



Learning Should Never Stop

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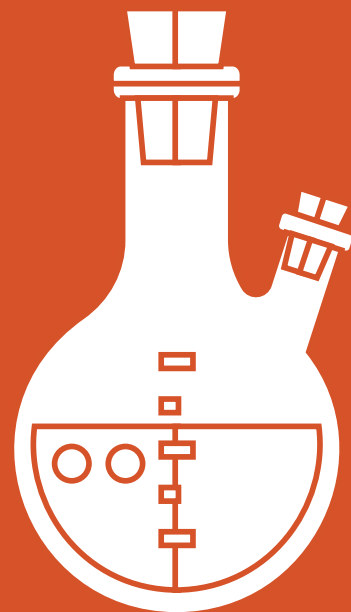
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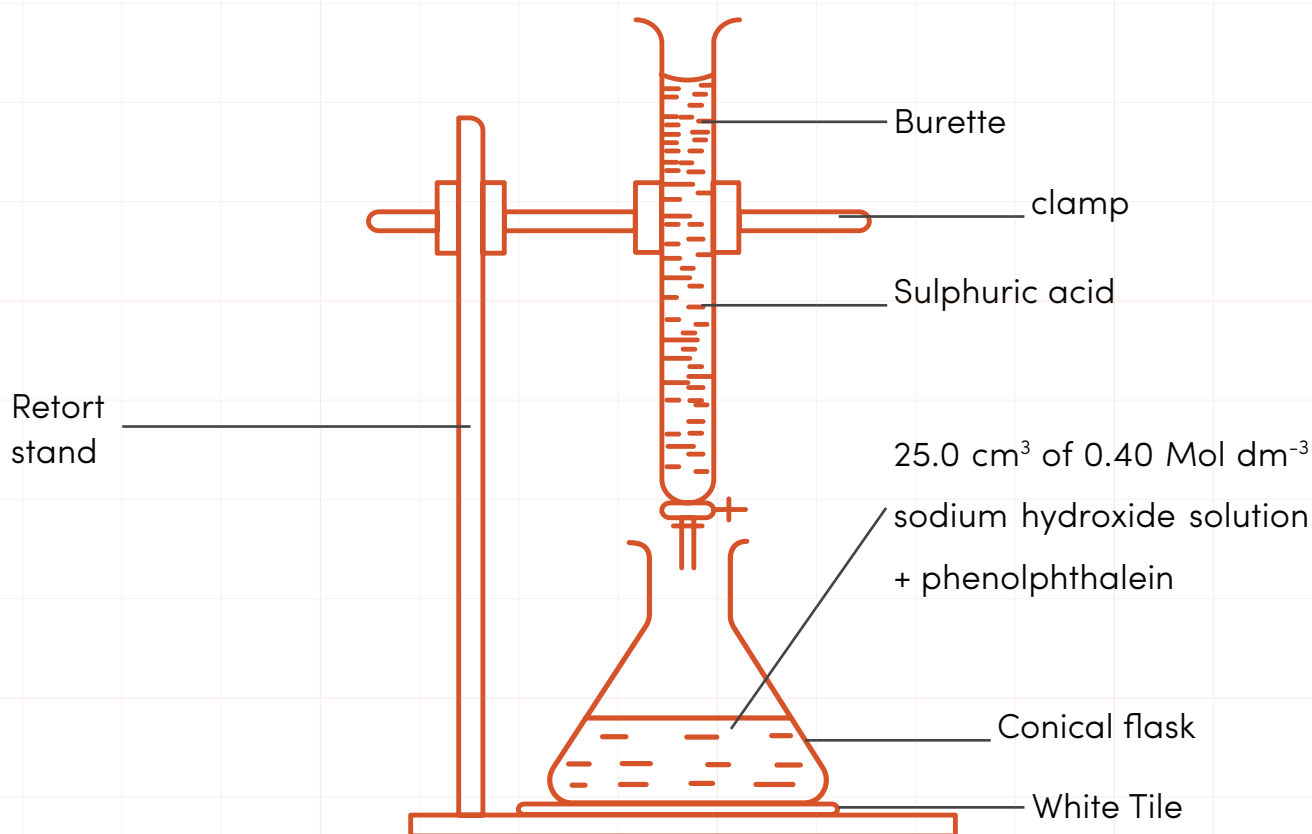
INTRODUCTION

Experimental chemistry is divided into two parts which are quantitative and qualitative analyses. Quantitative analysis deals with the determination of the amount (or concentration) of chemical species in samples of substances or physical properties of such species or their chemical reaction (e.g. molar mass, percentage purity, solubility, pH of an aqueous solution, heat change of a chemical reaction, rate of a chemical reaction, equilibrium constant of a reaction, etc.)

Qualitative analysis involves the purification and identification of chemical species (elements, cations, anions, compounds) in sample of substances based on tests and observations which can lead to appropriate conclusions.

The two types of analysis are not independent of each other. For instance, the prior determination of some physical properties may be necessary for the identification or determination of the purity level of some compounds in qualitative analysis.

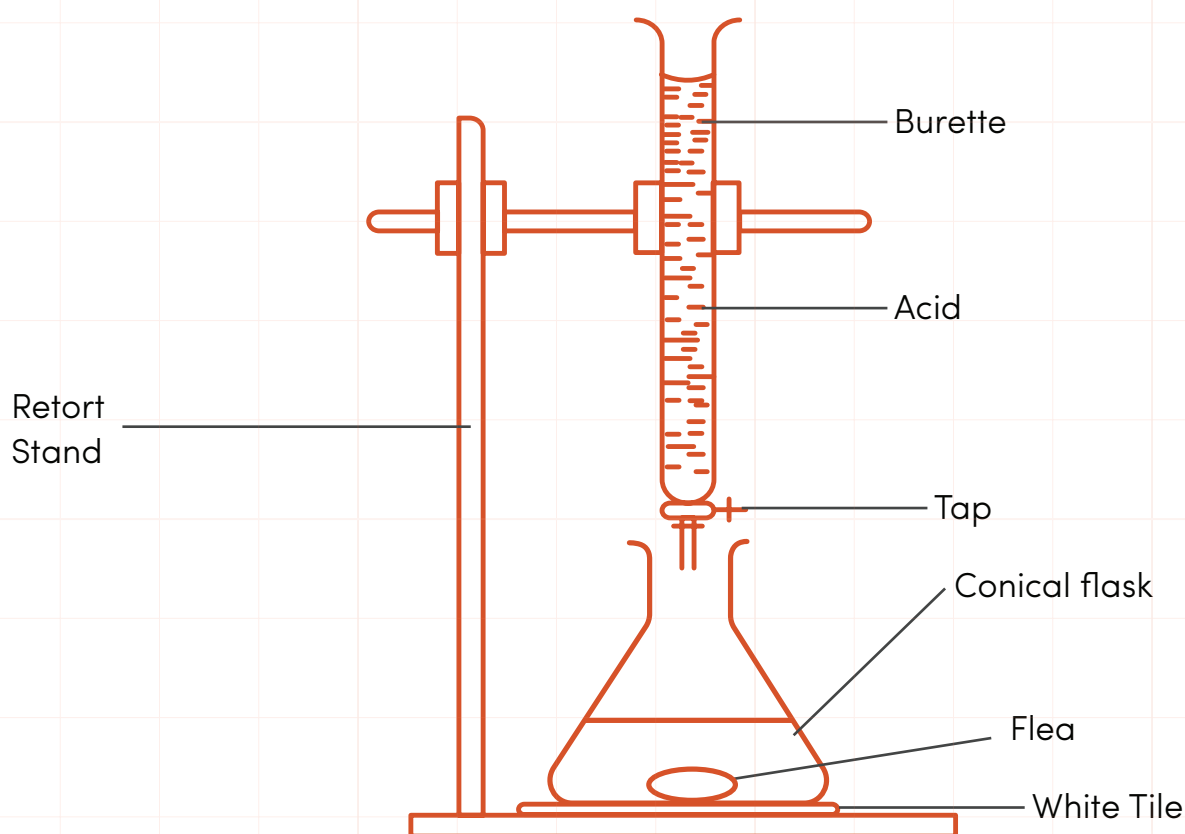
TITRATION



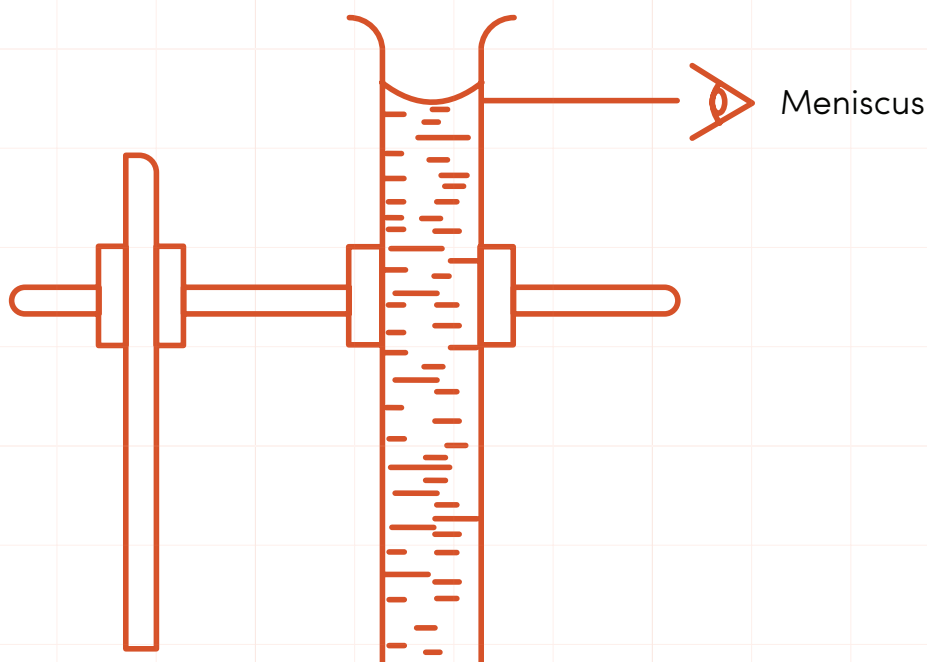
Acid-Base Titration

A titration is a process in which a measured volume of a solution is added to a reaction mixture until some observable property has changed. It is a common technique used for measuring amounts of acids and bases, and is then called an acid-base titration.

Titration is a procedure in which a solution – called the titrant – whose concentration is known very accurately is dispensed by a burette and reacted with a known volume of another solution of unknown concentration called the analyte. By measuring the amount of titrant needed to neutralize the analyte, you can determine the concentration of the analyte very accurately. The “end-point” of a titration is the point at which the titration is complete, typically when an added indicator solution such as methyl orange changes colour.



Acid-Base Titration



A diagram illustrating the meniscus (where the acid reaches in the burette) during acid-base titration

INDICATORS

An indicator is a substance that undergoes a distinct observable change when conditions in its solution change. Examples of indicators used in acid-base titration are methyl orange, methyl red, phenolphthalein etc.

COMMON INDICATORS AND THEIR COLOR CHANGE IN ACID, BASE AND AT THE END POINT.

	Indicator	Acid	Alkali	At end point	Acid/base titration used on
1.	Litmus	Red	Blue	Purple	Strong acid and strong base
2.	Methyl orange	Pink	Yellow	Orange	Strong acid and weak base or trioxocarbonates (iv)
3.	Phenolphthalein	Colorless	Pink	Colorless	Strong base and weak acid
4.	Methyl red	Pink	Red	Red	Strong acid and strong base

Note: No suitable indicator for titration of weak acid and weak base. Any indicator could be used for strong acid and base.

Acid-base titration	Example	pH of solution end-point	Suitable indicator
Strong acid Vs Strong base	HCl Vs NaOH	7	Any indicator
Strong acid Vs Weak base	H ₂ SO ₄ Vs Na ₂ CO ₃	5 – 6	Methyl orange
Weak acid Vs Strong base	CH ₃ COOH Vs NaOH	8 – 9	Phenolphthalein
Weak acid Vs Weak base	CH ₃ COOH Vs NH _{3(aq)}	Variable	No suitable indicator

Types of acid-Base Titration and the Choice of Indicator

Examples of strong acids: HCl, HBr, HI, HNO₃, H₂SO₄, HClO₄ and HClO₃

Examples of Weak acids: H₃PO₄, HNO₂, H₂SO₃, HClO, HClO₂, HF, H₂S, HC₂H₃O₂ etc.)

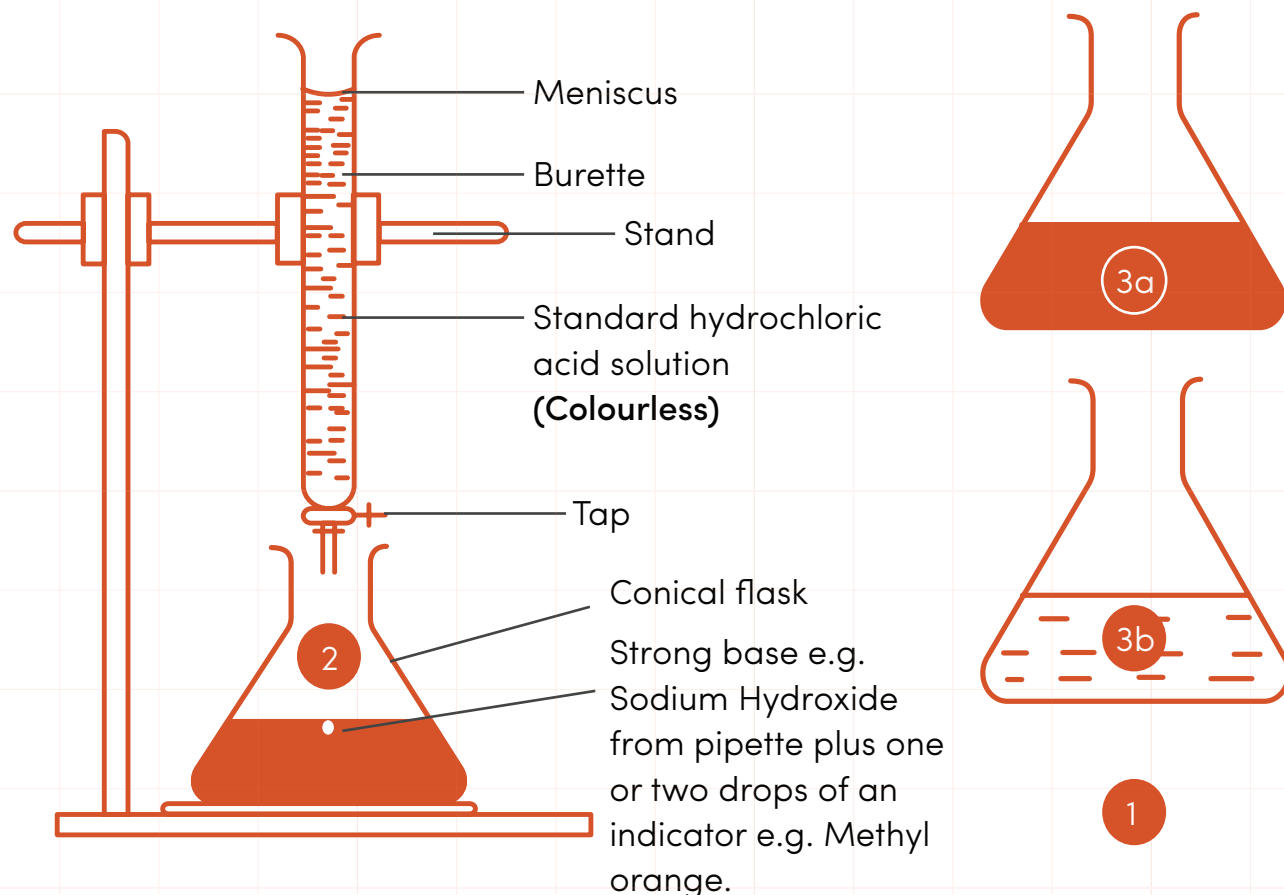
Examples of strong bases: LiOH, NaOH, KOH, Ca(OH)₂, Sr(OH)₂ and Ba(OH)₂

Examples of Weak bases: Ammonia (NH₃) and its derivatives (NH₂OH, (CH₃)₂NH etc.

Apparatus used in acid-base Titration

Some apparatus used in acid-base titration are as follows.

1. Retort stand with clamp and boss head
2. Burette
3. Pipette
4. Conical flask
5. Beaker
6. Dropping Bottle



A diagram illustrating an acid-base titration with the use of an indicator.

OPERATIONAL PROCEDURES DURING TITRATION

1. Rinse the inside of a clean burette thoroughly with the solution it will contain. Allow the solution to run out through the stopcock. Drain the burette completely. Repeat the rinse at least once.
2. Make sure the outside of the burette is clean and dry, and then mount it securely to a laboratory ring stand using a burette clamp of the proper size.
3. Fill the burette to above the zero mark, using a graduated cylinder, small beaker, flask or other container. Use a funnel if necessary to prevent spillage.
4. Run some solution through the stopcock to fill the burette tip completely, making sure there are no air bubbles and that the level of the solution falls to or below the zero mark.
5. Record the starting volume. When you complete the titration you will subtract the starting volume from the final volume to determine the amount of solution you have added (read the volume from the bottom of the meniscus).

RECORDING IN TITRATION

Titration work could be recorded thus:

1. State the size of the pipette used in cm^3 ;
2. Name the indicator used
3. Record your titration in tabular form as shown below:

	Burette	Rough(cm^3)	1st Titre (cm^3)	2nd Titre (cm^3)	3rd Titre (cm^3)
1.	Final Reading				
2.	Initial Reading				
3.	Volume of acid				

4. Find the average volume of acid used from any two or more titre values that do not differ by more than 0.20cm^3 (Rough titre value may be used in averaging as long as the difference of any two titre values is within 0.200cm^3).

