts except those of potassium and Sodium, decompose on heating, to liberate $CO_{2(g)}$.

e.g. $ZnCO_{3(s)} \longrightarrow ZnO_{(s)} + CO_{2(g)}$

$(NH_4)_2CO_{3(s)} \longrightarrow 2NH_{3(g)} + H_2O_{(g)} + CO_{2(g)}$

Note: Na_2CO_3 and K_2CO_3 are not affected by heating, to liberate carbon(IV) oxide e.g.

$ZnCO_{3(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H2O_{(l)} + CO_{2(g)}$

Ionically: $CO_{3(s)}^{2-} + 2H+_{(aq} \longrightarrow H_2O_{(l)} + CO_{2(g)}$

TRIOXOCARBONATE(IV) ACID

Trioxocarbonate(IV) [carbonic acid], $H_2\ CO_3$ is a very weak diabasic acid. It is obtained when carbon(IV) oxide dissolves in water. It is unsuitable; hence never isolated.

$CO_{2(g)} + H_2O \rightleftharpoons H_2CO_{3(aq} \rightleftharpoons 2H^+_{(aq)} + CO^{2-}{}_{3(aq)}$

The acid forms both the normal and acid salts; i.e the acid ionizes into two stages;

1. $H_2CO_3(aq) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+_{(aq)} + HCO^-{}_{3(aq)}$
2. $HCO^-{}_{3(aq)} \rightleftharpoons H+(aq) + CO^{2-}{}_{3(aq)}$

Uses of trioxocarbonate(IV) salts

1. Na_2CO_3 is used in softening hard water, in making soap and glass, and as an alkali in acid-base titration.
2. $CaCO_3$ is used in making quick lime, cement and glass; in agriculture [in liming the soil – to reduce acidity]

PERIOD 4: CHEMICAL TESTS FOR CO_3^{2-} SALTS

Test on liquid on Solid (dry test)---------(a)

Small solid sample of salt is put in a test tube and few drops of dilute hydrochloric acid was added---- effervescence occur, then an odourless colourless gas was given off which in turn moist blue litmus paper slightly red and turns lime water. Gas is $CO_{2(g)}$

Test (wet test) --------(b)

Barium chloride solution was added to few drops of solution of salt in test tube. A white precipitate was formed

$CO^{2-}_{3(ag)} + BaCl_{2(aq)} \longrightarrow BaCO_{3(s)} + 2Cl^{-}_{(aq)}$

The precipitate is soluble in dilute HCl, to give a colourless solution.

$BaCO_{3(s)} + 2HCl(aq) \longrightarrow BaCl_{2(aq)} + H_2CO_{3(aq)}$

EVALUATION

1. Describe the laboratory preparation of metallic trioxocarbonate(IV) salts
2. List two properties of trioxocarbonate(IV) salts
3. Give one method for preparation of trioxocarbonate(IV) acid

GENERAL EVALUATION

OBJECTIVE TEST

1. Where else is CO_2 found in free State apart from the atmosphere. A. carbonated trees B. dissolved form in water C. in corals D. in limestone region
2. All are decomposed by heat **except** A. $BaCO_3$ B. $CuCO_3$ C. AgCO3 D. $ZnCO_3$

3. Which of the following trioxocarbonates(IV) are **no**t decomposed by heat A. Calcium and Sodium trioxocarbonate(IV) C. Potassium and Zinc trioxocarbonate(IV) D. Sodium and potassium trioxocarbonate(IV)
4. It is dangerous to stay in a badly ventilated room which has a charcoal fire because of the presence of A.CO_2 B. CO C. Hydrogen D. Sulpur
5. One of these gases is heavier than air and do not support combustion. A. CO B. CO_2 C. H_2O D. N_2O

ESSAY QUESTIONS

1. Name one process which. (i) removes carbon(IV) oxide from the atmosphere (ii) fixes atmospheric nitrogen as trioxonitrate(III) oxide in the soil.
2. Describe one of the method of laboratory preparation of Carbon(II) oxide
3. Describe one method for the laboratory preparation of Carbon(IV) oxide
4. Explain fully how $CO_{2(g)}$ can be detected in the laboratory.
5. Explain the laboratory test for trioxocarbonate(IV) ion.

PRE READING ASSIGNMENT

Read hydrocarbon and its main classes, crude oil and natural gas; and importance of hydrocarbons.

WEEKEND ACTIVITY:

Explain in detail, the laboratory preparation of (i) $CO_{(g)}$ (ii) $CO_{2(g)}$ (iii) $CO^{2-}{}_3$ salts (iv)H_2CO_3 respectively.

WEEK 9

TOPIC: CARBON AND ITS COMPOUNDS

CONTENTS:

1. HYDROCARBON AND ITS MAIN CLASSES

2. CRUDE OIL AND NATURAL GAS- FRACTIONAL DISTILLATION OF CRUDE OIL AND USES OF PETROLEUM FRACTIONS

3. CRACKING OF PETROLEUM FRACTIONS, REFORMING, OCTANE NUMBER AND KNOCKING

4. IMPORTANCE OF CRUDE OIL AND PETROCHEMICALS

PERIOD 1: HYDROCARBON AND ITS MAIN CLASSES

Hydrocarbons, as the name implies, are compounds of only two elements; hydrogen and carbon. There are many such organic compounds.

Hydrocarbons are usually classified into two main groups namely, saturated and unsaturated hydrocarbons.

1. Saturated hydrocarbons (Alkanes). The alkanes have the general molecular formula $C_nH_{2n+2.}$. Members of this group include Methane, CH_4, ethane, C_2H_6, propane, C_3H_8, butane, $C_4H_{10.}$ The structure of butane is given below.