DETERMINATION OF THE PERCENTAGE PURITY IN A SUBSTANCE

It is sometimes possible for one of the substances used in titration to contain impurity. For example a solution of Na_2CO_3 may be contaminated by NaCl . The acid may be pure while the base is impure and vice versa. But, at least, one of them must be pure.

The concentration of an impure substances is usually greater than that of the pure part of the impure substance. That means that we need more of the impure substances to complete the pure reaction, than when it is very pure.

LESSON ACTIVITY 1

A is a solution containing 6.3gdm^{-3} of impure ethanedioic acid

B is 0.10mol dm^{-3} sodium hydroxide solution.

Put A into the burette and titrate it against 25.0cm^3 portion of B using phenolphthalein as indicator. Tabulate your result and calculate the average volume of acid used.

- a. From the information provided above, calculate the:
 - i. Concentration of solution A in mol dm^{-3}
 - ii. Concentration of solution B in g dm^{-3} and hence the percentage purity of the ethanedioic acid
 - iii. Volume of solution A that would neutralize a solution containing 0.005mole of sodium hydroxide. The equation for the reaction is

$$\text{H}_2\text{C}_2\text{O}_{4(\text{aq})} + 2\text{NaOH}_{(\text{aq})} \longrightarrow \text{Na}_2\text{C}_2\text{O}_{4(\text{aq})} + 2\text{H}_2\text{O}_{(\text{l})}$$
 (H = 1; C = 12; O = 16)
- b.
 - i. What would be the colour of methyl orange indicator in solution **B**.
 - ii. Give the reason why methyl orange is not suitable indicator for this titration.

MODEL ANSWER

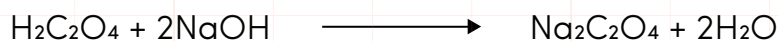
Indicator used: phenolphthalein

Volume of pipette used = 25cm^3

	Burette	Rough(cm^3)	1st Titre (cm^3)	2nd Titre (cm^3)	3rd Titre (cm^3)
1.	Final Reading	20.80	41.43	20.68	25.58
2.	Initial Reading	0.00	20.80	0.00	5.00
3.	Volume of acid	20.80	20.63	20.68	20.58

$$\text{Average Volume of Acid used} = \frac{20.63 + 20.68 + 20.58}{3} = \frac{61.89}{3} = 20.63\text{cm}^3$$

Equation for the reaction is



Concentration of A in mol dm^{-3} ;

No. of mole of NaOH in 25cm^3 of the solution = Molar conc. \times volume of NaOH in dm^3

$$= \frac{0.10 \times 25}{1000} = 0.0025\text{mole}$$

From the equation of the reaction,

1 mole of **A** produces 2 mole **B**

Therefore, x mole of **A** will produce 0.0025mole of **B**

$$\begin{aligned}\text{No. of mole of solution A} &= \frac{0.0025}{2} \\ &= 0.00125\text{mole}\end{aligned}$$

Since the mole ratio of acid to base is 1:2

Molar conc of **A** = No. of mole of **A**

$$\text{Volume of A in } \text{dm}^3 = \frac{0.00125 \times 1000}{20.63} = 0.06\text{mol dm}^{-3}$$

Or by using the relationship

$$\frac{C_A V_A}{C_B V_B} = \frac{n_A}{n_B}$$

Where $C_A = ?$; $C_B = 0.1$; $V_A = 20.63\text{cm}^3$

$V_B = 25\text{cm}^3$; $N_A = 1$; $N_B = 2$

$$\text{Hence, } C_A = \frac{0.1 \times 25 \times 1}{20.63 \times 2} = 0.061\text{mol dm}^{-3}$$

Mass conc. of **A** = molar conc of **A** \times molar mass of **A**

Molar mass of **A** = $(1 \times 2) + (12 \times 2) + (16 \times 4)$

$$= 90\text{g mol}^{-1}$$

$$\text{Mass conc of A} = 0.061 \times 90 = 5.49\text{g dm}^{-3}$$

$$\text{Conc. of B in g dm}^{-3} = \text{Conc. of B in mol dm}^{-3} \times \text{molar mass} = 0.1 \times 40 = 4\text{g dm}^{-3}$$

From (ii)

Percentage purity of the ethanedioic acid

$$\frac{\text{Mass conc. of pure H}_2\text{C}_2\text{O}_4 \times 100}{\text{Mass conc. of impure H}_2\text{C}_2\text{O}_4} = \frac{5.49 \times 100}{6.3} = 87.14\%$$

- iii. For 0.005 mole of NaOH, $(\frac{1}{2} \times 0.005)$ mole of $\text{H}_2\text{C}_2\text{O}_4$ will be needed
i.e 0.0025mole

$$\text{Volume required of H}_2\text{C}_2\text{O}_4 = \frac{\text{No. of mole}}{\text{Molar conc.}} = \frac{0.0025}{0.0061} = 0.04098\text{dm}^3 \text{ i.e } 40.98\text{cm}^3$$

c.)

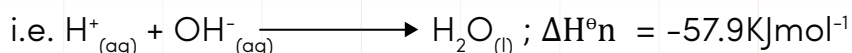
i. Yellow colour

- ii. The titration is a strong acid versus weak base and thus the end point of this titration will not coincide with the pH at which methyl orange indicator shows its colour change.

DETERMINATION OF THE HEAT OF NEUTRALIZATION.

Heat of neutralization is the heat evolved when acids react with alkalis to form salt and water.

The standard heat of neutralization, (ΔH°_n) is the heat change when one mole of hydrogen ions is completely neutralized under standard conditions. Its value is -57.9KJ mol^{-1}



The reaction is exothermic.

	Acid	Alkali	ΔH°_n (KJmol ⁻¹)
1	HCl	NaOH	-57.3
2	HNO ₃	NaOH	-57.3
3	H ₂ SO ₄	NaOH	-64.8
4	HCl	NH ₃	-51.5
5	CH ₃ COOH	NaOH	-55.2
6	CH ₃ COOH	NH ₃	-51.5

APPARATUS AND REAGENTS

1. A plastic cup
2. Beaker
3. A thermometer
4. 2 measuring cylinder
5. A particular volume and the molar solution of the acid and base
e.g. 50.0cm³, 1.0mol dm⁻³, HCl and 50.0cm³ 1.0mol dm⁻³ NaOH

PROCEDURE

1. Measure 50.0cm³ of 1.0mol dm⁻³ NaOH into the plastic cup and record the temperature T_1 of the solution
2. Measure 50.0cm³ of 1.0mol dm⁻³ HCl solution into the beaker and record temperature T_2 of the solution.
3. Pour the HCl solution all at once and as quickly as possible into the NaOH solution. Stir the mixture carefully with the thermometer and record the highest temperature T_3 of the mixture.

ASSUMPTIONS

The following assumptions have been made

- (a) The mass of 1cm³ of each solution is 1.0g

- (b) The heat gained or lost by the plastic cup or beaker is negligible
(c) The specific heat capacity of the solution formed is $4.2\text{Jg}^{-1}\text{K}^{-1}$

LESSON ACTIVITY 2

D is 2.00M ethanoic acid.

E is 2.00M potassium hydroxide solution.

- (a) Using 50cm^3 measuring cylinder, measure 50cm^3 of **D** and transfer the solution into the plastic cup. Record the temperature, T_1 of the solution. Rinse the cylinder with distilled water and allow to dry.
- (b) Using the dry measuring cylinder from (a) above, measure 50cm^3 of **E**. Record the temperature, T_2 of the solution.
- (c) Find the average temperature, T_3 of the two solutions and record the value.
- (d) Pour the measured quantity of solution E quickly from the measuring cylinder into the plastic cup containing solution **D**. stir the mixture with the thermometer. Record the highest temperature, T_4 attained.
- (e) (i) Find the rise in temperature ($T_4 - T_3$) and record the value.
(ii) Calculate the mass of the reaction mixture, given that 1cm^3 of the mixture weighs 1g
- (f) From your results in (a) to (e) above, calculate the
(i) heat evolved during the reaction, given that the specific heat capacity of water is $4.2\text{Jg}^{-1}\text{C}^{-1}$ and using the formula:
Heat evolved = mass x specific heat capacity x rise in temperature
(ii) heat of neutralization of one mole of ethanoic acid by potassium hydroxide.
- (g) List two sources of error in method used for determining heat of neutralization and suggest how their effects can be minimized.

MODEL ANSWER

Solution D is 2M CH_3COOH , and solution E is 2M KOH

- (a) Temp. T_1 of solution D = 31°C
(b) Temp. T_2 of solution E = 32°C

$$(c) \text{ Average Temperature } T_3 = \frac{T_1 + T_2}{2} = \frac{31 + 32}{2} = 31.50^\circ\text{C}$$

(d) The highest temperature, $T_4 = 40^\circ\text{C}$

(e) (i) Rise in temperature $T_4 - T_3 = 40 - 31.50 = 8.50^\circ\text{C}$

(ii) 50cm^3 of solution D + 50cm^3 of solution E = 100cm^3 of mixture.

1cm^3 of the solution weighs 1g (given)

100cm^3 of the mixture will weigh $1 \times 100 = 100\text{g}$.

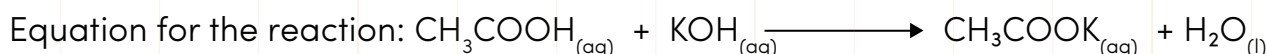
(f) (i) heat evolved = mass \times specific heat capacity \times rise in temperature

$$= 100 \times 4.2 \times 8.5 \text{ joules}$$

$$= 3570 \text{ joules.}$$

(ii) Number of moles = Conc. $\text{mol dm}^{-3} \times \text{Vol. dm}^3$

$$\text{For the acid: } \frac{50 \times 2}{1000} = 0.10 \text{ moles And for the base: } \frac{50 \times 2}{1000} = 0.10 \text{ moles}$$



From the aqueous neutralization above,

1 mole of CH_3COOH + 1 mole of KOH produces one mole of water.

0.1 mole of CH_3COOH will produce 0.1 mole of water.

Hence, 0.1 mole of H_2O is produced with the evolution of 3570 Joules of heat energy.

$$1 \text{ mole of } \text{H}_2\text{O} \text{ will be produced with the evolution of } \frac{3570}{0.1} \text{ J mol}^{-1}$$

$$= 35700 \text{ J mol}^{-1} = 35.70 \text{ KJ mol}^{-1}$$

The heat of neutralization is $35.70 \text{ KJ mol}^{-1}$ water formed.

(g) Sources of error:

(i) Heat is lost

(ii) The mixing rate of the solutions

(iii) Density of the solutions not exactly 1g cm^{-3}

(iv) Thermometer may not be accurately calibrated.

(v) Loss of solution during transfer and lagging

Methods of minimizing error:

(i) Use lagged calorimeter

(ii) Find water equivalent of calorimeter.

(iii) Accurate measurement of the mass of solution and mixture

(iv) careful stirring and transfer.

WATER OF CRYSTALLIZATION

Hydrated substances are used in water of crystallization but only the anhydrous part of it is neutralized. The water of crystallization only remain as an impurity in the solution.

Lesson Activity 3

A is a $0.0950 \text{ mol dm}^{-3}$ HCl

B is a solution containing 13.50 g dm^{-3} of $\text{X}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

Put A into the burette and titrate it against 25 cm^3 portions of **B** using methyl orange as indicator.

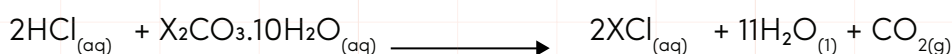
Tabulate your readings and calculate the average volume of **A** used.

From the information provided above, calculate the:

- Concentration of **B** in mol dm^{-3}
- Molar mass of $\text{X}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ in g mol^{-1}
- Percentage by mass of x in X_2CO_3 .

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

The equation for the reaction involved in the titration is

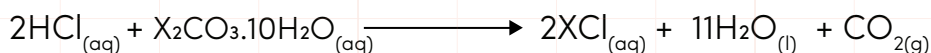


Model Answer

Burette Readings	Rough	1 st Titre	2 nd Titre	3 rd Titre
Final Burette Readings	26.30	24.50	24.60	25.00
Initial Burette Readings	0.00	0.00	0.00	0.00
Volume of Acid used	26.30	24.50	24.60	25.00

$$\text{Average volume of Acid used} = \frac{24.50 + 24.60 + 25.00}{3} = \frac{74.1}{3} = 24.70\text{cm}^3$$

Equation for the reaction



(i) To calculate the conc. of B in mol dm^{-3}

$$\text{Conc. (gdm}^{-3}\text{) of } \text{X}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}_{(\text{aq})} = 13.50\text{gdm}^{-3}$$

$$\text{By Using} = \frac{C_A V_A}{C_B V_B} = \frac{n_A}{n_B}$$

$$C_A = 0.0950\text{mol dm}^{-3}, n_A = 2, V_A = 24.70\text{cm}^3, n_B = 1, V_B = 25.0\text{cm}^3$$

$$C_B = ?$$

$$C_B = \frac{0.0950 \times 24.70 \times 1}{25.0 \times 2} = 0.04693\text{mol dm}^{-3}$$

(ii) $\text{Conc. (gdm}^{-3}\text{) = molar mass} \times \text{conc. (mol dm}^{-3}\text{)}$

$$13.50 = \text{molar mass} \times 0.04693$$

$$\text{Molar mass} = \frac{13.50}{0.04693}$$

$$\text{Molar mass } \text{X}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} = 287.70\text{g mol}^{-1}$$

(iii) $\text{X}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

$$2x + 12 + 3 \times 16 + 10(2 + 16) = 287.70$$

$$2x + 12 + 48 + 10(18) = 287.70$$

$$2x + 60 + 180 = 287.70$$

$$2x + 240 = 287.70$$

$$2x = 287.70 - 240 = 47.70$$

$$x = 23.85$$

$$\text{Since } x^2 = 2x = 2 \times 23.85 = 47.70$$

% by mass of X in $\text{X}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$

$$= \frac{47.70}{287.70} \times 100 = 16.60\%$$

REDOX TITRATIONS

Redox reactions involve reactions between oxidizing and reducing agents.

An oxidizing agent or oxidant is a compound or element which can bring about oxidation and itself will be reduced. Oxidizing agent generally accepts electrons. It is reduced to a lower oxidation number in a reaction and oxidizes other substances. Examples are solutions of Acidified KMnO_4 , acidified $\text{K}_2\text{Cr}_2\text{O}_7$, iron (iii) compounds, conc. HNO_3 , conc. H_2SO_4 , potassium trioxiodate (v) KIO_3 , iodine, I_2 , powdered manganese (iv) oxide, MnO_2 and gaseous O_2 and Cl_2 .

A reducing agent or reductant or reducer is a compound or element which can bring about reduction and itself will be oxidized. It is an electron donor. It loses electrons and is oxidized to a higher oxidation number. Examples of reducing agents are solution of iron(ii) compounds(Fe^{2+}), tin(ii) compounds, Sn^{2+} , sodium ethanoate, CH_3COONa , KI , conc. HCl , sodium trioxosulphate (iv), $\text{Na}_2\text{S}_2\text{O}_3$, ethanedioic acid, $\text{H}_2\text{C}_2\text{O}_4$, pure metals, carbon, H_2 , H_2S and SO_2 .

TEST FOR OXIDIZING AND REDUCING

TEST FOR AN OXIDIZING AGENT

A reducing agent is used to test for an oxidizing agent.

1. Heat the substance strongly in a test tube. The gas evolved is colourless, odourless, has no action on litmus paper, but relights a glowing splint.
The gas is oxygen. Oxygen is an oxidizing agent.
2. H_2S gas is allowed to come in contact with a solution of a substance on a strip of filter paper. If There is a yellow deposit of sulphur on the filter paper, this shows that the solution is an oxidizing agent.
3. Heat a little of the substance with conc. HCl . If a greenish-yellow gas with pungent smell is evolved. The gas, which bleaches litmus, is chlorine.
The substance is an oxidizing agent.

4. To the solution of an unknown substance, add a few drops of colourless acidified potassium iodide solution. If the solution turns brown, due to the evolution of Iodine, which turns starch solution blue-black. Then the solution is an oxidizing agent.

TEST FOR A REDUCING AGENT

An oxidizing agent is used to test for a reducing agent.

- i. To the solution of the substance, add a few drops of yellow or brown solution of FeCl_3 . The solution turns green, then the substance is a reducing agent.
2. To the solid substance in a test tube, add a few drops of bench dilute hydrochloric acid. There is effervescence; the gas given off is colourless, odourless, has no action on moist red or blue litmus paper, but gives a pop with lighted splint. The gas is hydrogen, while the substance is a metal above hydrogen in the activity series. The solid substance is a reducing agent.
3. To the solution of the substance, add a few drops of yellow acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution. If the yellow colour of $\text{K}_2\text{Cr}_2\text{O}_7$ solution turns green, then the substance is a reducing agent.
4. To the solution of the unknown substance, add a few drops of purple acidified KMnO_4 . If the KMnO_4 solution is decolourised. The substance is a reducing agent

OPERATIONAL PROCEDURES DURING REDOX TITRATION

All the basic procedures involved in acid – base titrations are also applicable to redox reactions. When the mole concept is applied to redox reagents, the amount of substance present in a given solution can be determined.

Indicators used in Redox titration

Some redox titrations require indicator while some do not.

END-POINT OF A REDOX TITRATION

Indicators such as methyl orange and phenolphthalein are not used in redox titrations.

1. In a redox titration involving KMnO_4 solution and a colourless reducing agent, no external indicator is required; KMnO_4 acts as its own indicator. The end-point is the first permanent pink colour.
2. In a redox titration involving iodine solution and a colourless reducing agent, starch solution is used. The end-point is confirmed by a change from blue-black to colourless. The starch solution is added towards the endpoint of the titration. Adding the starch earlier on in the titration would cause the formation of an iodine-starch complex that yields a reddish-brown coloured endpoint.

At the end-point, the amounts of the oxidizing agent, and that of the reducing agent, are exactly in the same ratio as that required in the balanced equation of reaction. That is:

$$\frac{\text{Mole of OA used}}{\text{Mole of RA used}} = \frac{\text{mole of OA in the equation}}{\text{mole of RA in the equation}}$$

RECORDING IN REDOX TITRATIONS

Titration work could be recorded thus:

1. State the size of the pipette used in cm^3 ;
2. Name the indicator used (if necessary)
3. Record your titrations in tabular form as shown below:

Burette Readings	Rough(cm^3)	1 st Titre(cm^3)	2 nd Titre (cm^3)	3 rd Titre (cm^3)
Final Burette Readings				
Initial Burette Readings				
Volume of Acid used				

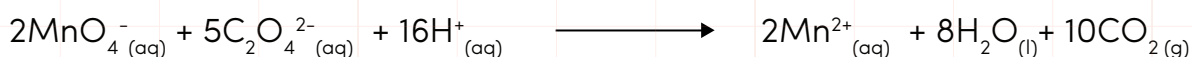
4. Find the average titre values of reagent used from any two titre values that do not differ by more than 0.20cm^3 (Rough titre value may be used in averaging as long as the difference of any two titre values is within 0.200cm^3).

Lesson Activity 4

A is a solution of $0.050 \text{ mol dm}^{-3} \text{ H}_2\text{C}_2\text{O}_4$ (ethanedioic acid), **B** is a solution of KMnO_4 , potassium tetraoxomanganate (vii), of unknown concentration. (a) put **B** into the burette. Pipette 20.0 cm^3 or 25 cm^3 of **A** into a conical flask and add about 10.0 cm^3 of dilute H_2SO_4 . Heat the mixture to about 40°C – 50°C and titrate it while still hot with **B**.

Repeat the titration to obtain consistent titre values.

Tabulate your results and calculate the average volume of B used. The equation of reaction is:



(b) From your results and the information provided, calculate the:

- (i) concentration of MnO_4^- in **B** in mol dm^{-3} ;
- (ii) concentration of KMnO_4 in **B** in g dm^{-3} ;
- (iii) volume of CO_2 evolved at s.t.p when 25.0 cm^3 of $\text{H}_2\text{C}_2\text{O}_4$ reacted completely.
[O=16.0, K=39.0, Mn=55.0, molar volume of gas at s.t.p. = $22.4 \text{ dm}^3 \text{ mol}^{-1}$]

Model Answer

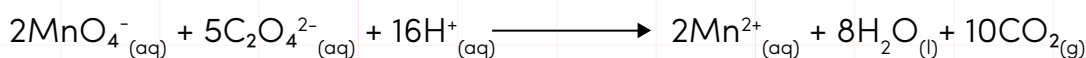
A = $0.050 \text{ mol dm}^{-3} \text{ H}_2\text{C}_2\text{O}_4$ (ethanedioic acid)

B = KMnO_4 (potassium tetraoxomanganate (vii))

Burette Readings	Rough	1 st Titration	2 nd Titration	3 rd Titration
Final Burette Readings	24.50	24.60	24.50	24.50
Initial Burette Readings	0.00	0.00	0.00	0.00
Volume of Acid used	24.50	24.60	24.50	24.50

$$\text{Average Titre value} = \frac{24.60 + 24.50 + 24.50}{3} = \frac{73.6}{3} = 24.53 \text{ cm}^3$$

Equation for the reaction:



(b) (i) Molar concentration of KMnO_4

$$\text{Conc. of } \text{X}_2\text{CO}_3 \cdot 10\text{H}_2\text{O} (\text{aq}) (\text{gdm}^{-3}) = 13.50 \text{gdm}^{-3}$$

By using
$$\frac{C(\text{MnO}_4^-) \times V(\text{MnO}_4^-)}{C(\text{C}_2\text{O}_4^{2-}) \times V(\text{C}_2\text{O}_4^{2-})} = \frac{n(\text{MnO}_4^-)}{n(\text{C}_2\text{O}_4^{2-})}$$

$$\frac{C(\text{MnO}_4^-) \times 24.53}{0.05 \times 25} = \frac{2}{5} \quad \text{Hence, } C(\text{MnO}_4^-) = \frac{0.05 \times 25 \times 2}{24.53 \times 5} = \frac{2.5}{122.65}$$

$$C(\text{MnO}_4^-) = 0.00204 \text{mol dm}^{-3}$$

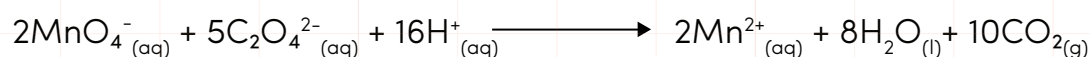
(ii) Mass concentration of KMnO_4

$$\begin{aligned} \text{Molar mass of } \text{KMnO}_4 &= 39 + 55 + (16 \times 4) = 39 + 55 + 64 \\ &= 158 \text{g mol}^{-1} \end{aligned}$$

$$\begin{aligned} \text{Mass Conc. } \text{KMnO}_4 &= \text{Molar conc} \times \text{molar mass} \\ &= 0.0204 \times 158 = 3.22 \text{gdm}^{-3} \end{aligned}$$

(iii) Volume of CO_2 (gas evolved)

From the equation for the reaction,



$$5 \text{mole of } \text{H}_2\text{C}_2\text{O}_4 \equiv 0.05 \text{mol dm}^{-3} \text{H}_2\text{C}_2\text{O}_4$$

$$10 \text{mole of } \text{CO}_2 \equiv x \text{mol dm}^{-3} \text{CO}_2$$

$$x = \frac{10 \times 0.05}{5}$$

$$n(\text{CO}_2) = 2 \times 0.05 = 0.100 \text{mol}$$

$$V(\text{CO}_2) \text{ at s.t.p.} = n \times V_n$$

$$25 \text{cm}^3 \text{ of } \text{H}_2\text{C}_2\text{O}_4 \equiv \frac{0.100 \times 22.4 \times 25}{1000}$$

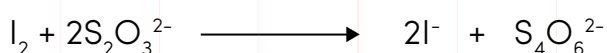
$$= 0.056 \text{dm}^3 \text{ or } 56.0 \text{cm}^3$$

LESSON ACTIVITY 5

A is a solution containing 15.8gdm^{-3} of $\text{Na}_2\text{S}_2\text{O}_3$.

B was obtained by dissolving 9.0g of an impure sample of I_2 in aqueous KI and the solution made up to 1dm^3 .

(a) Put **A** into the burette and titrate it against 20.0cm^3 or 25.0cm^3 portions of **B**. Use Starch solution as indicator. Repeat the titration to obtain concordant titre values. Tabulate your result and calculate the average volume of A used. The equation for the reaction involved in the titration is:



(b) From your result and the information provided, calculate the:

- (i) concentration of **A** in mol dm^{-3} ;
- (ii) concentration of I_2 in **B** in mol dm^{-3} ;
- (iii) percentage by mass of I_2 in the sample.

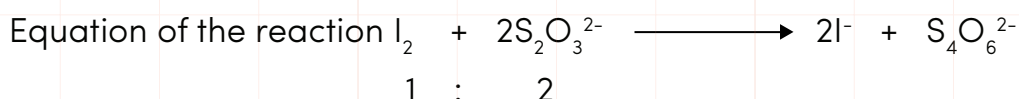
(c) Give reason why the starch indicator was not added to the titration mixture at the beginning of the titration. [$\text{O} = 16.0$; $\text{Na} = 23.0$; $\text{S} = 32.0$; $\text{I} = 127.0$]

Model Answer

(a) Burette Reading

Burette Readings	Rough	1 st Titration	2 nd Titration	3 rd Titration
Final Burette Readings	12.54	12.50	12.60	24.80
Initial Burette Readings	0.00	0.00	0.00	12.60
Volume of Acid used	12.54	12.50	12.60	12.20

$$\text{Average Titre value} = \frac{12.50 + 12.60 + 12.20}{3} = \frac{37.30}{3} = 12.43\text{cm}^3$$



(b) Concentration of **A** in mol dm^{-3}

$$\frac{\text{Concentration of A in gdm}^{-3}}{\text{Molar mass of A in g mol}^{-1}} = \frac{15.8\text{gdm}^{-3}}{\text{Molar mass of A}}$$

$$\text{Molar mass Na}_2\text{S}_2\text{O}_3 = 2(23) + 2(32) + 3(16) = 46 + 64 + 48 = 158\text{g mol}^{-1}$$

Concentration of **A** in mol dm^{-3}

$$= \frac{15.8\text{g dm}^{-3}}{158\text{g dm}^{-3}} = 0.100\text{mol dm}^{-3}$$

(ii) Concentration of I_2 in B in mol dm^{-3}

$$\text{By using } \frac{C_A V_A}{C_B V_B} = \frac{n_A}{n_B}$$

$$C_A = 0.100\text{mol dm}^{-3}, V_A = 12.43\text{cm}^3, C_B = ?, V_B = 25.00\text{cm}^3$$

$$\frac{0.100 \times 12.43}{C_B \times 25.00} = \frac{2}{1} \quad \text{Hence, } C_B = \frac{0.100 \times 12.43 \times 1}{2 \times 25.00} = \frac{1.24}{50}$$

$$C_B = 0.0248\text{mol dm}^{-3}$$

$$= 0.0250\text{mol dm}^{-3}$$

$$\text{(iii) Percentage by mass of } \text{I}_2 \text{ in the sample} = \frac{\text{Concentration in g dm}^{-3}}{9.0\text{g dm}^{-3} \text{ of impure } \text{I}_2 \text{ in KI}} \times \frac{100\%}{1}$$

$$\text{Concentration in g dm}^{-3} (\text{Pure}) = \frac{\text{Concentration in g dm}^{-3} (\text{pure})}{\text{Molar mass of } \text{I}_2 (\text{pure})}$$

$$0.0250\text{g dm}^{-3} = \frac{\text{Concentration in g dm}^{-3} (\text{pure})}{\text{Molar mass of } \text{I}_2 (\text{pure})}$$

$$\text{Molar mass of } \text{I}_2 = 127 \times 2 = 254\text{g mol}^{-1}$$

$$0.0250\text{g dm}^{-3} = \frac{\text{Concentration in g dm}^{-3} (\text{pure})}{254\text{g dm}^{-3}}$$

$$\text{Concentration in g dm}^{-3} (\text{pure}) = 0.0250 \times 254 = 6.35\text{g dm}^{-3}$$

Percentage by mass of I_2 in the sample

$$= \frac{6.35}{9.0} \times \frac{100\%}{1} = 70.555 = 70.56\%$$

(c) Starch indicator was not added to the titration mixture at the beginning of the titration in order to obtain accurate end-point or to prevent the formation of complex which reduces the accuracy of the titre value.

QUALITATIVE ANALYSIS

Qualitative analysis deals with the identification of elements or grouping of elements present in a sample. In quantitative analysis, the amount of a particular material is measured, but in qualitative analysis, we simply confirm the presence or absence of certain materials in a sample. One of the common analysis is the identification of aqueous ions. This analysis involves two phases:

First, we develop a scheme to separate the ions from each other. Once that is done, their identity can further be verified by a confirmatory test. In a confirmatory test, we can identify each ion by adding a chemical to the solution of that ion. Such a solution changes colour or forms a precipitate. This response confirms the presence of the ion.

Apparatus used in Qualitative analysis	Some of the reagents used in qualitative analysis
<ol style="list-style-type: none">1. Beakers2. Test tubes racks3. Test tubes4. Boiling tubes5. Ignition tubes6. Stirring rods funnel7. Flasks8. Bunsen burner, wooden splint9. Glass tubes10. Test tube holder, glass delivery tubes, spatula e.t.c.	<ol style="list-style-type: none">1. Litmus papers2. Starch-iodide papers3. Solution of sodium hydroxide4. Concentrated or dilute Solution of ammonia or ammonium hydroxide5. Barium chloride solution6. Lead (ii) ethanoate solution7. Concentrated or dilute H_2SO_4 solution8. Anhydrous CuSO_4 (white)9. Anhydrous CoCl_2 (blue)10. Concentrated or dilute hydrochloric acid11. Lead (ii) ethanoate solution12. Fresh starch solution13. Potassium iodide solution14. Acidified KMnO_4 solution15. Acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution16. Lime water (fresh)17. Silver trioxonitrate (v) solution etc.

IDENTIFICATION OF CATIONS

Cations are also called metallic radicals. Cations are the positively charged ions.

To identify cations, add a suitable reagent and note the colour (i.e. if there is any colour change), the precipitate (if any) and dissolution (i.e. whether it is soluble in the reagent or not). The solution of sodium Hydroxide $\text{NaOH}_{(\text{aq})}$ and that of Ammonium Hydroxide ($\text{NH}_4\text{OH}_{(\text{aq})}$) are commonly used.

Test for Zn^{2+}

	Test	Observation	Inference
1	To the unknown solution, add dilute $\text{NaOH}_{(\text{aq})}$ in drops and then in excess	White gelatinous precipitate formed which is soluble in excess $\text{NaOH}_{(\text{aq})}$	Zn^{2+} or Pb^{2+} or Al^{3+} present
2	To the unknown solution, add a few drops of dilute $\text{NH}_3_{(\text{aq})}$; And then in excess	White gelatinous precipitate formed Precipitate formed which is soluble in excess $\text{NH}_3_{(\text{aq})}$	Zn^{2+} or Pb^{2+} or Al^{3+} present Zn^{2+} confirmed
3	To the unknown solution, add potassium hexacyanoferrate (ii), $[\text{K}_4\text{Fe}(\text{CN})_6]$ solution	White gelatinous precipitate formed	Zn^{2+} confirmed
4	Pass ammonium sulphide, H_2S gas solution	Dirty white precipitate formed	Zn^{2+} confirmed
5	To the unknown solution, add dilute $\text{HCl}_{(\text{aq})}$ or dilute $\text{H}_2\text{SO}_{4(\text{aq})}$ OR To the unknown solution, add dilute $\text{NH}_3_{(\text{aq})}$ then add $\text{NH}_4\text{Cl}_{(\text{aq})}$	No precipitate formed	Zn^{2+} confirmed

Test for Pb^{2+}

	Test	Observation	Inference
1	To the unknown solution add $\text{NaOH}_{(\text{aq})}$ in drops and then in excess	White gelatinous precipitate formed which is insoluble in excess $\text{NaOH}_{(\text{aq})}$	Zn^{2+} or Pb^{2+} or Al^{3+} present
2	To the unknown solution, add a few drops of dilute $\text{NH}_{3(\text{aq})}$; and then in excess	White gelatinous precipitate formed. precipitate formed which is insoluble in excess $\text{NH}_{3(\text{aq})}$	Zn^{2+} or Pb^{2+} or Al^{3+} present Pb^{2+} or Al^{3+} present
3	To the unknown solution, add a few drops of conc. $\text{HCl}_{(\text{aq})}$, then warm the mixture and cool.	White precipitate formed which is soluble when warm and appears when cool.	Al^{3+} absent Pb^{2+} present
4	To the unknown solution, add potassium iodide KI solution or potassium tetraoxochromate (vi), K_2CrO_4 solution.	Yellow precipitate formed	Pb^{2+} confirmed
5	To the unknown solution, add dilute $\text{H}_2\text{SO}_{4(\text{aq})}$	White powdery precipitate formed	Pb^{2+} confirmed
6	To the unknown solution, add dilute $\text{NH}_{3(\text{aq})}$ then add $\text{NH}_4\text{Cl}_{(\text{aq})}$	White crystalline precipitate is formed on adding $\text{NH}_4\text{Cl}_{(\text{aq})}$	Pb^{2+} present
7	Pass H_2S gas into the unknown solution, then add dilute $\text{HCl}_{(\text{aq})}$	Black precipitate formed	Pb^{2+} or Cu^{2+} present

Test for Al^{3+}

S/N	Test	Observation	Inference
1	To the unknown solution, add a few drops of dilute $\text{NH}_3(\text{aq})$ and then, in excess	White gelatinous precipitate formed. Precipitate formed is insoluble in excess $\text{NH}_3(\text{aq})$	Zn^{2+} or Pb^{2+} or Al^{3+} present, Pb^{2+} or Al^{3+} present
2	To the unknown solution, add dilute $\text{NH}_3(\text{aq})$ then add $\text{NH}_4\text{Cl}(\text{aq})$ OR To the unknown solution, add dilute $\text{NH}_4\text{Cl}(\text{aq})$ then add $\text{NH}_3(\text{aq})$	White gelatinous precipitate formed White gelatinous precipitate formed	Al^{3+} present Al^{3+} present

Test for Ca^{2+} and NH_4^+)