2. Unsaturated hydrocarbons (Alkenes and alkynes). The alkenes have the general formula is C_nH_{2n}. Members of this group include ethene, C_2H_4 propene, C_3H_6 butene, C_4H_8 etc

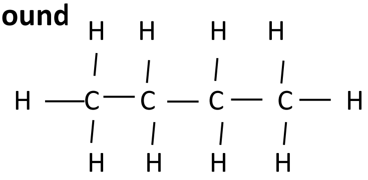
Hydrocarbons can be classified into:

1. Aliphatic compounds

2. Aromatic compounds

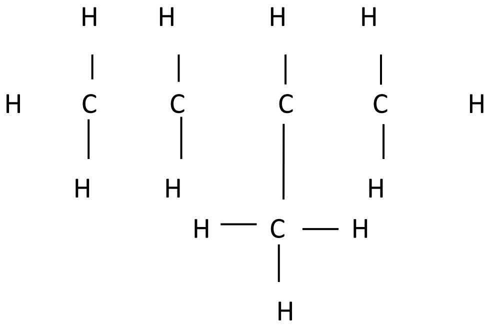
Aliphatic compounds are classified into two sub-classes: 1. Acyclic compounds 2. Cyclic compounds

In acyclic compounds the molecules are made up of straight chain carbon atoms or branch chain e.g. **Butane (a straight chain compound**



$$\begin{array}{ccccccccccc} & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & H \\ & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & \end{array}$$

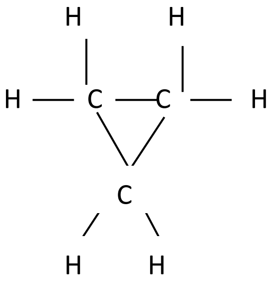
2 methyl butane (a branched chain compound)



$$\begin{array}{ccccccccccc} & & H & & H & & H & & H & & \\ & & | & & | & & | & & | & & \\ H & & C & & C & & C & & C & & H \\ & & | & & | & & | & & | & & \\ & & H & & H & & | & & H & & \\ & & & & H & - & C & - & H & & \\ & & & & & & | & & & & \\ & & & & & & H & & & & \end{array}$$

In cyclic compounds the end carbon atoms of an open aliphatic chain can also join together to form a closed system or ring e.g.

Cyclopropane

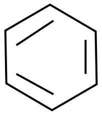


AROMATIC COMPOUNDS

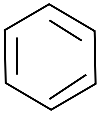
Aromatic compounds are Benzene or derivative of benzene (that is compounds whose structures are based on the structure of benzene)

Due to resonance exhibit by the structures of benzene, i.e.

(i)

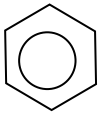


(ii)



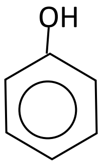
The structure of benzene would be (i) or (ii)

Conventionally the structure of benzene is now a hexagon with a ring within it.



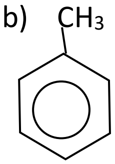
Examples of other derivatives of benzene,

(a)



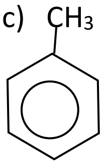
Phenol

(b)



Toluene

(c)

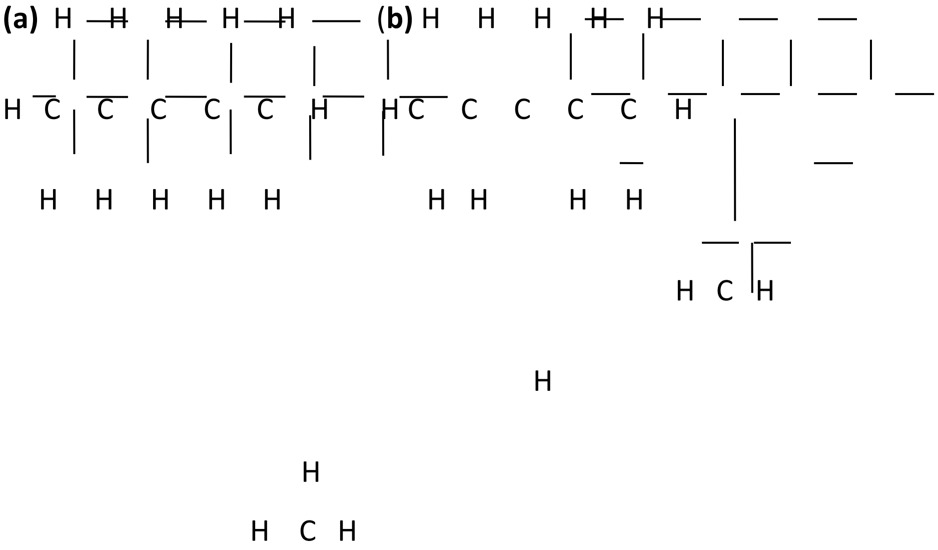


Xylene

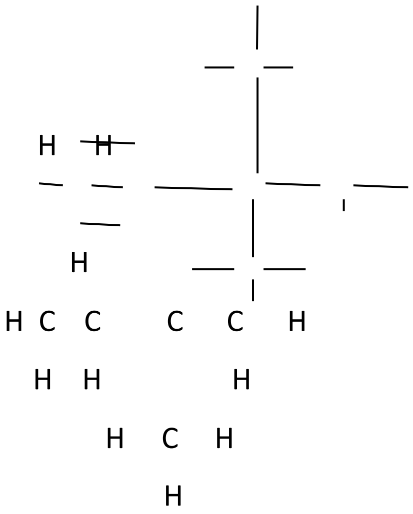
EVALUATION:

Name the following aliphatic compounds.

(a) **(b)**



(c)



PERIOD 2: CRUDE OIL AND NATURAL GAS, REFINING OF CRUDE OIL AND USES OF PETROLEUM FRACTIONS

Another name for crude oil is petroleum. It is the chief source of hydrocarbons. Crude oil occurs as a dark, sticky, viscous liquid. It is believed that crude oil is formed by the gradual decomposition of the remains of marine plants and animals that became incorporated in the sediment and rocks formed at the bottom of the sea.

Crude oil is a mixture of gaseous, liquid and solid alkanes, cycloalkanes, aromatic hydrocarbons etc.

Natural gas; Natural gas is usually found together with crude oil; and water in traps or reservoirs in between some layers of rocks at the bottom of the sea. Natural gas consists mainly of methane. It is used as a domestic and industrial fuel.

In Nigeria crude oil is found in Oloibiri in 1956. In Niger Delta, Calabar and in Burutu in Delta state.

REFINING OF CRUDE OIL AND USES OF PETROLEUM FRACTIONS

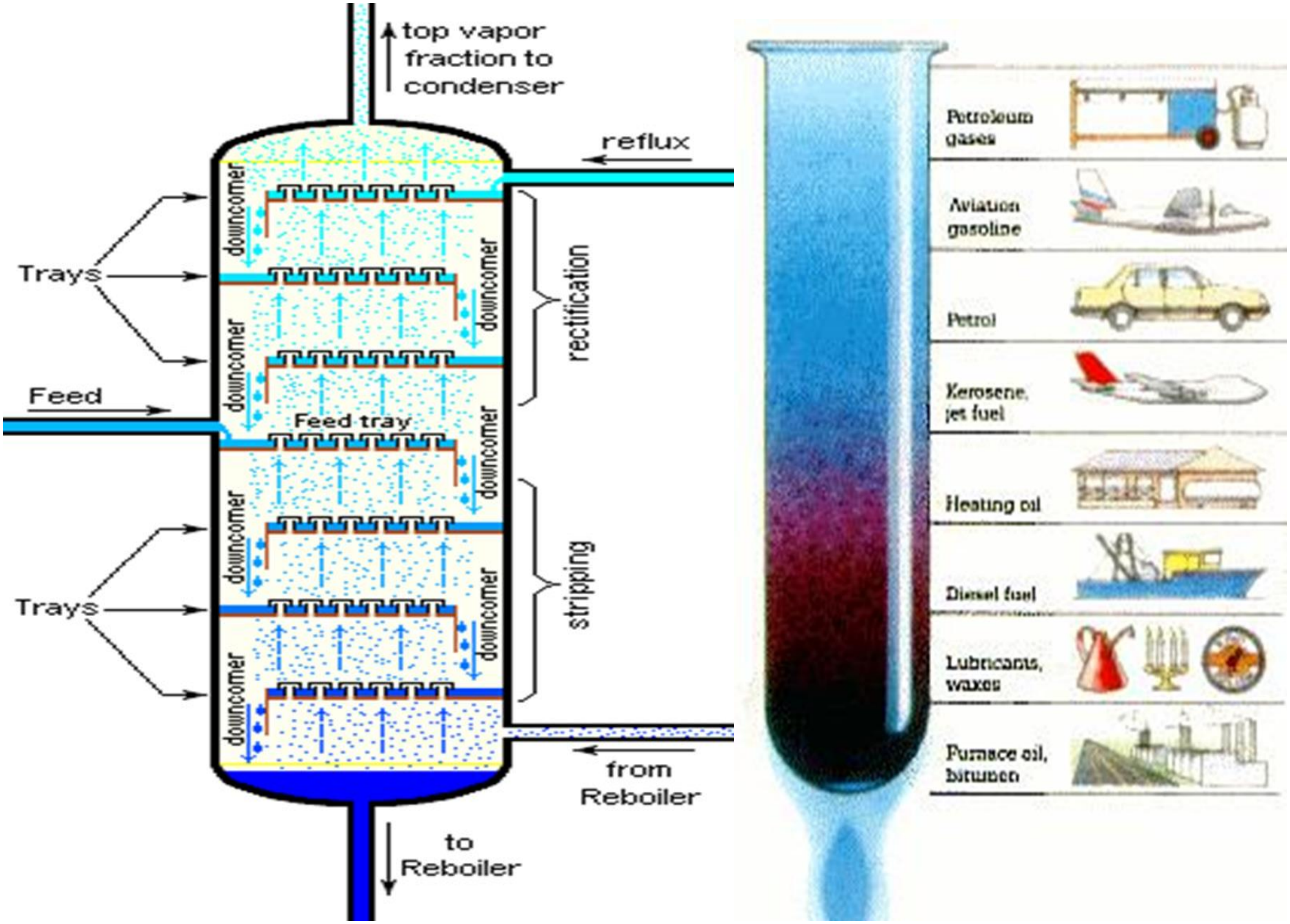
Crude oil must be refined to make useful fuels and chemicals. The crude petroleum taken from the oil fields to refineries is processed in three stages**: separation, conversion and purification.**

Fractional Distillation of oil

Petroleum products are the fractions obtained directly from the fractionating tower where the crude oil has been refined by fractional distillation. The separation of petroleum fractions is based on the differences in their boiling points. The amin products or fractions are shown in the table below:

	Fraction	**No. of Carbon atoms**	**Boiling points**	**Uses**
1.	**Petroleum gas**	C_1- C_4	**Below 40°c**	**Fuel and manufacture of other organic compounds**
2.	**Petrol or gasoline**	C_5-C_{10}	**40 - 200°C**	**Used as fuel in motor cars and generators**
3.	**Kerosene or Paraffin oil**	C_{11}- C_{15}	**200 – 250°C**	**Used as aviation fuels in aircraft and also as fuel for lantern**
4.	**Diesel or light gas oil**	C_{16} – C_{20}	**250 -350°C**	**Used as fuels in engines or buses, trains, boats, tractors etc.**
5.	**Lubricating oil**	C_{20} –C_{30}	**350 – 500°C**	**Used in candle making, creams, hair**

				care products.
6.	**Bitumen or Asphalt**	**>C_{30}**	**Above 500°C**	**For road surfacing**



FRACTIONAL DISTILATION OF CRUDE OIL

EVALUATION:

1. Explain the formation of crude oil.

2. Mention four fractions of petroleum and their uses

PERIOD 3: CRACKING OF PETROLEUM FRACTIONS, REFORMING, OCTANE NUMBER AND KNOCKING

CRACKING AND REFORMING

The quality of petrol obtained from the Fractional distillation of crude oil is about 20% by volume.

Cracking is therefore employed so as to provide more petrol, since its demand is high and as a source of alkenes.

CRACKING: cracking is the process whereby large molecules of heavy oils are broken into smaller molecules (light oils) at high temperature, pressure and in the presence of a catalyst. Usually petroleum fractions with more than eleven carbon atoms in their molecules can be cracked.