	Test	Observation	Inference
1	To the unknown solution, add a few drops of $\text{NH}_3(\text{aq})$	No visible reaction or precipitate formed	Ca^{2+} or NH_4^+ Present
2	To the unknown solution, add a few drops of $\text{NaOH}(\text{aq})$	A dirty white precipitate which is insoluble in excess $\text{NaOH}(\text{aq})$	Ca^{2+} confirmed
3	To the unknown solution, add a few drops of $\text{NH}_3(\text{aq})$, then ammonium trioxocarbonate (iv), (NH_4CO_3) solution Or ammonium oxalate in drops and then in excess.	White precipitate insoluble in excess NH_4CO_3 or ammonium oxalate solution	Ca^{2+} present
4	To the unknown solution, add a few drops of $\text{H}_2\text{SO}_4(\text{aq})$	No precipitate formed	Ca^{2+} present
5	To the unknown solution, add a few drops of $\text{NaOH}(\text{aq})$	No precipitate is formed but on warming, a gas which has a pungent or irritating or urine smell, turns red litmus paper blue and forms white fume with conc. HCl is given off.	The gas is ammonia (NH_3) from ammonium salt (NH_4^+)
6	To the unknown solution, add a few drops of ammonia solution, then heat.	A colourless gas with choking smell which turns red litmus paper blue was evolved.	NH_4^+ confirmed

Test for Cu^{2+}

	Test	Observation	Inference
1	To Unknown solution, add $\text{NaOH}_{(\text{aq})}$ in drops and then in excess	A light or pale blue gelatinous precipitate which is insoluble in excess $\text{NaOH}_{(\text{aq})}$ was formed.	Cu^{2+} confirmed
2	To the unknown solution, add a few drops of $\text{NH}_3(\text{aq})$ and then in excess.	A pale blue precipitate which is soluble in excess ammonia solution to form a deep blue solution.	Cu^{2+} confirmed

Test for Fe^{2+}

	Test	Observation	Inference
1	To the unknown solution, add dilute $\text{NaOH}_{(\text{aq})}$ in drops and then in excess	Green gelatinous precipitate insoluble in excess $\text{NaOH}_{(\text{aq})}$ and turns reddish-brown on exposure to air.	Fe^{2+} confirmed
2	To the unknown solution, add a few drops of $\text{NH}_3(\text{aq})$ and then in excess.	Dirty green precipitate which is insoluble in excess ammonia solution.	Fe^{2+} confirmed

Test for Fe^{3+}

	Test	Observation	Inference
1	To the unknown solution, add dilute $\text{NaOH}_{(\text{aq})}$ in drops and then in excess	Reddish-brown precipitate insoluble in excess $\text{NaOH}_{(\text{aq})}$	Fe^{3+} confirmed
2	To the unknown solution, add a few drops of $\text{NH}_3(\text{aq})$ and then in excess.	Reddish-brown precipitate insoluble in excess $\text{NH}_3(\text{aq})$	Fe^{3+} confirmed

Test for Mg^{2+}

	Test	Observation	Inference
1.	To the unknown solution, add dilute $NaOH_{(aq)}$ in drops and then in excess	White precipitate formed Precipitate insoluble in excess dilute $NaOH_{(aq)}$; white crystalline precipitate formed.	Mg^{2+} confirmed

Test for Mn^{2+}

	Test	Observation	Inference
1.	To the unknown solution, add dilute $NaOH_{(aq)}$ in drops and then in excess	White precipitate which turns brown on standing	Mn^{2+} confirmed
2.	To the unknown solution, add a few drops of $NH_{3(aq)}$ and then in excess.	Slight white precipitate insoluble in excess dilute ammonia solution.	Mn^{2+} confirmed

Test for Na^+

Sodium hydroxide solution $NaOH_{(aq)}$ and ammonia, $NH_{3(aq)}$ cannot be use to identify sodium ion in its solution.

	Test	Observation	Inference
1.	To the unknown solution, add a few drops of few zinc uranyl ethanoate solution	Yellow precipitate is formed	Na^+ confirmed

IDENTIFICATION OF ANIONS

Anions are acid radicals. They are non-metallic Radicals. Examples of anions are: SO_4^{2-} , SO_3^{2-} , CO_3^{2-} , HCO_3^- , S^{2-} , NO_3^- , NO_2^- , Cl^- , Br^- , I^- etc. They can be identified by some precipitating and oxidizing agents. For examples:

1. CO_3^{2-} , SO_3^{2-} , SO_4^{2-} , S^{2-} , Cl^- , Br^- and I^- are precipitated by $\text{Pb}(\text{NO}_3)_2$ or $\text{Pb}(\text{CH}_3\text{COO})_2$ or AgNO_3 solution.
2. CO_3^{2-} , S^{2-} , SO_3^{2-} , SO_4^{2-} are also precipitated by BaCl_2 or $\text{Ba}(\text{NO}_3)_2$ solution
3. CO_3^{2-} is also precipitated by MgSO_4 solution.

The confirmatory test for some anions are summarized below:

Test for SO_4^{2-}

Solution of SO_4^{2-} that can be used to test for the ion are Magnesium tetraoxosulphate (vi) solution, Calcium tetraoxosulphate (vi) solution, Sodium tetraoxosulphate (vi) solution etc.

Test for SO_4^{2-}

	Test	Observation	Inference
1.	To the unknown substance, add BaCl_2 or $\text{Ba}(\text{NO}_3)_2$ solution	White precipitate formed.	SO_4^{2-} or SO_3^{2-} or CO_3^{2-} or S^{2-} present
2.	To the unknown substance, add BaCl_2 or $\text{Ba}(\text{NO}_3)_2$ solution then add dilute $\text{HCl}_{(\text{aq})}$ or $\text{HNO}_{3(\text{aq})}$ in drops.	White Precipitate insoluble in excess dilute acid	SO_4^{2-} confirmed

Test for CO_3^{2-} and HCO_3^-

Substances that can be used to test for CO_3^{2-} are Calcium trioxocarbonate (iv), Sodium trioxocarbonate (iv) etc.

substances that can be used to test for HCO_3^- are Sodium hydrogen trioxocarbonate (iv), potassium hydrogen trioxocarbonate (iv),

	Test	Observation	Inference
1	To the unknown solution, add dilute $\text{HCl}_{(\text{aq})}$ or dilute $\text{HNO}_{3(\text{aq})}$	Solution of a colourless, odourless and tasteless gas which turns lime water milky and acidic to moist litmus paper.	The gas is CO_2 from CO_3^{2-} or HCO_3^-
2	To the unknown solution, add $\text{AgNO}_{3(\text{aq})}$ in drops and then in excess, then add dilute $\text{HCl}_{(\text{aq})}$ or dilute $\text{HNO}_{3(\text{aq})}$	White precipitate gradually turns brown. White precipitate soluble in dilute $\text{HCl}_{(\text{aq})}$ or dilute $\text{HNO}_{3(\text{aq})}$ with vigorous effervescence.	CO_3^{2-} confirmed
3	To the unknown solution, add phenolphthalein solution in drops	Pink colouration is formed	CO_3^{2-} confirmed
4.	To the unknown solution, add $\text{BaCl}_{2(\text{aq})}$ or $\text{MgSO}_{4(\text{aq})}$ then heat.	No visible reaction or change or precipitate, White precipitate is formed, No visible reaction on heating.	HCO_3^- confirmed
5.	To the unknown solution, add phenolphthalein solution in drops then heat.	The solution turns pink.	HCO_3^- confirmed

Test for S^{2-}

Substances that can be used to test for S^{2-} are potassium sulphide, sodium sulphide, ammonium sulphide etc.

	Test	Observation	Inference
1.	To the unknown solution, add $AgNO_{3(aq)}$ in drops then, in excess.	White precipitate is formed in drops. Black precipitate is formed	Cl^- , or S^{2-} or SO_3^{2-} present, S^{2-} confirmed

Test for NO_3^- and NO_2^-

Substances that can be used to test for NO_3^- are sodium trioxonitrate (V), magnesium trioxonitrate (v) etc., Substances that can be used to test for NO_2^- , sodium dioxonitrate (III), potassium dioxonitrate (iii)

	Test	Observation	Inference
1.	To 2 cm ³ of the unknown solution, add 3 cm ³ of freshly prepared $FeSO_{4(aq)}$, then add about 3 cm ³ of conc. $H_2SO_{4(aq)}$ slowly down the side of the test tube held in a slanting position.	A brown ring is formed at the junction of the two layers	NO_3^- confirmed
2.	To the unknown solution, add conc. $H_2SO_{4(aq)}$	Reddish brown fumes evolved	NO_3^- confirmed
3.	To 1cm ³ of the unknown solution, add freshly prepared iron (ii) tetraoxosulphate (vi), $FeSO_{4(aq)}$ followed by 2 or 3 drops of ethanoic acid solution To the unknown solid sample, add dilute $HCl_{(aq)}$ then heat. (this test is used to distinguish NO_2^- from NO_3^- . While there is an evolution of a gas in NO_2^- , there is no evolution of any gas in NO_3^-	Formation of a brown solution Evolution of a Reddish-brown gas.	NO_2^- confirmed NO_2^- confirmed

Test Halogens Test Cl^-

Substances that can be used to identify Cl^- ion are Sodium Chloride solution, dilute hydrochloric acid etc.

	Test	Observation	Inference
1.	To the unknown solution, add $\text{AgNO}_{3(\text{aq})}$ in drops	White precipitate is formed	Cl^- , or S^{2-} or SO_3^{2-} present
2.	To the unknown solution, add $\text{AgNO}_{3(\text{aq})}$; then add dilute $\text{HNO}_{3(\text{aq})}$ in drops and then in excess;	White precipitate insoluble in excess dilute $\text{HNO}_{3(\text{aq})}$. The precipitate dissolves	Cl^- confirmed Cl^- confirmed Cl^- confirmed
3.	To the unknown solid sample, add 1cm^3 of conc. $\text{H}_2\text{SO}_{4(\text{aq})}$ then heat.	Evolution of a steamy and choking white fume which turns moist blue litmus paper red and gives a dense white fume with the lid of concentrated ammonia bottle.	Cl^- confirmed
4.	To the unknown solid sample, add conc. $\text{H}_2\text{SO}_{4(\text{aq})}$ then, add MnO_2 ; then heat.	Liberation of a greenish-yellow gas with a suffocating odour or pungent smell which turns moist blue litmus paper red and then bleaches it. It also turns starch iodide paper blue-black.	Cl_2 gas evolved Cl^- confirmed

Test for Br^-

We can detect Br^- in sodium bromide.

	Test	Observation	Inference
1.	To the unknown solution, add $\text{AgNO}_{3(aq)}$. Then add dilute $\text{HNO}_{3(aq)}$. Then add NH_4OH solution or NH_3 solution	Cream or pale - yellow precipitate formed. The precipitate is insoluble. The precipitate partially dissolves in excess dilute $\text{NH}_{3(aq)}$ or $\text{NH}_4\text{OH}_{(aq)}$	Br^- confirmed Br^- confirmed Br^- confirmed

Test for I^-

A solution that contains I^- is sodium iodide solution.

	Test	Observation	Inference
1.	To the unknown solution, add a few drops of dilute $\text{HCl}_{(aq)}$. Then add $\text{AgNO}_{3(aq)}$. Then add NH_4OH solution or NH_3 solution	Yellow precipitate formed. The precipitate is insoluble. The yellow precipitate is insoluble in excess NH_3 solution.	I^- confirmed I^- confirmed I^- confirmed

IDENTIFICATION OF GASES

Gases evolved in qualitative analysis helps in identifying anions (acid radicals or non-metallic ions) and cations (metallic radicals). Gases may be acidic, alkaline or neutral. A gas may evolve when

1. a substance is heated;
2. reagents such as dilute hydrochloric acid solution is added to a given salt.

The gas evolved is identified by following the steps below.

Note: Most gases are poisonous, and so it is advisable that as much as possible, they should not be inhaled.

To detect the odour of a gas, place the test tube or the reagent bottle a few centimeters away from your nose and by using the palm of your hand, fan some of the air above the container towards your nose and breathe in for a short time.

How to identify a gas

1. You need to observe the colour and feel the odour of the gas;
2. Test the gas with moist blue and red litmus paper at the same time;
3. Do a specific confirmatory test on the gas.
4. Since a specific confirmatory test is carried out, always use the term 'confirmed' instead of 'may be present', 'present', or 'suspected'.
5. It is advisable to write the name of the gas in full but where chemical formula is used, it must be written correctly.
6. Properly record your test, observation and inference.

IDENTIFICATION OF GASES

To identify a gas, note the colour and odour of the gas. Test the gas with moist blue and red litmus. Then carry out a specific confirmatory test.

Hints on colour, odour and friendliness of gases.

COLOUR OF GASES

Some gases are colourless. They include Hydrogen, Oxygen, steam, Carbon (iv) oxide, Hydrogen Chloride, Sulphur (iv) oxide, Ammonia and Hydrogen Sulphide.

Nitrogen (iv) Oxide and Bromine are reddish brown;

Chlorine is greenish-yellow; and Iodine is purple or violet

ODOUR

Odourless gases are Hydrogen, Oxygen, Steam and Carbon (iv) oxide

Irritating or pungent smell gases are Hydrogen Chloride, Sulphur (iv) oxide, Nitrogen (iv) oxide, Bromine, Chlorine and iodine. Hydrogen sulphide has a repulsive smell, like that of rotten eggs; While Ammonia has a choking or irritating or urine smell.

Some Poisonous gases are : Sulphur (iv) oxide, Chlorine, Hydrogen Chloride, Hydrogen Sulphide, Nitrogen (iv) oxide

1. Carbon (IV) Oxide

Carbon (IV) oxide is a colourless, odourless and tasteless acidic gas which turns blue litmus paper red, turns lime water milky and extinguishes fire.

	Test	Observation	Inference
1.	Pass the gas into lime water (aqueous solution of calcium hydroxide)	White precipitate forms in lime water or lime water turns milky due to the formation of CaCO_3 . The CaCO_3 later disappears in excess gas due to the formation of soluble $\text{Ca}(\text{HCO}_3)_2$	The gas is CO_2 .

Carbon (iv) oxide evolve when (i) Dilute acid is added to anhydrous Na_2CO_3 or KHCO_3
(ii) Solid CaCO_3 or NaHCO_3 is heated in a test tube.

	Test	Observation	Inference
1.	Put a little amount of solid CaCO_3 or NaHCO_3 in a test tube, and heat	A gas is given off which is colourless, odourless and turns blue litmus paper to red (i.e. acidic to moist litmus paper), turns lime water milky and extinguishes flame.	The gas is CO_2
2.	Put a little of anhydrous Na_2CO_3 or NaHCO_3 in a test tube and add dilute HCl dropwise	There is a brisk effervescence, a gas is given off which is colourless, odourless and turns blue litmus paper to red (i.e. acidic to moist litmus paper), turns lime water milky and extinguishes flame.	The gas is CO_2

2. Hydrogen

Hydrogen is a colourless, odourless and Tasteless Neutral gas. Hydrogen gas burns with a pop sound when a lighted splinter is inserted into a test tube containing the gas.

	Test	Observation	Inference
1.	Insert a lighted splinter into a test-tube containing the unknown gas	The gas burn with a pop sound (explosive sound) with a lighted splinter (a burning splint. It burns with a blue luminous flame	The gas is hydrogen
2.	OR Test the gas with lighted wooden splinter	Gas burning with a pop sound	The gas is hydrogen

Note: This test should only be carried out with a small quantity of gas.

Hydrogen is given off when a dilute acid such as HCl reacts with a metal higher up in the activity series such as Ca, Mg, Zn, Fe etc

	Test	Observation	Inference
1.	Put some zinc granules or magnesium ribbon or magnesium ribbon in a test-tube, and add dilute H_2SO_4	There is effervescence, evolution of a colourless and odourless gas which has no effect on litmus paper and does not support combustion (extinguishes lighted splint).	The gas is hydrogen

3. Ammonia.

Ammonia is a Colourless alkaline gas which turns moist red litmus paper to blue. It has an irritating or choking or urine smell. It is also a poisonous gas.

	Test	Observation	Inference
1.	Bring the unknown gas in contact with drops of concentrated Hydrochloric acid on a glass rod	Formation of white fumes due to the presence of Ammonium Chloride	The gas is Ammonia.

5. Nitrogen (iv) oxide

Nitrogen (iv) oxide is a reddish brown gas. It is an acidic gas. It has an irritating smell. It turns moist blue litmus paper red.

	Test	Observation	Inference
1.	Test the unknown gas with starch iodide paper	The starch iodide paper turns blue black (or purple)	The gas is nitrogen (iv) oxide

Nitrogen (iv) oxide evolve when

1. Dilute HCl is added to NaNO_2 crystals
2. $\text{Pb}(\text{NO}_3)_2$ is heated in a test tube.
3. Conc. H_2SO_4 is added to NaNO_3 crystals

	Test	Observation	Inference
1.	Put some NaNO_2 crystals in a test tube, add dilute HCl	There is effervescence. Gas evolved is reddish-brown, has pungent or irritating smell, and acidic to litmus paper	The gas is Nitrogen (iv) oxide
2.	Put some $\text{Pb}(\text{NO}_3)_2$ crystals in a test tube and heat strongly.	There is effervescence. Gas evolved is reddish-brown, has pungent or irritating smell, and acidic to litmus paper	The gas is Nitrogen (iv) oxide
3.	Put some NaNO_3 crystals in a test-tube and add conc. H_2SO_4 and warm	There is effervescence. Gas evolved is reddish-brown, has pungent or irritating smell, and acidic to litmus paper	The gas is Nitrogen (iv) oxide

6. Sulphur (IV) Oxide

Sulphur(IV) oxide is a colourless and a poisonous acidic gas with an irritating or choking smell. It turns moist blue litmus paper red.