During cracking, ethene, C_2H_4 is produced; it is the major raw material in the petrochemical industry.

CRACKING TECHNIQUES

The two main cracking processes are: thermal cracking and catalyst cracking.

There is also a less common cracking known as hydro cracking.

1. THERMAL CRACKING: Thermal cracking involves heating heavy oils, such as lubricating oil, diesel oil and kerosene to about 600^{0}C under pressure; it leads to the decomposition and formation of a mixture of more volatile alkanes, alkenes and hydrogen. The mixture is then separated by fractional distillation. e.g.

$$C_{11}H_{28} \longrightarrow C_8H_{18} + C_3H_6$$

Kerosene (Alkane) petrol Alkene propene)

2. CATALYTIC CRACKING: in catalytic cracking, the heavy oil is heated to about 500^{0}C under reduced pressure and in the presence of natural clay (a mixture of silicon (iv) oxide and aluminium oxide) as the catalyst. Under these conditions, a mixture of alkanes and alkenes, which can be separated by fractional distillation, is obtained e.g.

$$C_{18}H_{38} \longrightarrow C_6H_{14} + C_8H_{16} + 2C_2H_4$$

Note: note that the products of cracking depend on the starting material and the reaction conditions, such as temperature, pressure and the nature of the catalyst used.

In hydro cracking, hydrogen is passed into the reaction mixture during the cracking process. Under this condition, only the lower saturated alkanes are obtained.

REFORMING: In reforming the molecules do not crack but are reformed or reshaped. In reforming straight chain alkanes are converted catalytically into branched chain isomers, cycloalkanes and benzene, the purpose is to convert low grade petro to higher grades, i.e. improve the quality. Reforming techniques includes: **ISOMERISATION, CYCLIZATION AND AROMATIZATION**

DIFFERENCE BETWEEN CRACKING AND REFORMING

1. Cracking involves breaking large molecules of petrol fractions into smaller molecule, while reforming involves rearrangement of atoms in the molecules of petroleum fraction to obtain branched and cylic hydrocarbons.
2. Cracking can be achieved thermally or catalytically, while reforming is in the presence of a catalyst.
3. Cracking occurs at a temperature higher than that of reforming.
4. Cracking is employed to increase the quantity of petrol, while reforming is to improve its quality.

OCTANE NUMBER OR RATING

Each grade of gasoline (petrol) is rated according to the term octane number. The octane rating or number is based on the proportions of the straight chain heptane, C_7H_{16} and the branched- chain 2,2,4 –Trimethylpentane, an isomer of C_8H_{18} called iso-octane in petrol. When petrol with a high proportion of straight chain, heptane is used in the engine of a vehicle, the combustion will not be smooth, and can knock the engine, i.e. damage the engine, while petrol with a high proportion of the branched chain 2,2,4-Trimethylpentane burns smoothly and does not cause knocking in engines. The higher the octane number of petrol, the lower the knocking tendency.

EVALUATION:

1. What is the advantage of catalytic cracking over thermal cracking.

2. Mention the methods of reforming gasoline.

3. Mention two ways of improving the octane number of petrol.

PERIOD 4: IMPORTANCE OF CRUDE OIL AND PETROCHEMICALS

In Nigeria, natural gas is used as fuel for heavy duty vehicles and engines. The gas power stations Ughelli and Sapele use natural gas to generate electricity.

Economic importance: Nigeria proposes to set up a liquefied natural gas plant. This will enable Nigeria not only to increase its natural gas consumption at home, but also to express the gas.

Petroleum and natural gas are now used in increasing amounts to produce many organic compounds e.g. Ethanol, ethane, propane 1,2,3-triol, benzene, toluene. These are in turn used to make large- molecule organic compounds like plastics, synthetic rubber, insecticides, detergents, synthetic fibres like nylon and dacron. The oil industry has provided employment in various aspects at the industry.

EVALUATION:

1. Name some places in the Niger Delta in Nigeria where crude oil is found.

2. Write short not on this: **IMPORTANCE OF HYDROCARBONS.**

GENERAL EVALUATION

OBJECTIVE TEST:

1. Oil deposits in Nigeria are (a) on land and offshore (b) only offshore (c) mainly imported (d) downstream

2. Fractional distillation involves the following process (a) boiling (b) boiling and condensation (c) boiling, evaporation and condensation (d) condensation and collection

3. Which is the odd- one out of? (a) petroleum ether, petroleum gases, kerosene (b) gas oil and diesel lubricating oil (c) petroleum ether and bitumen (d) Haematite and asphalt

4. Which of the following is a source of hydrocarbons? (a) Haemitite (b) marble (c) coal (d) slag

5. Crude oil can be obtained in Nigeria in the following places except. (a) Afam (b) Abata (c) Owaza (d) Kano

ESSAY QUESTIONS

1. Describe how you would show that crude oil is not a single compound.

2. (a) What are hydrocarbons? (b) Give three examples and their main sources in nature.

3. With the help of a diagram, briefly describe the industrial fractionation of petroleum.

4. Write short notes on (a) crude oil (b) Natural gas

5. Name four fractions of petroleum stating their uses.

WEEKEND ASSIGNMENT:

Read the topic ‘Fractional distillation of crude oil’

WEEKEND ACTIVITY:

On a cardboard sheet draw how crude oil and natural gases are formed.

PRE READING ASSIGNMENT:

Read all the notes for this third term.

VOLUMETRIC ANALYSIS

INTRODUCTION

Volumetric analysis is an aspect of quantitative analysis which involves the measurement of the volume of reacting solutions in order to find the masses of substances dissolved in them.in other words, two solutions are given; one is a solution of an acid and other a solution of a base .one of them is a standard solution and you are required, by titration to standardize the other.

The other aspect of quantitative analysis is gravimetric analysis, which involves weighing and determining the masses of reactants and products of a chemical reaction.

The most popular aspect of Volumetric analysis is the acid – base (neutralization) reactions. The technique of determination is by titration. Other aspects are redox and precipitation reaction.

APPARATUS USED IN VOLUMETRIC ANALYSIS ARE:

The burette, pipette, beaker, flasks, funnel, wash bottle, chemical balance, dropping pipette and retort stand.

Basic definitions in volumetric analysis

I.TITRATION: It is the technique for carrying out volumetric analysis**.**

II.CONCENTRATION: The concentration of a solution is the amount of solute in a given volume of the solution.

III.STANDARD SOLUTION: It is a solution containing a known amount of solute in a known volume of solution. An example of a standard solution is a molar solution.

IV.MOLAR SOLUTION: It is a solution which contains one mole of solute in 1dm^{3}solution.

V.BUFFER SOLUTION: It is a solution which resists a change in p^H or H$^+$upon further addition of acid or alkali. Buffers are usually made of solutions of a weak acid and its conjugate base or a weak base and its conjugate acid. The weak acid usually has a p^H value lower than 7 and is therefore used to buffer systems in the basic region. Examples of buffers solution and their p^H ranges over which they are effective are given below:

BUFFER SYSTEM	**P^H RANGE**
Ethanoic acid/Sodium ethanoate(CH_3COOH/CH_3COON_A)	4.25-5.25
Trioxocarbonate(iv)(carbonic) acid/Sodium hydrogentrioxocarbonate	5.87-6.87
Ammonia/Ammonium chloride(NH_3/NH_4Cl)	8.75-9.75
Sodiumtrioxocarbonate/sodiumhydrogentrioxocabonate	9.75-10.75

MOLAR MASS: This is the mass of one mole of a substance expressed in grams. Its unit is gram per mole.

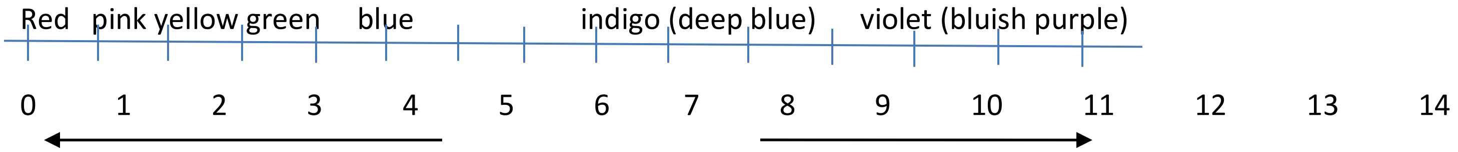
END POINT: This is the point at which the chemical reaction is complete during titration. The end point is detected with the help of an indicator.

INDICATORS: These are weak organic acids or bases whose colors change with pH of the solution. Indicators are widely used in monitoring titration involving colorless solutions of acids and bases.

DIFFERENT INDICATORS AND THEIR COLOURS IN DIFFERENT MEDIA

INDICATOR	COLOUR IN ACIDIC MEDIUM	COLOUR IN ALKALINE MEDIUM	COLOUR AT END POINT
Methyl Orange	Pinkish red	yellow	Orange
Phenolphthalein	Colorless	red	colorless
Litmus	Red	blue	Pink/purple
Methyl red	Pink	yellow	orange
Screened methyl orange	Purple(violet)	green	grey
Bromothymol blue	Yellow	blue	green

UNIVERSAL INDICATOR: This is a mixture of indicators used either as solution on a test paper to test the p^H value of a solution. The pH scale is shown below:



Acidity increases

Alkalinity decreases

EFFECT OF WRONG USE OF INDICATOR

The success of a titration exercises depend on the use of the correct indicator. Wrong use of indicator will definitely give wrong result. For instance, let’s consider a case of the titration of a solution of a wrong acid say **HCl** with that of a weak base say Na_2CO_3, methyl orange is the suitable indicator, but if phenolphthalein indicator is used instead, the end point will appear when only half of the weak base has been used up. This can then be represented with the following equation.

$$HCl + Na_2CO_3 \xrightarrow[\text{Indicator}]{\underline{\text{phenolphthalein}}} NaHCO_3 + NaCl$$

This happened because the phenolphthalein is sensitive to a weak acid such as Na_2CO_3.

TITRATION	EXAMPLE	P^H RANGE	SUITABLE INDICATOR
1.Strongacid vs. strong base(3-11)	$H_2SO_{4(aq)}$ and $KOH_{(aq)}$	3.5 – 9.5	Any indicator is suitable.
2.Weak acid vs. strong base(7-11)	$H_2C_2O_4$and NaOH	7.0-9.5	phenolphthalein
3.strong acid vs. Weak base(3-7)	$HCl_{(aq)}$and$NH_{3(aq)}$ or $K_2CO_{3(aq)}$ or $Na_2CO_{3(aq)}$ or $Ca(OH)_{2(aq)}$	3.5-7.0	Methyl orange or screened Methyl orange
4 Weak acid vs. Weak base	$CH_3COOH_{(aq)}$ and $NH_{3(aq)}$	No sharp change	No suitable indicator. Or phenol red.

IMPORTANCE OF VOLUMETRIC ANALYSIS

I. Standardize unknown solution

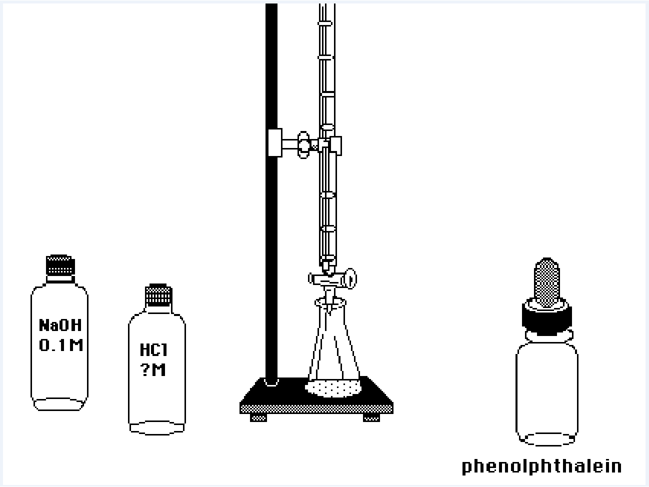
II. Calculate molar mass, water of crystallization and solubility.