	Test	Observation	Inference
1.	Bubble the unknown gas through $K_2Cr_2O_7$ acidified with dilute H_2SO_4	The colour of $K_2Cr_2O_7$ changes from golden yellow or orange to green.	The gas is SO_2
2.	Bubble the unknown gas through acidified solution of $KMnO_4$	The colour of acidified $KMnO_4$ changes from purple to colourless (reducing agent)	The gas is SO_2
3.	Place some moist coloured flowers into a jar of the unknown gas	The flowers are bleached	The gas is SO_2

Note: Both sulphur (iv) oxide SO_2 and Hydrogen sulphide H_2S produce similar colour changes with acidified potassium heptaoxodichromate (vi) $K_2Cr_2O_7$ and potassium tetraoxomanganate (vii) $KMnO_4$. They are both reducing agents. However, Hydrogen sulphide also produces a yellow precipitate of sulphur, while sulphur (iv) oxide does not. Sulphur (iv) oxide evolve when dilute HCl is added to solid Na_2SO_3 dropwise.

	Test	Observation	Inference
1.	Put a little amount of solid Na_2SO_3 in the test tube and add dilute HCl dropwise.	There is a brisk effervescence. The gas evolved is colourless, has irritating smell and acidic to litmus paper	The gas is sulphur (iv) oxide

7. Hydrogen sulphide (H_2S)

Hydrogen sulphide is a colourless acidic and a poisonous gas. It has a repulsive smell, like that of rotten eggs. It turns moist blue litmus paper red.

Lead (ii) ethanoate paper or solution and lead (ii) trioxonitrate (v) can also be used to distinguished between sulphur (iv) oxide and Hydrogen sulphide.

	Test	Observation	Inference
1.	Moisten a piece of filter paper with lead (ii) trioxonitrate (v) solution and drop it into a gas jar of the unknown gas	The paper turns black due to the formation of black lead (ii) sulphide.	The gas is H_2S
2.	Test the gas with a piece of moist lead (ii) ethanoate paper	The paper turns black	The gas is H_2S
3.	Pass the gas through a solution of lead (ii) ethanoate	A shiny black-brown precipitate of lead (ii) sulphide is formed	The gas is H_2S

Hydrogen Sulphide evolves when dilute HCl or HNO_3 is added to any Sulphide salt and warm (if necessary). E.g. FeS .

	Test	Observation	Inference
1.	Put a little amount of powdered FeS in a test tube, then add dilute HCl dropwise, with warm (if necessary)	There is effervescence; A gas evolved is colourless, has a rotten egg smell and slightly acidic to litmus paper	The gas is hydrogen sulphide

8. Water vapour or Steam (H_2O)

Steam is a colourless and odourless gas. It is neutral to moist litmus paper.

	Test	Observation	Inference
1.	Test the unknown gas with white anhydrous copper (ii) tetraoxosulphate (vi)	The white CuSO_4 turns to blue $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	The gas is steam or water vapour
2.	Test the unknown gas with blue cobalt (ii) chloride.	The blue colour of cobalt (ii) chloride change to pink.	He gas is steam or water vapour.

9. Hydrogen Chloride gas (HCl)

Hydrogen Chloride is a colourless, acidic and a poisonous gas. It fumes in moist air. It has an irritating or a pungent smell. It also changes blue litmus paper red.

	Test	Observation	Inference
1.	Place a glass rod dipped with ammonia solution at the mouth of a gas jar containing the unknown gas	Formation of dense white fumes composed of suspended particles of ammonium chloride	The gas is Hydrogen Chloride.
2.	Add a few drops of silver trioxonitrate (v) solution to a gas jar containing the unknown gas and shake	Formation of white fume of silver chloride	The gas is Hydrogen Chloride.
3.	Add a few drops of lead (ii) trioxonitrate (v) solution to a gas jar containing the unknown gas and shake	Formation of a white fume of lead (ii) chloride	The gas is Hydrogen Chloride.

HCl gas evolve when conc. H_2SO_4 is heated with any chloride e.g. NaCl.

	Test	Observation	Inference
1.	Put some NaCl crystals in the test-tube, add a few drops of conc. H_2SO_4 and warm	There is effervescence, gas evolved is colourless, has irritating smell, and acidic to litmus paper	The Gas is HCl

9. Chlorine

Chlorine is a greenish – Yellow gas with choking or unpleasant or irritating or pungent or suffocating smell. It is also a poisonous gas. It turns moist blue litmus paper red and finally bleaches it. It turns starch iodide paper blue-black (or purple).

Chlorine gas evolve when conc. H_2SO_4 is added to a mixture of a chloride (e.g. NaCl) and MnO_2 powder and heated.

	Test	Observation	Inference
1.	Put some NaCl crystals in a test tube, add a little of MnO_2 (black) powder and a few drops of conc. H_2SO_4 and warm	There is effervescence. Evolution of a greenish-yellow gas with an unpleasant smell which turns blue litmus paper to red and bleaches it.	The Gas is HCl

11. Bromine (Br_2)

Bromine gas is a reddish brown vapour with an irritating smell. It turns moist blue litmus paper red and bleaches it.

	Test	Observation	Inference
1.	Test the unknown gas with tetrachloromethane (CCl_4) solution.	The solution turns brown	The gas is bromine

Bromine gas evolves when conc. H_2SO_4 is added to a mixture of KBr and MnO_2 and warm.

	Test	Observation	Inference
1.	Put some KBr crystals in a test tube, add a little MnO_2 Powder and a few drops of conc. H_2SO_4 and warm	A reddish-brown vapour with irritating smell and acidic to litmus is evolved	The gas is Br_2

12. Iodine I_2

Iodine is violet or purple. It has an irritating smell. It turns moist blue litmus paper red and bleaches it.

	Test	Observation	Inference
1.	Test the unknown gas with CCl_4 solution	The solution turns purple	The gas is iodine
2.	Test the unknown gas with moist starch iodide paper	The paper turns blue-black	The gas is iodine

Iodine gas evolve when conc. H_2SO_4 is added to a mixture of KI and MnO_2 and warm

	Test	Observation	Inference
1.	Put some KI crystals in a test tube , add a little MnO_2 powder and a few drops of conc. H_2SO_4 and warm	The gas evolved is violet or purple, irritating and acidic to litmus paper	The gas is I_2

TEST FOR UNSATURATION

Alkanes are saturated hydrocarbons while alkenes and alkynes are unsaturated hydrocarbons. Saturated hydrocarbons do not undergo addition reaction but unsaturated hydrocarbons do.

Unsaturated hydrocarbons decolorize the reddish brown bromine water but saturated hydrocarbons do not. A purple solution of potassium tetraoxomanganate (vii) also become colourless when added to unsaturated hydrocarbons

The difference between Alkenes and Alkynes.

Alkynes form white precipitate with silver trioxonitrate (v) solution but alkenes have no effect on the solution.

Test for Alcohol

1. Esterification

	Test	Observation	Inference
1.	To the unknown liquid, add a few drops of ethanoic acid followed by a few drops of conc. H_2SO_4 then heat the mixture.	A liquid is formed with the characteristic pleasant fruity smell.	The liquid formed is ester. This indicates the presence of alcohol.

2. Sodium Test

	Test	Observation	Inference
1.	To the unknown liquid, add a little amount of Na metal.	There is vigorous effervescence, with the evolution of a colorless tasteless and odorless gas which has no effect on litmus paper	The gas is Hydrogen. This indicates the presence of alcohol.

TEST FOR ALKANOIC ACID

Alkanoic acids are colourless liquid with a characteristic sharp and pungent smell.

The dilute solution had a sour taste. It turns blue litmus red.

	Test	Observation	Inference
1.	To little amount of the unknown substance, add $\text{NaHCO}_{3(aq)}$ or $\text{KHCO}_{3(aq)}$	There is effervescence, a colourless and odorless gas is given off which is acidic to litmus paper and turns lime water milky.	The gas is CO_2 and hence the substance is carboxylic acid.
2.	To 2cm^3 of the unknown solution, add 2cm^3 of ethanol, followed by 1cm^3 of conc. $\text{H}_2\text{SO}_{4(aq)}$ then heat the mixture.	A liquid with the characteristic pleasant fruity smell is formed.	This indicates the presence of organic acid.

TEST FOR CARBOHYDRATES

1. Glucose

	Test	Observation	Inference
1.	To the unknown solution, add a few drops of Fehling's solution then heat.	A brick - red precipitate is obtained on boiling.	The unknown solution is glucose.

2. Sucrose

	Test	Observation	Inference
1.	To 1cm^3 of the unknown solution, add selivanoff reagent, then warm in a water bath.	The mixture turns red after 10 minutes.	The unknown solution is glucose.

3. Starch

	Test	Observation	Inference
1.	To the unknown substance, add a few drops of Iodine solution, then heat the mixture.	Formation of a dark-blue colouration which disappears on heating and re-appears on cooling.	The unknown substance is starch

TEST FOR PROTEINS/AMINO ACIDS

1. Biuret Test

	Test	Observation	Inference
1.	To 1cm ³ of the unknown solution, add a few drops of NaOH _(aq) and swirl, then add a few drops of CuSO _{4(aq)} and swirl.	Formation of a purple coloration	This confirms the presence of amino acid or protein.

2. Million's Test

	Test	Observation	Inference
1.	To 1cm ³ of the unknown solution, add a few drops of millions reagent and warm.	Formation of a white precipitate which turns red after a while.	This shows the presence of amino acid/ protein.

3. Xanthoprotein Reaction

	Test	Observation	Inference
1.	To the unknown solution, add a few drops of dilute HNO _{3(aq)} and warm	Formation of a yellow coloration.	Amino acid is confirmed.

4. Ninhydrin Reaction

	Test	Observation	Inference
1.	To the unknown substance, add ninhydrin reagent and warm.	There is formation of deep blue colour.	Amino acid is confirmed.

5. Test for fats and oil

	Test	Observation	Inference
1.	To a little amount of the substance in a test tube, add a few drops of sudan(III) solution	A reddish colouration is observed	The substance is fat or oil.

SUMMARY

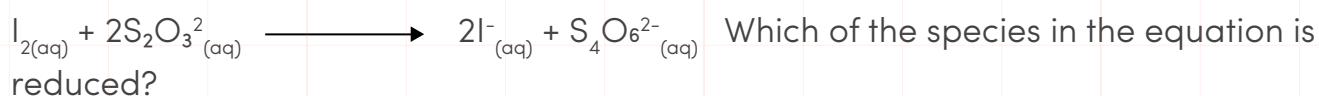
So far, we have learnt how to

1. Solve problems in acid-base titration
2. Solve problems in redox titration
3. Identify cations
4. Identify anions
5. Identify gases
6. Identify organic compounds

INTERACTIVE ASSESSMENT QUESTIONS

1. 25.0cm^3 of a solution containing 1.0g impure sodium hydroxide pellets per 250cm^3 required 20.0cm^3 of 0.050mol dm^{-3} tetraoxosulphate (vi) acid for complete neutralization. Determine the percentage purity of the sodium hydroxide pellets. (Na=23, O=16, H=1.0, S=32.0)
- A 20%
B 50%
C 80%
D 100%
E 60%
2. 250cm^3 of aqueous solution of ethanedioic acid (oxalic acid) crystals, $\text{H}_2\text{C}_2\text{O}_4 \cdot \text{XH}_2\text{O}$ contains 5g of the crystals. If 25cm^3 of this solution require 15.9cm^3 of 0.5mol dm^{-3} NaOH solution to neutralize it. Calculate the number of molecules of water of crystallization in the acid. (H=1, C=12, O=16)
- A 4.0
B 3.0
C 2.0
D 1.0
E 0
3. Consider the reaction represented by the equation $\text{XO} + \text{YO} \longrightarrow \text{X} + \text{YO}_2$;
In the reaction YO acts as
- A An acidic oxide
B A reducing agent
C A weak base
D An oxidizing agent
E An amphoteric solution

4. Consider the redox reaction as represented by the equation:



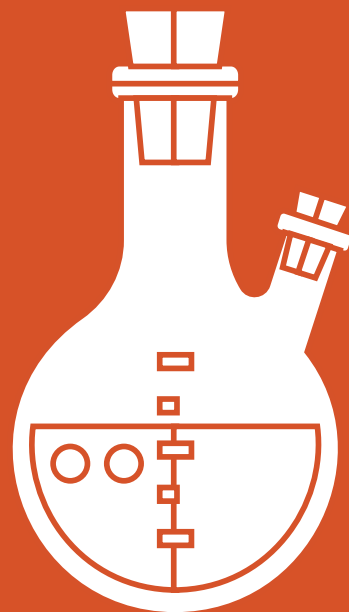
- A $\text{S}_4\text{O}_6^{2-}{}_{(\text{aq})}$
B $\text{S}_2\text{O}_3^{2-}{}_{(\text{aq})}$
C $\text{I}_{2(\text{aq})}$
D $2\text{I}^{-}{}_{(\text{aq})}$
E Both $\text{I}^{-}{}_{(\text{aq})}$ and $\text{S}_2\text{O}_3^{2-}{}_{(\text{aq})}$
5. Which of the following gives a green gelatinous precipitate when its compound is treated with $\text{NaOH}_{(\text{aq})}$ and turns reddish brown on exposure to air
- A NH_4^{+}
B Ca^{2+}
C Fe^{2+}
D Fe^{3+}
E K^{+}
6. When aqueous ammonia is added to one of the following solutions, a white precipitate which dissolves in excess ammonia is formed. Identify the solution.
- A $\text{ZnCl}_{2(\text{aq})}$
B $\text{Pb}(\text{NO}_3)_{2(\text{aq})}$
C $\text{CuSO}_{4(\text{aq})}$
D $\text{FeSO}_{4(\text{aq})}$
E $\text{K}_2\text{CO}_{3(\text{aq})}$
7. Which of the following pairs of solutions will produce a precipitate when mixed?
- A $\text{Pb}(\text{NO}_3)_{2(\text{aq})}$ and $\text{NaCl}_{(\text{aq})}$
B $\text{MgSO}_{4(\text{aq})}$ and $\text{NaCl}_{(\text{aq})}$
C $\text{MgSO}_{4(\text{aq})}$ and $\text{HCl}_{(\text{aq})}$
D $\text{ZnCl}_{2(\text{aq})}$ and $\text{Na}_2\text{SO}_{4(\text{aq})}$
E $\text{NaOH}_{(\text{aq})}$ and $\text{HNO}_{3(\text{aq})}$

8. If chlorine gas is tested with a damp starch-iodide paper, the paper turns. A salt sample was added to cold dilute HCl. The gas evolved turned acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution to green. It can be inferred that the salt sample contains
- A Green
 - B Pale-red
 - C Blue-black
 - D Orange
 - E Red
9. A salt sample was added to cold dilute HCl. The gas evolved turned acidified $\text{K}_2\text{Cr}_2\text{O}_7$ solution to green. It can be inferred that the salt sample contains
- A SO_4^{2-}
 - B SO_3^{2-}
 - C CO_3^{2-}
 - D S^{2-}
 - E NH_4^+
10. The presence of un-saturation in an organic compound can be confirmed by the use of the reagent,
- A SO_4^{2-}
 - B SO_3^{2-}
 - C CO_3^{2-}
 - D S^{2-}
 - E NH_4^+



THEME

02



Chemical World.

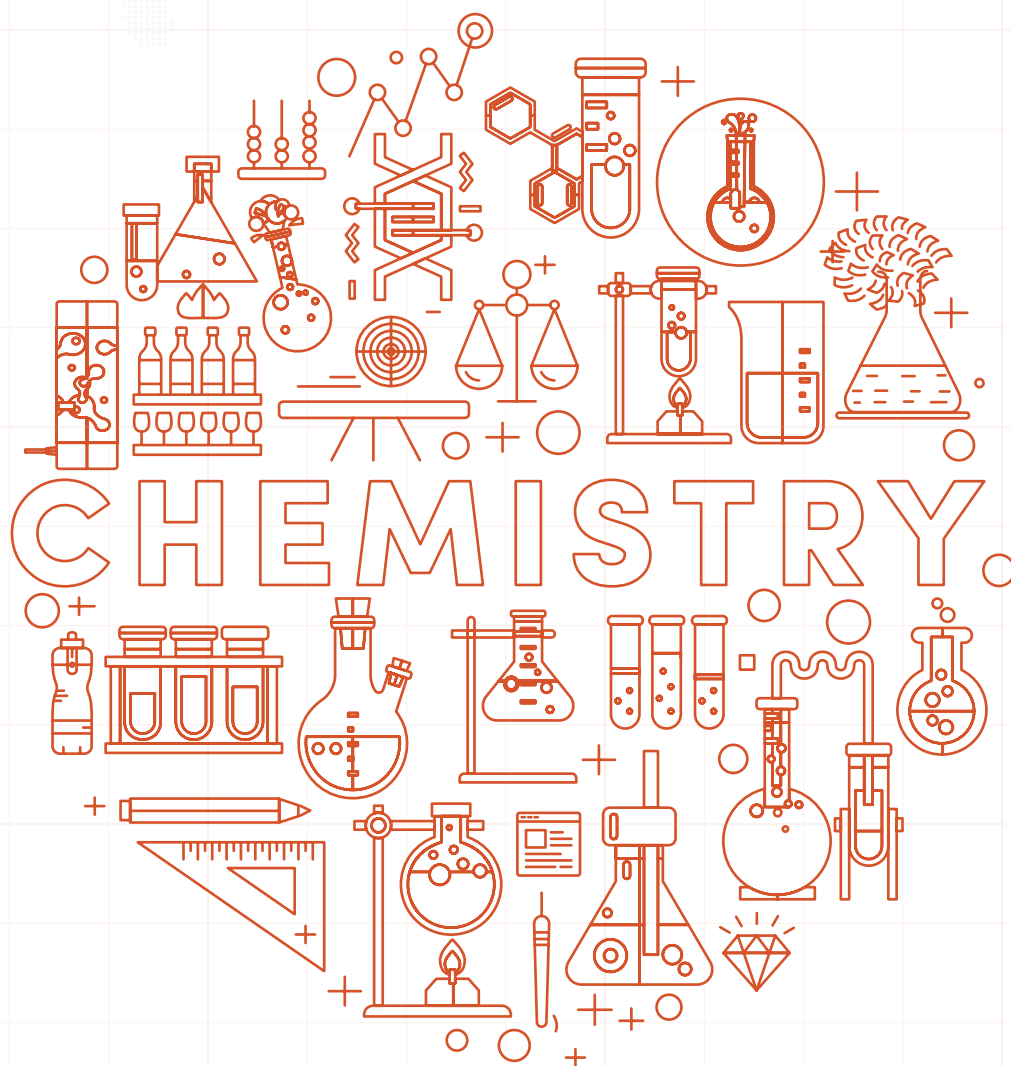
Chemistry and Industry.

Chemistry of life.

PETROLEUM OR CRUDE OIL

PERFORMANCE OBJECTIVES

1. State the origin of crude oil and list the composition of crude oil.
2. Discuss the exploration and drilling of crude oil in Nigeria.
3. Explain the fractional distillation of crude oil.
4. List the major fractions (products)
5. List the location of Nigeria refineries.
6. Explain the terms cracking and reforming and discuss the term petrochemicals.
7. Explain the use of octane number in determining the quality of petrol.
8. Explain the liquefaction of natural gases.



INTRODUCTION

Crude oil petroleum is the chief source of hydrocarbons. Its fractional distillation yields petroleum gases, petrol, kerosene, diesel oil, lubricating oil, and bitumen. We can also produce other products from petroleum products which are in turn used to produce other things. Today, we shall be discussing how our commonly used cooking gases, petrol, kerosene etc. are being manufactured.

THE ORIGIN OF CRUDE OIL.

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.

THE COMPOSITION OF CRUDE OIL

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.

Crude oil is found in certain parts of the world e.g. Nigeria, Saudi Arabia, Iran, U.S.A, Iraq and Russia. In Nigeria, crude oil was discovered in Oloibiri in Niger delta region in 1956.

EXPLORATION AND DRILLING OF CRUDE OIL

Geologists use seismometers to study the underlying layers of the earth's crust and from the information obtained, decide where the oil 'caps' are located for drilling. Successful test drillings hit the 'caps' directly. Petroleum is always associated with gas because it is a mixture of several hydrocarbons. When a well is carefully bored through the impervious rock cap, the gas pressure could be sufficient to force the oil to the surface. The gas is at the top of the crude oil and is called natural gas.

Natural gas is mainly methane, CH_4 . As the principal constituent of natural gas, methane is of great importance to the fuel industry as a source of energy.

FRACTIONAL DISTILLATION AND MAJOR PRODUCTS OF CRUDE OIL

The separation of petroleum fractions is based on the differences in their boiling points. The distillation process is carried out by heating crude oil to a high temperature. The crude oil changes to vapour and ascends the fractional column. As the vapor ascends the column, it cools, condenses and separates into its fractions. The fractions with lower boiling points separate out on the trays in the upper part of the column, while fractions with higher boiling points separate out in the trays in the lower part of the column.

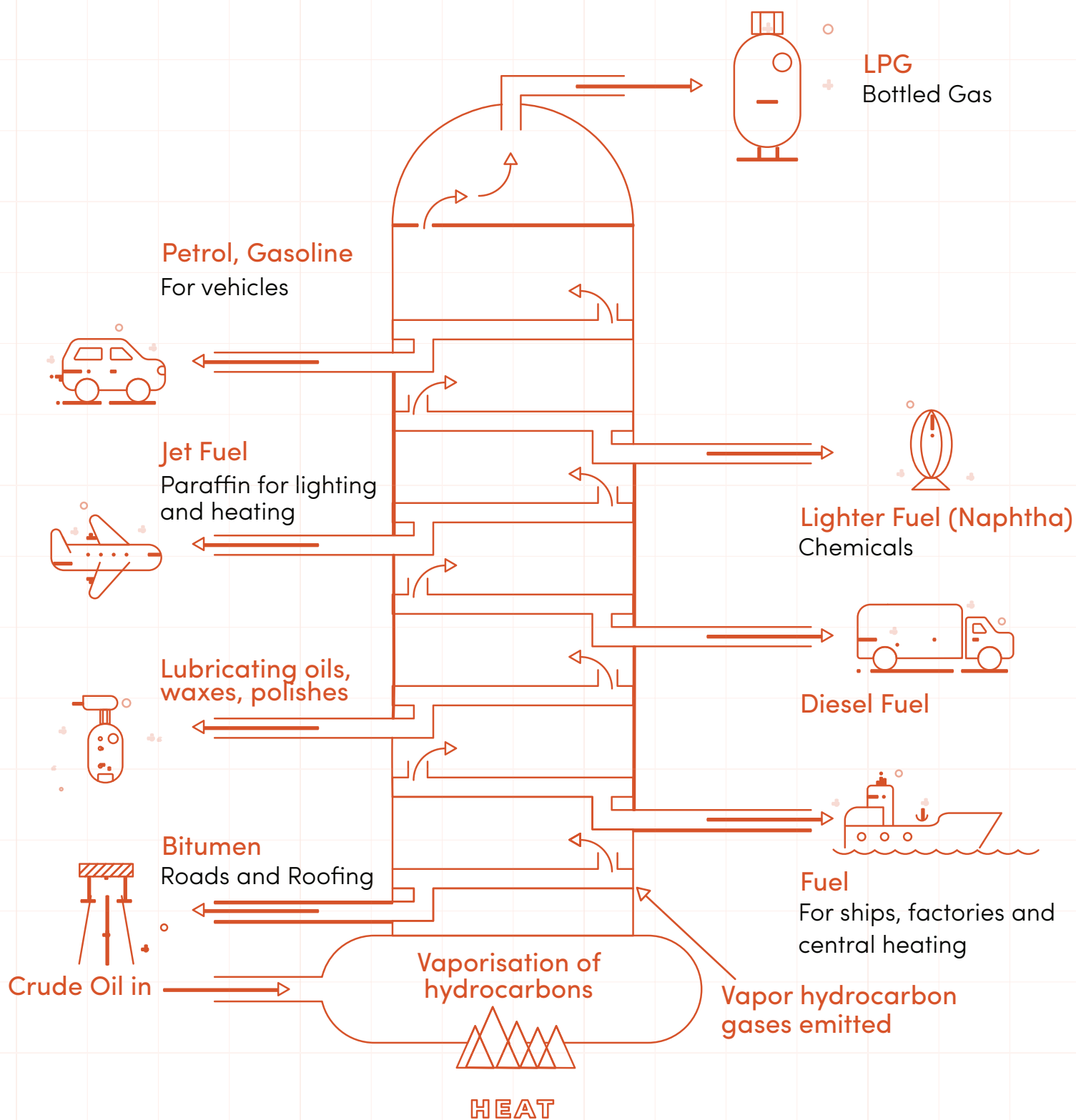
During the separation of crude oil, three stages are involved, separation, conversion and purification.

1. Separation is the first stage where the fractions are split by heat.
2. Conversion is the conversion of less useful fractions into more useful ones through thermal cracking or polymerization.
3. Purification is the removal of impurities.

Crude Oil Fractionates

Crude oil can be exported (or sold) to foreign countries. When refined, its products have a wide range of uses, namely:

Fraction	No. of Carbon Atoms	Boiling Points	Uses
Petroleum gas or natural gas: This is a mixture of gases like methane, butane and ethane use as cooking gas.	$C_1 - C_4$	Below 40°C	It is a fuel which provides heat for domestic and industrial uses. At home, it is used for cooking. Industries use it to manufacture useful chemicals like hydrogen, ethane and tetrachloromethane. Ugheli and Sapele Gas Power Stations produce electricity, using natural gas. It is also used to run furnaces in the manufacture of various goods
Petrol or gasoline: Petrol is a mixture of volatile liquids. Volatile liquids quickly change into gas.	$C_5 - C_{10}$	40°C to 200°C	Motor vehicles and electric generators use it as fuel and It is also used as a solvent for paints and grease
Kerosene or Paraffin oil: It is a mixture of fairly volatile liquids.	$C_{11} - C_{15}$	200°C to 250°C	It is used in our homes for domestic cooking. It is also used as aviation fuel.
Diesel or light gas oil: These are also liquid mixtures of heavy hydrocarbons.	$C_{16} - C_{20}$	250°C to 350°C	They are used as fuel by diesel engines for heating. They are also used to produce lighter hydrocarbons, by a process called 'cracking' (i.e breaking into lighter compounds)
Lubricating oil: These are heavy and viscous liquid mixtures of hydrocarbon. Viscous liquids are thick and sticky.	$C_{20} - C_{30}$	350°C to 500°C	They are heavy liquids for lubricating some parts of engines, where movement occurs. Vaseline and paraffin wax are obtained from re-distillation of these oils. Vaseline is used in producing hair and body creams, while paraffin wax is used in producing candles, polish, pomade and ointments.
Bitumen or asphalt or residual wax: These are solid remains from fractional distillation of crude oil.	$> C_{30}$	500°C	Bitumen or pitch is used in the construction of roads and airfields. Other residues could be used in waterproofing roofs, protecting pipes, and as fuel.



A diagram showing the fractional distillation of crude oil.

LOCATIONS OF NIGERIAN REFINERIES

There are three petroleum refineries in Nigeria. These are

1. Port-Harcourt Refining and Petrochemical Company Limited (PHRC)
2. Kaduna Refining and Petrochemical Company Limited (KRPC)
3. Warri Refining and Petrochemical Company Limited (PHRC)

Although these oil refineries have not been maintained properly. This means that Nigeria do import petrol, diesel and aviation fuel.

Nigeria has oil wells in Bayelsa, Delta, Akwa-Ibom, Edo, Imo and Rivers states.

Nigeria is the 6th largest exporter of crude oil in the world.

A Nigeria Oil Refinery



CRACKING AND REFORMING

CRACKING

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 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.

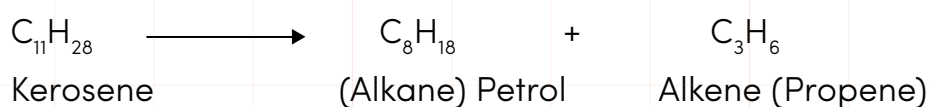
During cracking, ethene, C_2H_4 is produced; it is the major raw material in the petrochemical industry.

CRACKING TECHNIQUES

The two main cracking processes are: thermal cracking and catalytic 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°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.



2. Catalytic Cracking: In catalytic cracking, the heavy oil is heated to about 500°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.



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 petrol to higher grades, i.e. improve the quality.

Reforming techniques includes:

1. Isomerisation;
2. Cyclization; And
3. Aromatization

Difference Between Cracking And Reforming

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

PETROCHEMICAL AS A STARTING MATERIALS FOR ORGANIC SYNTHESIS

Petrochemicals are chemicals made from the by-products of petroleum (crude oil) and natural gas. Petroleum and natural gas are made up of hydrocarbon molecules, which are comprised of one or more carbon atoms, to which hydrogen atoms are attached. Petroleum and natural gas are increasingly used to produce many organic compounds. Examples of these organic compounds are ethanol, ethane, propanol, benzene and toluene. These organic compounds are in turn used to make large molecular organic compounds like plastics, synthetic rubber, and detergents, insecticides and synthetic fibers like Dacron and nylon which has made an impact in manufacturing industries. Only about five percent of the oil and gas consumed each year is needed to make all the petrochemical products. People that do the exploration are geophysicist, petroleum engineer, and geologist.

QUALITY OF PETROL: OCTANE NUMBER OR RATING

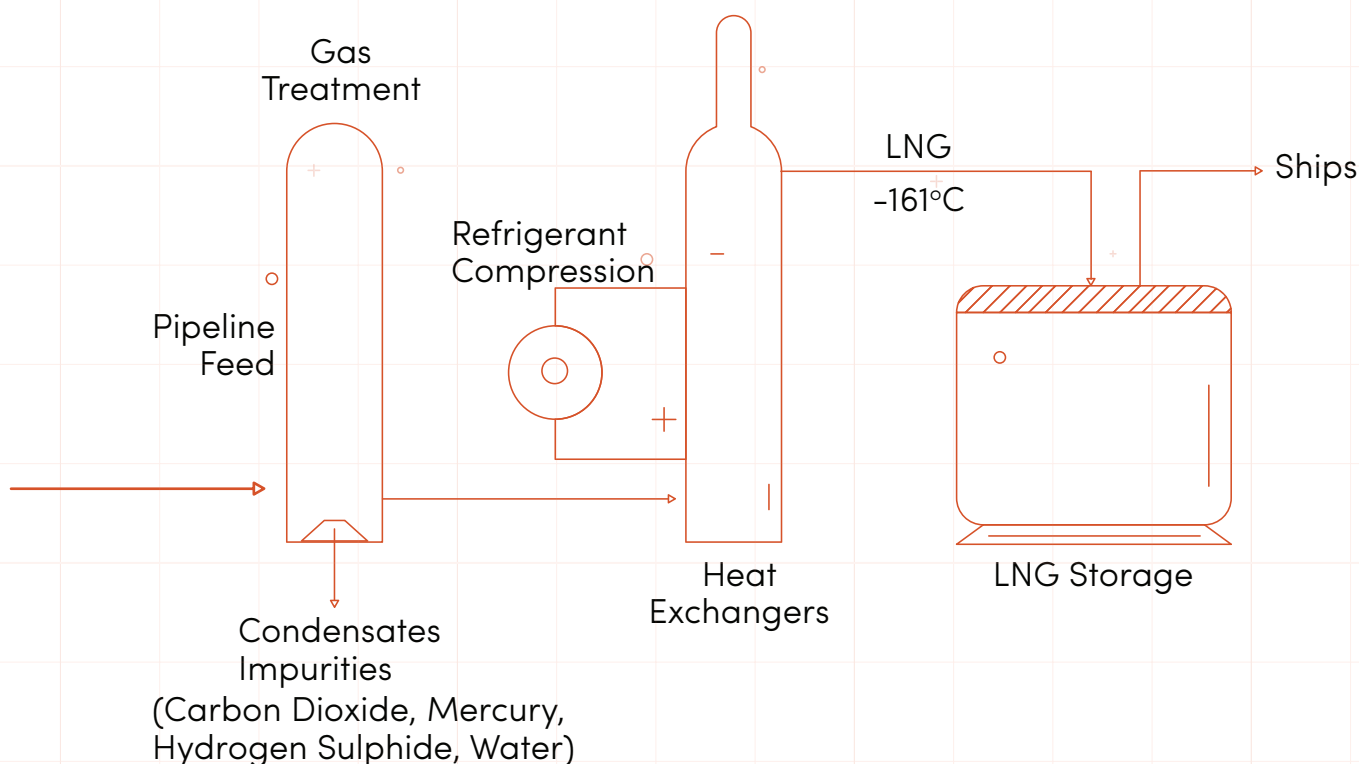
Each grade of gasoline (petrol) is rated according to the term octane number. The octane rating or number is based on the proportions of the straight chain heptane, C_7H_{16} and the branched-chain 2,2,4 -Trimethylpentane, an isomer of C_8H_{18} called iso-octane in petrol. When petrol with a high proportion 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.

LIQUEFIED NATURAL GAS

Natural gas is one of the Nigeria major exports. Nigeria is endowed with the world's tenth largest natural gas reserves. Scientists estimate that Nigeria's reserves of natural gas exceed its crude oil reserves. Natural gas can be used in the home for cooking. It can also be used to generate large amount of energy. Although the industry is not as developed as the crude oil industry, natural gas has the potential to become a large source of revenue for the country. In order to further develop this industry, the Nigeria Liquefied Natural Gas company (NLNG) has constructed a liquefied natural gas facility on Bonny Island in the Niger Delta. This facility will enable Nigeria to harness its natural gas formed.

Natural gas is liquefied by lowering the temperature of the hydrocarbon to approximately -260 degrees Fahrenheit (-160 degrees Celsius). This temperature drop liquefies the methane present in the natural gas, making transportation at atmospheric pressure in the form of LNG possible.



A diagram showing a chemical plant for the liquefaction of natural gas.

SUMMARY

So far, we have learnt how to

1. State the origin of crude oil.
2. List the composition of crude oil.
3. Discuss the exploration and drilling of crude oil in Nigeria.
4. Explain the fractional distillation of crude oil.
5. List the major fractions (products)
6. List the location of Nigeria refineries.
7. Explain the terms cracking and reforming
8. Discuss the term petrochemicals.
9. Explain the use of octane number in determining the quality of petrol.
10. Explain the liquefaction of natural gases.