III. Determine the purity of substances.

IV. Determine the masses of substances dissolved.

V. Faster and more convenient

GENERAL PROCEDURES AND PRECUTIONS DURING ACID –BASE TITRATION



A) STEPS INVOLVES IN FILLING THE BURETTE WITH DILUTE ACIDES

STEP1. Clamp the burette in a vertical position to avoid error due to parallax while taking reading. Rinse it with the given acid solution, alloing part of the acid to pass through the tap and the jet. Then cloe the tap.

STEP2. With the funnel at the top of the burrette, fill the burettewith acid to a desired level ensure that the jet is filled with acid to avoid air bubbles inside it.tightly close the buette tap to avoid leakages. Remove the funnel to**avoid droplets of acid from it.**Hold a piece of white paper behind the burette so that the acid level is clearly shown and note the reading of the burette.

B) STEPS INVOLVES IN MEASURING 25.00Cm^3 (20.00Cm^3) of standard base solution.

STEP1. Collect four conical flasks and wash with distiled water only. Make sure that none of the flasks contain any acid or alkali.

STEP2. Rinse the pipette with the given base solution.

STEP3.suck the base solution into the pipette until the level is about 1cm^3 or2cm^{3}above the forefinger. Gently release the pressure until the bottom of the concave meniscus is at the graduation mark,with the eye level aligned.

STEP4. While filing the pipette ensure that the jet lies well inside the base solution to **aviod air bubbles in the pipette.**

STEP5. Run the base solution into one of the conical flasks.the sides of the flask should not be splased with the solution as the splasings may not be neutralised by acid later in the experiment. To removethe little alikali retained at the tip of the pipette after delivery,do not blow out thepipette or shake out the last drop of the solution but allow the pipette to drain for about 15 seconds and then allowthe tip of the pipette to touch bottom of the flask.

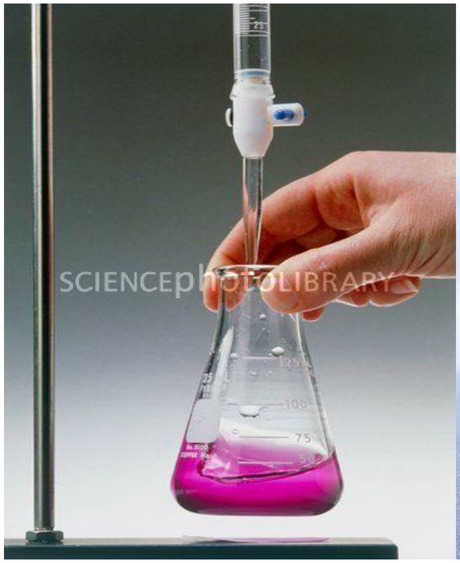
STEP6. Fill the remaing conical flasks as stated above.

(C)STEPS IN INVOLVES IN TITRATION OF THE ALIKALI SOLUTION WITH DILUTED ACID SOLUTION.

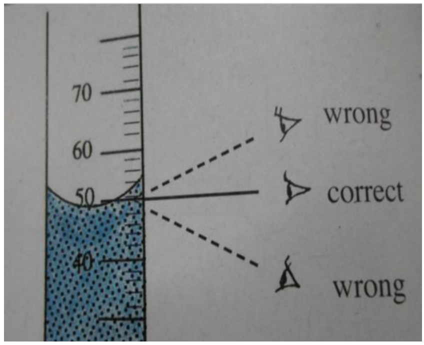
STEP1. Add 2 drops of the given indicator to each conical flask to obtain a shape end-point.

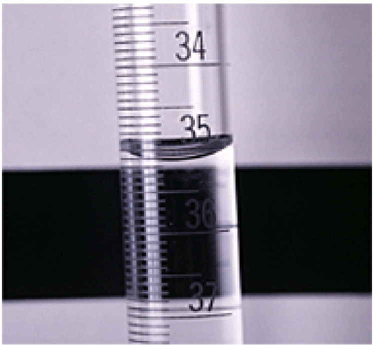
STEP2. Place one of the conical flasks on a piece of white paper or white tile beneath the burette to aideasy recognition of colour change at the end point.Run in the acid from the burette addingabout 1.00cm^3 at a time.

Shake the conical flask gently during titration to ensure homogeneity of the two solutions but aviod spillage of the reacting solutiopns. Note the level of the acid when the colour of the indicator changes.this first titration is the trial or roug titration.

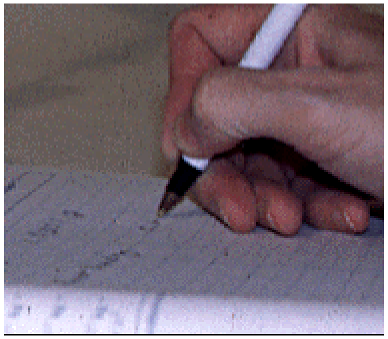


STEP3. Repeat the above procedures for the base in other three conical flasks.Take burette readings at the lowest concave meniscus for each titration.





These should be taken at the eyes levels to avoid error of parallax.the volmes of the acids used in the second,third and fourth accurate titrations should agree within ±0.20cm^3 and should always be recorded to two places of decimals. These make a concordant orconcurrent results to be obtained.Record all your readings as they are taken and do not try to remember them or write on scripts of papers.



TITRATION PRECUTIONS

1. The burette must be clamped vertically or not tilted.
2. Wash the burette and pipette with water andrinse with distiled water.
3. Rinse the burette with acid,the pipette with base (alkali)before putting these solutions into them.
4. Ensure no air bubbles in the burette or pipette.
5. Remove the funnel after putting the acid into the burette(if a funnel is used).
6. The content of the pipette should be allowed to run into the conical flask without blowing air into it.
7. Use a drop or two (small amount)of indicators.
8. Read the lower meniscus.
9. Ensure the tap of the burette is not leaking.

NOTE: Most examination bodies have different ways of assessing students practical skills and report writing procedures. For instance, the following are some of the penalities.

i)use of pencil;   -2marks

ii)Alteration(cancillation) on table of titrevalues; -2marks foreach,maximum of -4marks.

iii)No unit or wrong unit on table; -1mark.

iv)Non concordant values(i.e.difference greater than pluse or minus 0.2)for average titre value; -1mark.