INTERACTIVE ASSESSMENT QUESTIONS

1. The separation of petroleum fraction depends on the differences in their

- A Melting points
- B Molar masses
- C Solubilities
- D Boiling points
- E Physical state

2. Which of the following is not a direct petroleum product?

- A Methane
- B Ethanol
- C Petrol
- D Vaseline
- E Kerosene

3. Which of the following fractions of crude oil is likely to contain the hydrocarbon $C_{12}H_{26}$?

- A Kerosene
- B Naphtha
- C Gas oil
- D Fuel oil
- E Bitumen

4. Which of the following hydrocarbons is not likely to be present in petrol?

- A $C_{14}H_{30}$
- B $C_{10}H_{22}$
- C C_9H_{20}
- D C_7H_{16}
- E C_5H_{12}

5. Petrol can be obtained from diesel by

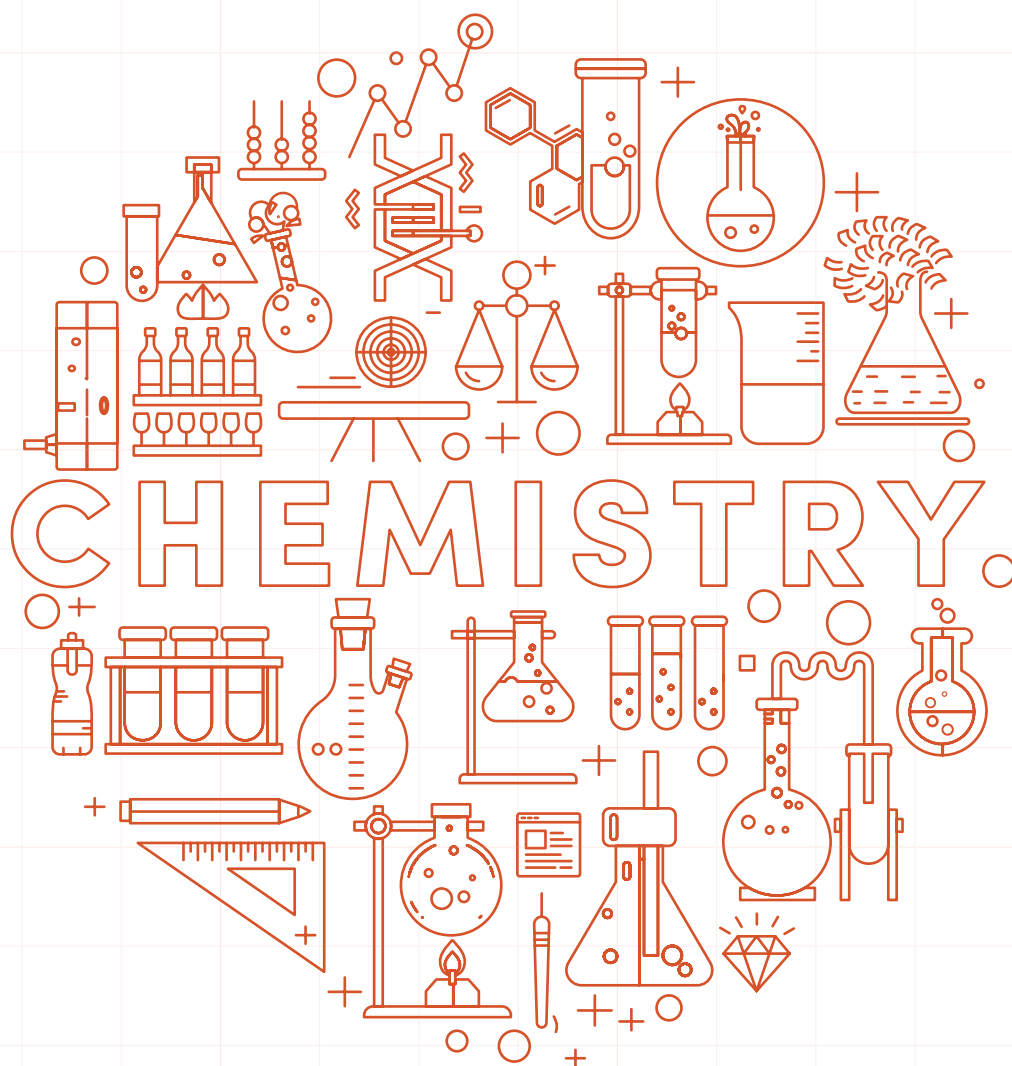
- A Distillation
- B Cracking
- C Catalysis
- D Polymerization
- E Dehydrogenation

METALS AND THEIR COMPOUNDS

PERFORMANCE OBJECTIVES

1. List the materials made of metals around you.
2. List metal ores and their location in Nigeria.
3. List the metals in the periodic table.
4. Give the general physical properties of metals.
5. State the chemical properties of metals.
6. Explain the activity series of metals.
7. List the compounds formed by metals
8. Explain the general principles of extractions of metals
9. List the alkali metals and give the general physical properties of alkali metals.
10. Describe sodium and explain how it is extracted.
11. State physical properties of sodium and explain its chemical properties
12. Test for sodium, list its compounds and uses
13. List alkaline earth metals and give the general properties of alkaline earth metals.
14. Describe and explain the extraction of calcium
15. List the physical and chemical properties of calcium
16. Test for calcium
17. List the various compounds of calcium and highlight the uses of calcium
18. Describe aluminum and explain how it is extracted
19. List physical properties of aluminum
20. test for aluminum and state its chemical properties
21. List the compounds of aluminium and give the various uses of aluminum
22. Describe tin
23. Explain the extraction of tin, list physical and chemical properties of tin and lastly, state the uses of tin

24. Define transition elements
25. List the elements of the first transition series.
26. Write the electronic configurations of the elements of the first transition series.
27. State the physical properties of transition elements
28. Explain the chemical properties of transition elements.
29. Describe copper
30. Explain how to extract copper
31. Give the physical properties of copper
32. Explain the chemical properties of copper.
33. Test for copper.
34. State the uses of copper.



INTRODUCTION

Materials made of metals are everywhere and around us. For example, earrings used by ladies are made of metals, many wrist watches have metallic stripes in them, frames and handles of doors are made of metals, most cooking utensils are made of metals etc.

In the periodic table, elements are classified into metals, non-metals and metalloids. More than three-quarters of all known elements are metals. All metals except mercury are liquid at room temperature. Metals possess some characteristics that distinguish them from non-metals.

Most metals do not exist in free states in nature. They are rather too reactive to exist as free elements. They are more often found as compounds in the form of ores. These ores can exist either as the oxides, hydroxides, trioxocarbonates, sulphates, sulphides, chlorides or nitrate of the metals. For example, highly reactive metals such as sodium and potassium are not found free in nature due to their high level of reactivity. They are found as chlorides or trioxocarbonates (IV). Some metals such as Iron, zinc, Lead etc. are moderately reactive. They are not found free in nature but occur as sulphides or oxides. Other elements such as gold, silver, platinum, mercury etc. are found in free state in nature because they are unreactive metals.

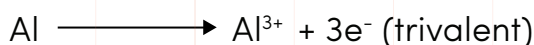
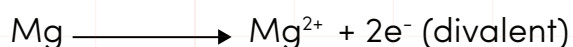
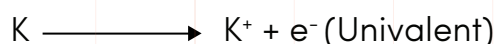
Location of some ores of metals in Nigeria

	Ores of metals	Locations
1.	Lead/Zinc	Zamfara, Plateau, F.C.T, Ebonyi, Cross Rivers.
2.	Tin ore	Kano, Kaduna, Bauchi, Plateau, Nasarawa, Cross Rivers.
3.	Iron ore	Nasarawa, Kogi, Enugu, F.C.T,
4.	Barite	Zamfara, Nasarawa, Taraba, Plateau, Cross Rivers.
5.	Tantalite	Kogi, Ekiti, Kwara, Cross Rivers, Nasarawa.
6.	Gold	Zamfara, Katsina, Kaduna, F.C.T., Kogi, Niger, Kebbi, Kwara, Osun.
7.	Limestone	Sokoto, Ogun, Edo, Cross Rivers, Ebonyi, Gombe, Benue.

- vi. Metals are ductile i.e. they can be drawn into wires.
- vii. Metals are sonorous (i.e. they produce sound)
- viii. All Metals except graphite have high melting and boiling points.
- ix. Metals have high moderate density.

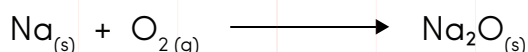
GENERAL CHEMICAL PROPERTIES OF METALS

1. Ionization Power: Metals are elements whose atoms ionize by losing electrons e.g.



Metals are generally reducing agents.

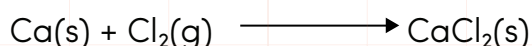
2. Reaction with oxygen: Most metals react with oxygen to give basic oxides e.g.



3. Reaction with acids: Metals which are more electropositive than hydrogen readily displace hydrogen ion, H^+ from an acid e.g.



4. They form electrovalent (ionic) compounds with non-metals such as chlorine.

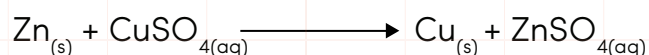


ACTIVITY SERIES.

Metals can be arranged in series according to their tendencies to release (or donate) their valence electrons i.e. according to their electropositivity. This series is known as activity series or electrochemical series.

Potassium K is the most electropositive element (metal) and hence the strongest reducing agent, while gold is the weakest.

The activity series arranges the metals in the order of their ability to react and displace the ions of one another from the solutions of their salts. Generally, a metal higher up in the series will displace the metals lower down the series from the solutions of their salts. For instance, Zn metal will displace copper in a solution of a copper (II) salt.



The activity series or electrochemical series of metals is based on their standard electrode potentials values of elements. The more reactive metals have highly negative electrode potential values

Activity series of metals and their electrochemical series

Metals	Reactivity	Process	Process
Potassium, K	Very Reactive Metals	$\text{K}^+ + \text{e}^- \longrightarrow \text{K}$	-2.92
Sodium, Na		$\text{Na}^+ + \text{e}^- \longrightarrow \text{Na}$	-2.71
Calcium, Ca		$\text{Ca}^{2+} + 2\text{e}^- \longrightarrow \text{Ca}$	-2.87
Magnesium, Mg		$\text{Mg}^{2+} + 2\text{e}^- \longrightarrow \text{Mg}$	-2.37
Aluminum, Al	Moderately Reactive Metals	$\text{Al}^{3+} + 3\text{e}^- \longrightarrow \text{Al}$	-1.66
Zinc, Zn		$\text{Zn}^{2+} + 2\text{e}^- \longrightarrow \text{Zn}$	-0.76
Iron, Fe		$\text{Fe}^{2+} + 2\text{e}^- \longrightarrow \text{Fe}$	-0.44
Tin, Sn		$\text{Sn}^{2+} + 2\text{e}^- \longrightarrow \text{Sn}$	-0.14
Lead, Pb		$\text{Pb}^{2+} + 2\text{e}^- \longrightarrow \text{Pb}$	-0.13
Hydrogen, H		$2\text{H}^+ + 2\text{e}^- \longrightarrow \text{H}_2$	0.00
Copper, Cu	Least Reactive Metals	$\text{Cu}^{2+} + 2\text{e}^- \longrightarrow \text{Cu}$	+0.34
Mercury, Hg		$\text{Hg}^+ + \text{e}^- \longrightarrow \text{Hg}$	+0.62
Silver, Ag		$\text{Ag}^+ + \text{e}^- \longrightarrow \text{Ag}$	+0.80
Gold, Au		$\text{Au}^{3+} + 3\text{e}^- \longrightarrow \text{Au}$	+1.50

Compounds formed by metals;

Metals form different compounds.

- | | |
|-------------------------|----------------------|
| a. Oxides | d. Trioxonitrates(v) |
| b. Hydroxides | e. Chlorides |
| c. Trioxocarbonates(iv) | f. Sulphides |

GENERAL PRINCIPLES OF THE EXTRACTION OF METALS

The method used in the extraction of metals from their ores depends on the reactivity of the ore and this in turn depends on the position of the metal in the activity series.

The methods used for extracting metals from their ores are as follows:

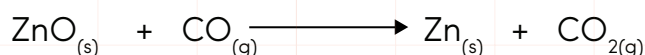
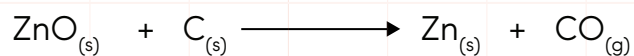
1. Electrolytic reduction
2. Chemical reduction
3. Thermal reduction

1. **Electrolytic reduction:** The more reactive metals such as K, Na, Ca and Mg are extracted from their ores by electrolysis. The ores of these more electropositive metals are very stable chlorides and trioxocarbonates (IV). During the electrolysis, the cathode act as a reducing agent. This is because the cathode supply electrons to the metallic ions in the electrolyte, resulting in the deposition of the free metal.

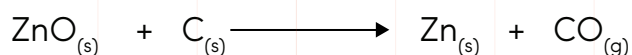
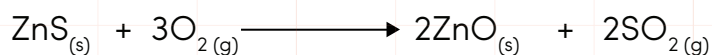
Note: Electrolytic process is expensive to install and maintain. It is used only when chemical or thermal reduction of the ore is not possible.

2. **Chemical reduction:** This method is used for the extraction of moderately or less reactive metals from their ores. Examples of such metals are Zn, Fe, Sn and Pb. Two methods are involved in chemical reduction. These are:

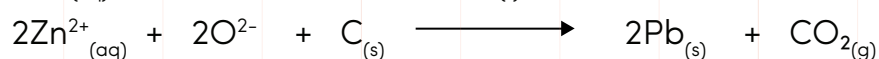
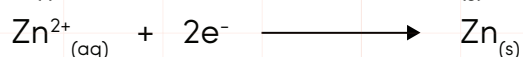
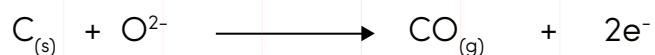
- Reducing the oxides of metals with coke or carbon (II) oxide e.g.



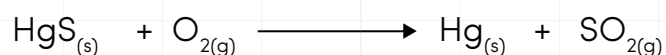
- Oxidation of the sulphide to the oxide, followed by reduction of the oxide e.g.



During the process, the coke combines with the oxide ions to release the electrons necessary for the reduction of the oxides.



3. Thermal reduction: This is the method which involves the extraction of metals from their ores by heating. For example, Mercury (Hg) is extracted by heating mercury (II) sulphide in air.



The ore (HgS) is first converted to ammonium hexachloroplatinate (IV).

This is then reduced to platinum by heating

Activity series of metals and methods of extraction.

Metals	Reactivity	Process	Process
Potassium, K	Very Reactive Metals	Chlorides	Electrolysis of fused chlorides and hydroxides
Sodium, Na		Chlorides and Magnesium Trioxocarbonates (IV)	
Calcium, Ca			
Magnesium, Mg			
Aluminium, Al		Oxides	Electrolysis of oxides
Zinc, Zn	Moderately Reactive Metals	Oxides, trioxocarbonates (IV) and sulphides	Roasting of trioxocarbonates (IV) and sulphides to form oxides; reduction of oxides by carbon or carbon (II) oxide.
Iron, Fe			
Tin, Sn			
Lead, Pb			
Copper, Cu	Least Reactive Metals	Sulphides	Roasting in air.
Mercury, Hg			Heating in air.
Silver, Ag		Free elements	Mined as free elements.
Gold, Au			

ALKALI METALS

The periodic table showing Alkali Metals (group 1 elements)

1

H

HYDROGEN

3

Li

LITHIUM

4

Be

BERYLLIUM

11

Na

HYDROGEN

12

Mg

MAGNESIUM

19

K

POTASSIUM

20

Ca

CALCIUM

21

Sc

SCANDIUM

22

Ti

TITANIUM

23

V

VANADIUM

24

Cr

CHROMIUM

25

Mn

POTASSIUM

26

Fe

IRON

26

Co

COBALT

27

Ni

NICKEL

28

Cu

COPPER

29

Zn

ZINC

30

Ga

GALLIUM

31

Ge

GERMANIUM

32

As

ARSENIC

33

Se

SELENIUM

34

Br

BROMINE

35

Kr

KRYPTON

37

Rb

RUBIDIUM

38

Sr

STRONTIUM

39

Y

YTTRIUM

40

Zr

ZIRCONIUM

41

Nb

NIOBIUM

42

Mo

MOLYBDENUM

43

Tc

TECHNETIUM

44

Ru

RUTHENIUM

44

Rh

RHODIUM

45

Pd

PALLADIUM

46

Ag

SILVER

47

Cd

CADMIUM

48

In

INDIUM

49

Sn

TIN

50

Sb

ANTIMONY

51

Te

TELLURIUM

52

I

IODINE

53

Xe

XENON

55

Cs

CAESIUM

56

Ba

BARIUM

72

Hf

HAFNIUM

73

Ta

TANTALUM

74

W

TUNGSTEN

75

Re

RHENIUM

76

Os

OSMIUM

76

Ir

IRIDIUM

77

Pt

PLATINUM

78

Au

GOLD

79

Hg

MERCURY

80

Tl

THALLIUM

81

Pb

LEAD

82

Bi

BISMUTH

83

Po

TELLURIUM

84

At

ASTATINE

85

Rn

RADON

87

Li

LITHIUM

88

Ra

RADIUM

104

Rf

RUTHERFORDIUM

105

Db

DUBNIUM

106

Sg

SEABORGIUM

107

Bh

BOHRNIUM

108

Hs

HASSIUM

109

Mt

MEITNERIUM

110

Ds

DARMSTADTIUM

111

Rg

ROENTGENIUM

112

Cn

COPERNICIUM

113

Uu

UNUNTRIUM

114

Fl

FLEROVIUM

115

Uup

UNUNPENTIUM

116

Po

POLONIUM

117

Uup

UNUNSEPTIUM

118

Uuo

XENON

57

La

LANTHANUM

58

Ce

CERIUM

59

Pr

PRASEODYMIUM

60

Nd

NEODYMIUM

61

Pm

PROMETHIUM

62

Sm

SAMARIUM

63

Eu

EUROPIUM

64

Tb

TERBIUM

65

Dy

DYSPROSIUM

66

Ho

HOLMIUM

67

Er

ERBIUM

68

Sb

ANTIMONY

69

Tm

THULIUM

70

Yb

YTTERBIUM

71

Lu

LUTETIUM

89

Ac

ACTINIUM

90

Th

THORIUM

91

Pa

PROTACTINIUM

92

U

URANIUM

93

Np

NEPTUNIUM

94

Pu

PLUTONIUM

95

Am

AMERICIUM

96

Bk

BERKELIUM

97

Cf

CALIFORNIUM

98

Es

EINSTEINIUM

99

Fm

FERMIUM

100

Bi

BISMUTH

101

Md

MENDELEVIUM

102

No

NOBELIUM

103

Lr

LAWRENCIUM

Alkali Metals

General Properties of Alkali Metals.