STEPS IN RECORDING OBSERVATIONS MADE DURING ACID- BASE TITRATION EXPERIMENT

i.Construct the specimen table:Example

Burette Readings in cm^3	**Trial or Rough**	**1st**	**2nd**
Final Burette reading	**24.80**	**24.00**	**24.00**
Initial Burette reading	**0.00**	**0.00**	**0.00**
Volume of Acid used	**24.80**	**24.00**	**24.00**

ii.Determine the average volume of acid used (i.e. average titer value).

Thus:**Average Titre:-** $\frac{24.00 + 24.00}{2} = 24.00cm^3$

Depending on the differences in readings of the titre values. All your readings must have their units, i.e.cm^3.

NOTE: This value and that of the table should be recorded to two places of decimal.

Iii. SIGNIFICANT FIGURES

Sudent should learn to round off their calculation numbers to three significant figures,since they are using foure figure table for their calculations.

Significant figures start from non-zero digit and all other digits that follow including zero are considered Significant. As usual the digits, 5,6,7,8,9 are rounded up while 1,2,3,4,are round off.

Examples:

Numbers	**Rounded off**
299.30	**299 to 3 S.f**
0.0128	0.0128 to 3 S.f
6.0246	6.02 to 3 S.f

NOTE : for the sake of the examination,prepere your table on a sheet of paper and then neatly transfer it in **INK** to the answer sheet.

EXAMPLE 1

A is a solution of tetraoxosulphate {vi} acid.

B is a solution containing 0.0500 mole of anhydrous Na_2CO_3 per dm3.

(a)Put A in the burette and titrate 20.00 or 25.00 cm3 portions of B using methyl orange as the indicator. Record the size of your pipette. Tabulate the burette readings, and calculate the average volume of the acid used.

(b) From your result and data provided, calculate the

I amount of Na2CO3 IN 25.00 CM3 OF B used

Ii concentration of A in moldm^{-3}

Iii concentration of A in gdm^{-3}

Iv number of hydrogen ions in 1.00dm3 of A. {Avogadro number = 6.02x1023 mol1}

The equation of reaction is: $H_2SO_4\{aq\} + Na_2CO_3\{aq] \longrightarrow Na_2SO_4\ \{aq\} + H_2O + CO_2$

{H =1,O=16, S=32}

SOLUTION

A Volume of pipette: 25cm^{-3}

Titration results {Hypothetical data}

Burette reading	1cm^3	II cm^3	IIIcm^3
Final	24.75	49.15	25.70
Initial	0.00	24.75	1.35
Volume of acid used	24.75	24.40	24.35

Average volume of acid used from titrations II and III:

$\frac{24.40+24.35}{2} = \frac{48.75}{2} = 24.38\text{cm}^3$

NOTES: Only the titre values from titrations I and II can be used in averaging, since they are within ± 0.20cm3 of each other. …Rough of first titre can also be used in averaging, if it is within ± 0.20cm3 of any other titre value, and is not crossed.-----Do not round up 24.38cm3 to 24.40cm3

(b)To calculate the amount of Na2CO3IN 25.00CM3 Given: conc of B = 0.050moldm3 :Volume = 25/1000dm3

Amount = Conc {moldm3 x Volume {dm3} = 0.050x25/1000 = 0.00125mol

To calculate the concentration of A in moldm3: The various titration variables are:

CA = xmoldm3; VA = 24.38CM3; Na = 1, CB = 0.050moldm3 VB = 25CM3: nB =1

Method 1: proportion method {from the first principle}

From the balanced equation of reaction:

1mol of Na_2CO_3 = 1 mol of H_2SO_4

. ∴ 0.00125mol Na2CO = 0.00125molH2so4

i.e. 24.38cm3 of A contained 0.00125 mol H2SO4

∴ $1000cm3\ of$ A contained {0.00125 x 1000} /24.38 mol = 0.0513mol.Hence, concentration of A is 0.0513mol moldm3.

Method 2:

Mathematic formula method

From the data above, it is safe to use the mole ratio expression, in order to calculate the concentration CA of A, which the required variable.

Using CAVA/CBVB = nA/nB

Substituting; CA X 24.38/0.050 X25 =1/1

Making CA the subject of the formula

∴ CA =1 X0.050X25 /24.38 X1 = 0.0513 moldm-3

(iii) To calculate the concentration of A in gdm-3:

Using conc. {gdm-3} x Molar mass {gmol-1}

Concentration of H2SO4, moldm-3 =0.0513moldm-

Molar mass H2SO4, = 2 {1.0} + 32.0 + 4{16.0

= 2.0 +32.0 +64.0 = 98.0gmol-1

Substituting; Mass conc = 0.0513 x98 = 5.0274gdm-3.

=5.03gdm-3 {3 sig fig.}

(Iv).Number of hydrogen ions in 1.00dm3 of A

1 dm3 of A contained 0.0513mol of H2SO4.

H2SO4 ionizes in water completely thus:

$H_2SO_4 \text{ (a q)} \longrightarrow 2H^{+}SO_4^{2-}\text{(a q)}$

1mol 2mol

From the equation;

1 mole of H2SO4 produces2 x 0.0513 moles of H^+ = 0.103 mol 0f H+

But 1 mole of H+ contains 6.02 x 1023 ions;

Therefore, 0.103 x 6.02 x 1023 ions =6.02 x10 23 ions.{3 sig fig.]

2. DETERMINE OF RELATIVE MOLAR MASS

In the determination of relative molar mass of an acid or bases by titration, the concentration of both acid and base, at least in gram per dm^3, will be provided together with the balanced equation of reaction so as to establish the mole ratio

EXAMPLE 1.

A contains 1.6g of HNO_3 in $250cm^3$ of solution

B contains $10gdm^{-3}$ of $XHCO_3$

25cm3 portion of B requires an average of 24.90cm3 of A for complete neutralization. Calculatethe

(i) Concentration of acid in moldm-3

(ii) Concentration of XHCO3 in B in moldm-3

(iii) Mass of XHCO3

(iv) Value of X

Equation of the reaction

$$HNO_{3(aq)} + XHCO_{3(aq)} \rightarrow XNO_{3(aq)} + CO_{2(g)} + H_2O_{(l)}$$

$$(H = 1; C = 12; O = 16$$

Solution

C_a =? Mole per dm3 $V_a = 24.90cm^3$; n_a =1

C_b =? Mole per dm3; $V_b = 25cm^3$; $n_b = 1$

(a) To calculate the molar concentration of A.

The given mass concentration of A is

1.6g of HNO_3 in $250cm^3$

i.e. 250cm^3 of the solution contained 1.6g of acid

Therefore, 1000cm^3 of A contained

$$\frac{1.0 \times 1000}{250} = 6.40gdm^{-3}$$

i.e. the mass concentration of A = 6.40gdm^{-3}

But $molar\ concentration = \frac{mass\ concentration}{molar\ mass}$

Molar mass of HNO_3 = (1x1) + (14x1) + (16x3) = 1+14+48 =63gmol^{-1}

Molar conc $C_a = \frac{6.4}{63} = 0.102moldm^{-3}$

(b) To calculate the molar concentration of B

Mass conc. Of $XHCO_3$ in B = 10.0gdm^{-3} (given)

Since the value of X in the base $XHCO_3$ is not known, the mole ratio expression must be used in order to find its molar concentration,

$$\frac{C_aV_a}{n_a} = \frac{C_bV_b}{n_b}$$

Substituting

$$\frac{0.102\ \times 24.9}{1} = \frac{C_b \times 25}{1}$$

Making **C_b** the subject of the formula

$$C_b = \frac{0.102 \times 24.9}{25} = 0.102moldm^{-3}$$

(c) To find the mass of X in $XHCO_3$

$$molar\ mass = \frac{mass\ conc}{molar\ conc} = \frac{10.0gdm^{-3}}{0.102moldm^{-3}} = 98.0gmol^{-1}$$

(d) To find the value of X in $XHCO_3$

Molar mass of XHCO3 =98.0gmol-1

i.e X +1 + 12 + (16 x 3) = 98

X + 1 + 12 + 48 = 98

X + 61 = 98

X = 98-61

Relative atomic mass of X is X = 37 (no unit)

2. DETERMINATION OF MOLE RATIO

In order to determine the mole ratio of acid to base (or base to acid) by titration, the solution of the acid and the base provided for the titration must be known concentrations (standard solution). However, the equation of reaction will not be provided.

SOLVED PROBLEM 1

A is a solution of 0.0500moldm^{-3} hydrochloric acid

B is 0.0250moldm^{-3} of a trioxocarbonate (iv) solution

25.00cm^{3} portions of B required an average of 24.60cm^{3} of A for complete neutralization, using methyl orange as the indicator

a. **calculate:**

i. amount of acid in the average volume of A used

ii. amount of trioxocarbonate (IV) in the volume of B used

iii. mole ratio of the acid to trioxocarbonate (IV) solution in the reaction, express your answer as a whole number ratio of one

b. state whether the PH of the following would be equal to 7, greater than 7 or less than 7

  i. solution A

  ii. solution B

  iii. titration mixture of A and B before end point

SOLUTION

a. (i) To calculate the amount of acid in A used

Amount of the acid = molar conc of A x volume in dm^3.

$= 0.050 \times {}^{24.60}/_{1000}$ mol

$= 0.00123$mol

(ii) To calculate the amount of trioxocarbonate (iV) in B used

Amount of Base = molar conc. Of B x volume in dm^3

$= 0.025 \times {}^{25}/_{1000}$ mol.

$= 0.000625$ mol

(iii) Mole ratio of acid to trioxocarbonate (iV)

Mole ratio of acid to base, A: B = 0.00123: 0.000625

A: B = $\frac{0.00123}{0.000625} : \frac{0.000625}{0.000625}$

A: B = 2 : 1

b. (i) PH of A is less than 7

(ii) PH of B is greater than 7

(iii) PH is titration mixture before end point is greater than 7

SOLVED PROBLEM 2

In an acid – base titration, 24.80cm^3 of 0.05000moldm^{-3} of a mineral acid **Y** neutralized 25.00cm^3 of a solution containing 5.83g of Na_2 CO_3per dm^3.

a. From the information given above calculate:

   i. Amount (in moles) of acid Y used

   ii. Amount in moles of Na_2CO_3 used

   iii. Mole ratio of the acid to Na_2CO_3 I the titration

b. i. What is the basicity of Y?

   ii. Suggest what Y could be. Give reason for your answer.

   iv. From your answer, write a balance equation of the reaction

Solution

a. i. amount $\mathbf{n_Y}$ = conc (moldm^{-3}) x volume (dm^3)

$$= 0.0500 \times \frac{24.80}{1000} = 0.00124mol$$

ii. Amount in mole of Na_2CO_3 used

first, calculate the concentration of Na2CO3 in moldm-3

Molar mass of Na_2CO_3 = 2 (23.0) + 12 + 3 (16)

= 46 + 12 + 48 = 106gmol^{-1}

Conc of Na_2CO_3 $= \frac{mass\ concentration}{molar\ mass} = \frac{5.83}{106} = 0.0550 moldm^{-3}$

Amount of Na_2CO_3 , $n_z = 0.0550 \times \frac{25}{1000} = 0.00138 mol$

v. mole ratio of the acid to Na2CO3 in the titration

Mole ratio of the acid to Na2CO3 = $n_y : n_z$ = 0.00124: 0.00138

$$n_y : n_z = \frac{0.00124}{0.00124} : \frac{0.00138}{0.00124}$$

$n_y : n_z$ = 1: 1

b. The basicity of Y is Y since one mole of Y requires one mole of Na_2CO_3 .

ii. Y is H_2SO_4. Reason: one mole of the acid Y produces two mole of H^+.

$$H_2SO_4 + Na_2CO_3 \rightarrow Na_2SO_4 + H_2O + CO_2$$

$$C = 12.0. O = 16.0, Na = 23.0$$