Alkali metals are group 1 elements: All the elements in group 1 except Hydrogen are metals.

The following are their general properties.

- They have one electron in their valence shell, hence they ionize to form univalent positive ion $M \rightarrow M^+ + e^-$
- They are reducing agents
- They tend to be soft and light with relatively low melting points.
- Their first ionization energy decreases down the group.
- They all burn in air with characteristics flame colours which are used to identify them.
- They react with water to form alkali, hence the name alkali metals. Sodium reacts vigorously, potassium violently and lithium readily.

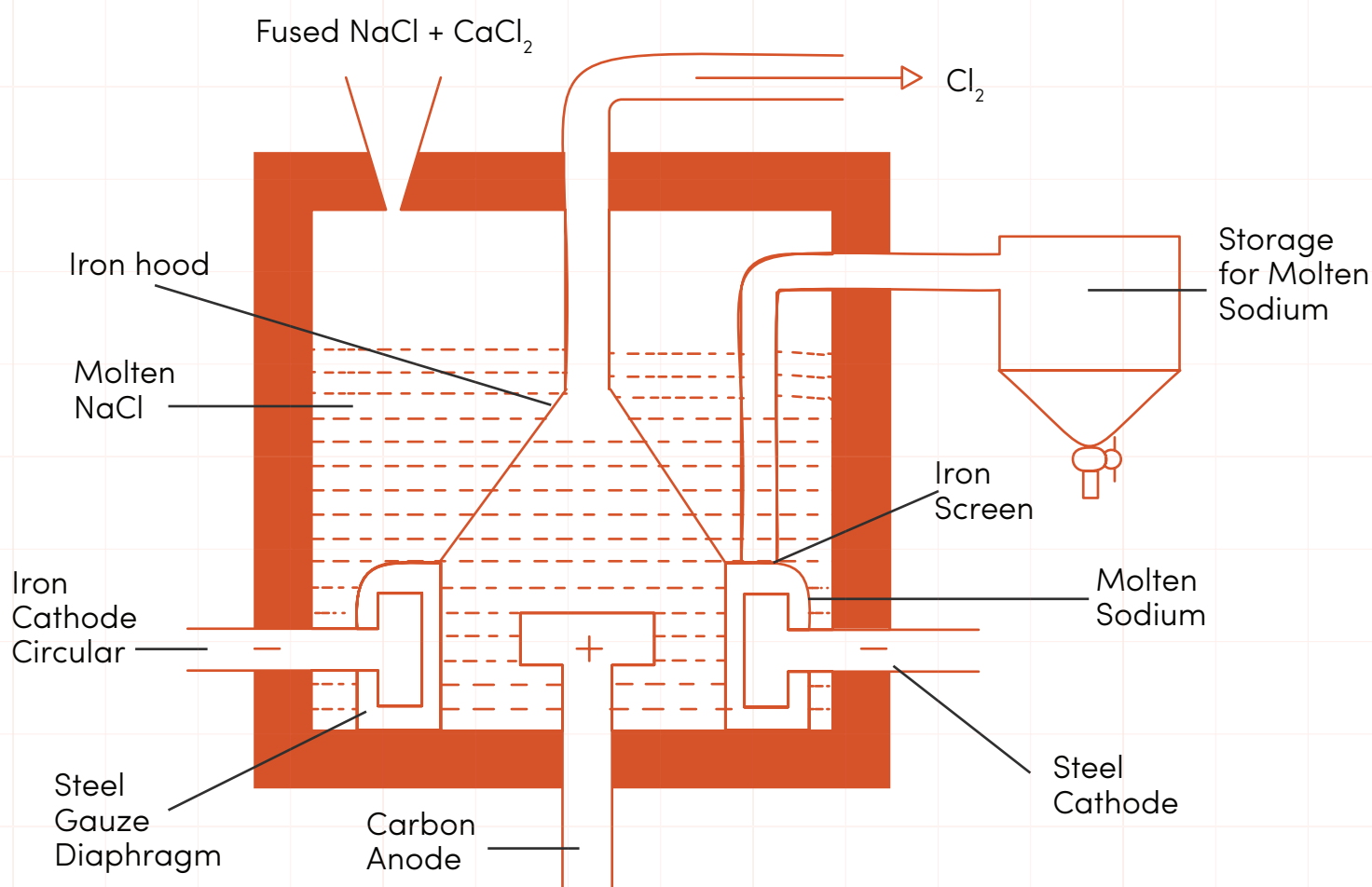
SODIUM (Na)

This is the second member of the group I metals. It is very reactive and hence not found free in nature. Sodium occurs in sea water, as chloride, bromide or iodide i.e. NaCl, NaBr, and NaI.

It also occurs as rock salt, NaCl in deposits. Sodium trioxonitrate (V), NaNO_3 is found abundantly in Chile and often called chile salt. It is also found in clay soil as complex trioxosilicate (IV).

EXTRACTION OF SODIUM

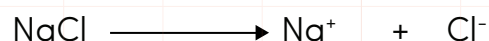
Sodium is extracted (in commercial quantity) from fused sodium chloride by electrolysis. The electrolytic cell used is called down cell as shown below:



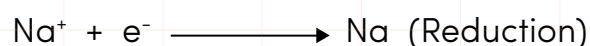
Extraction of Sodium (Down Cell)

The anode is a graphite rod centrally placed through the base of the cell, the cathode is a steel cylinder surrounding the anode. The molten sodium chloride has a melting point of 800°C . The molten sodium chloride is placed in a cell and is maintained in the molten state by heat from an electric current. An excess calcium chloride is added to lower the melting point of the molten sodium chloride to 600°C . The molten sodium chloride is collected in the cathode apartment where it rises to the top and is tapped off via a pipe. The gaseous chlorine is guided by a hood and is collected from another pipe.

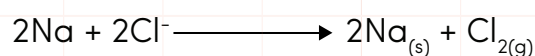
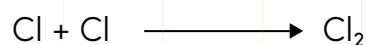
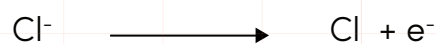
Fused sodium chloride contains chloride ions



At the cathode: Na^{+} ions takes up an electron each and are reduced to metallic sodium



At the Anode: The chloride ions releases (or donate) an electron each to become atomic chlorine which then pair up to form gaseous chlorine molecules. The chloride ion is said to be oxidized.

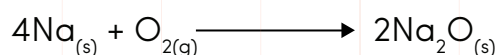


PHYSICAL PROPERTIES OF SODIUM

1. It is a silvery metallic solid
2. Relative density is 0.98gcm^{-3} , it therefore floats on water.
3. It is soft and very malleable
4. It has a low melting point of 97°C
5. It is a good conductor of heat and electricity.

CHEMICAL PROPERTIES OF SODIUM**1. Reaction with Air**

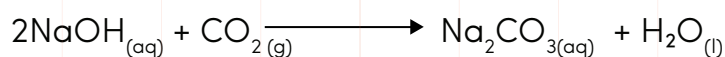
Sodium tarnishes (i.e. loses its metallic lustre) readily and gets oxidized by air to form sodium oxide.



The sodium oxide reacts with water vapour in air to form sodium hydroxide

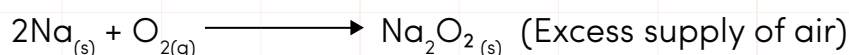
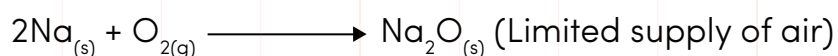


$\text{NaOH}_{(aq)}$ slowly absorbs carbon (iv) oxide, CO_2 in the atmosphere to form crystals of hydrated sodium trioxocarbonate(iv)

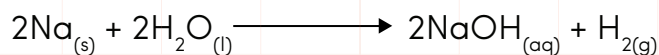


Due to this great affinity of sodium for atmospheric gases, it is always stored in a paraffin oil, toluene or naphtha.

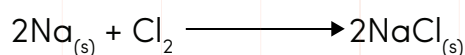
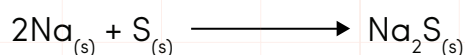
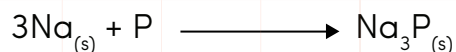
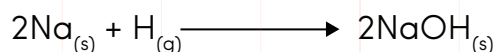
If heated in excess air, sodium burns with golden yellow flame to form Na_2O_2 (sodium peroxide) and Na_2O (sodium oxide) in limited supply of air.

**2. Reaction with water**

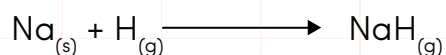
Sodium reacts violently with cold water to give sodium hydroxide. Hydrogen gas is given off and a lot of heat is released.

**3. Reaction with non – Metals**

On heating, sodium reacts with hydrogen, halogens, sulphur, phosphorous and most other non-metals except carbon and nitrogen

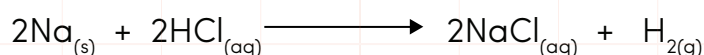


Sodium dissolves in mercury to give sodium amalgam



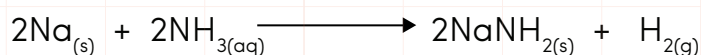
4. Reaction with Acid

Sodium reacts explosively with dilute acids to form hydrogen and salt (This reaction is dangerous and should not be carried out in the laboratory)



5. Reaction with Ammonia

Sodium reacts with ammonia to form sodamide and hydrogen gas.



TEST FOR SODIUM

Flame test: Compounds containing sodium ions burn with a golden yellow flame in non-luminous flame.

USES OF SODIUM

1. Sodium is used in manufacturing some compounds like sodium peroxide, sodium cyanide, as well as lead (iv) tetraethyl which is an anti-knock agent in petrol.
2. Liquid sodium is used as coolant in nuclear reactors
3. Mixtures of sodium amalgam and water or sodium and ethanol are useful reducing agents in organic chemistry. Sodium is used in reducing titanium tetrachloride to a metal in the extraction of titanium.
4. Sodium is used as a vapour in sodium lamps which are widely used in lighting streets, highways and airports because they give bright orange yellow light.

COMPOUNDS OF SODIUM

Sodium forms ionic compounds with high melting points. The compounds are water soluble and mostly white in colour.

Some sodium compounds are:

1. Sodium oxide.
2. Sodium hydroxide.
3. Sodium peroxide.
4. Sodium tetraoxosulphate (VI).
5. Sodium trioxonitrate (V).
6. sodium trioxocarbonate (IV).
7. Sodium hydrogen trioxocarbonate (IV) etc.

ALKALINE EARTH METALS

The periodic table showing Alkaline Earth Metals (group 2 elements)

<div>1</div> <div>H</div> <div>HYDROGEN</div>																	<div>2</div> <div>He</div> <div>HELIUM</div>						
<div>3</div> <div>Li</div> <div>LITHIUM</div>	<div>4</div> <div>Be</div> <div>BERYLLIUM</div>																	<div>5</div> <div>B</div> <div>BORON</div>	<div>6</div> <div>C</div> <div>CARBON</div>	<div>7</div> <div>N</div> <div>NITROGEN</div>	<div>8</div> <div>O</div> <div>OXYGEN</div>	<div>9</div> <div>F</div> <div>FLUORINE</div>	<div>10</div> <div>Ne</div> <div>NEON</div>
<div>11</div> <div>Na</div> <div>SODIUM</div>	<div>12</div> <div>Mg</div> <div>MAGNESIUM</div>																	<div>13</div> <div>Al</div> <div>ALUMINIUM</div>	<div>14</div> <div>Si</div> <div>SILICON</div>	<div>15</div> <div>P</div> <div>PHOSPHORUS</div>	<div>16</div> <div>S</div> <div>SULFUR</div>	<div>17</div> <div>Cl</div> <div>CHLORINE</div>	<div>18</div> <div>Ar</div> <div>ARGON</div>
<div>19</div> <div>K</div> <div>POTASSIUM</div>	<div>20</div> <div>Ca</div> <div>CALCIUM</div>	<div>21</div> <div>Sc</div> <div>SCANDIUM</div>	<div>22</div> <div>Ti</div> <div>TITANIUM</div>	<div>23</div> <div>V</div> <div>VANADIUM</div>	<div>24</div> <div>Cr</div> <div>CHROMIUM</div>	<div>25</div> <div>Mn</div> <div>POTASSIUM</div>	<div>26</div> <div>Fe</div> <div>IRON</div>	<div>26</div> <div>Co</div> <div>COBALT</div>	<div>27</div> <div>Ni</div> <div>NICKEL</div>	<div>28</div> <div>Cu</div> <div>COPPER</div>	<div>29</div> <div>Zn</div> <div>ZINC</div>	<div>30</div> <div>Ga</div> <div>GALLIUM</div>	<div>31</div> <div>Ge</div> <div>GERMANIUM</div>	<div>32</div> <div>As</div> <div>ARSENIC</div>	<div>33</div> <div>Se</div> <div>SELENIUM</div>	<div>34</div> <div>Br</div> <div>BROMINE</div>	<div>35</div> <div>Kr</div> <div>KRYPTON</div>						
<div>37</div> <div>Rb</div> <div>RUBIDIUM</div>	<div>38</div> <div>Sr</div> <div>STRONTIUM</div>	<div>39</div> <div>Y</div> <div>YTTRIUM</div>	<div>40</div> <div>Zr</div> <div>ZIRCONIUM</div>	<div>41</div> <div>Nb</div> <div>NIOBIUM</div>	<div>42</div> <div>Mo</div> <div>MOLYBDENUM</div>	<div>43</div> <div>Tc</div> <div>TECHNETIUM</div>	<div>44</div> <div>Ru</div> <div>RUTHENIUM</div>	<div>44</div> <div>Rh</div> <div>RHODIUM</div>	<div>45</div> <div>Pd</div> <div>PALLADIUM</div>	<div>46</div> <div>Ag</div> <div>SILVER</div>	<div>47</div> <div>Cd</div> <div>CADMIUM</div>	<div>48</div> <div>In</div> <div>INDIUM</div>	<div>49</div> <div>Sn</div> <div>TIN</div>	<div>50</div> <div>Sb</div> <div>ANTIMONY</div>	<div>51</div> <div>Te</div> <div>TELLURIUM</div>	<div>52</div> <div>I</div> <div>IODINE</div>	<div>53</div> <div>Xe</div> <div>XENON</div>						
<div>55</div> <div>Cs</div> <div>CAESIUM</div>	<div>56</div> <div>Ba</div> <div>BARIUM</div>		<div>72</div> <div>Hf</div> <div>HAFNIUM</div>	<div>73</div> <div>Ta</div> <div>TANTALUM</div>	<div>74</div> <div>W</div> <div>TUNGSTEN</div>	<div>75</div> <div>Re</div> <div>RHENIUM</div>	<div>76</div> <div>Os</div> <div>OSMIUM</div>	<div>76</div> <div>Ir</div> <div>IRIDIUM</div>	<div>77</div> <div>Pt</div> <div>PLATINUM</div>	<div>78</div> <div>Au</div> <div>GOLD</div>	<div>79</div> <div>Hg</div> <div>MERCURY</div>	<div>80</div> <div>Tl</div> <div>THALLIUM</div>	<div>81</div> <div>Pb</div> <div>LEAD</div>	<div>82</div> <div>Bi</div> <div>BISMUTH</div>	<div>83</div> <div>Po</div> <div>TELLURIUM</div>	<div>84</div> <div>At</div> <div>ASTATINE</div>	<div>85</div> <div>Rn</div> <div>RADON</div>						
<div>87</div> <div>Li</div> <div>LITHIUM</div>	<div>88</div> <div>Ra</div> <div>RADIUM</div>		<div>104</div> <div>Rf</div> <div>RUTHERFORDIUM</div>	<div>105</div> <div>Db</div> <div>DUBNIUM</div>	<div>106</div> <div>Sg</div> <div>SEABORGIUM</div>	<div>107</div> <div>Bh</div> <div>BOHRIUM</div>	<div>108</div> <div>Hs</div> <div>HASSIUM</div>	<div>109</div> <div>Mt</div> <div>MEITNERIUM</div>	<div>110</div> <div>Ds</div> <div>DARMSTADTIUM</div>	<div>111</div> <div>Rg</div> <div>ROENTGENIUM</div>	<div>112</div> <div>Cn</div> <div>COPERNICIUM</div>	<div>113</div> <div>Uu</div> <div>UNUNTRIUM</div>	<div>114</div> <div>Fl</div> <div>FLEROVIUM</div>	<div>115</div> <div>Uup</div> <div>UNUNPENTIUM</div>	<div>116</div> <div>Po</div> <div>POLONIUM</div>	<div>117</div> <div>Uuh</div> <div>UNUNSEPTIUM</div>	<div>118</div> <div>Uuo</div> <div>XENON</div>						
<div>57</div> <div>La</div> <div>LANTHANUM</div>	<div>58</div> <div>Ce</div> <div>CERIUM</div>	<div>59</div> <div>Pr</div> <div>PRASEODYMIUM</div>	<div>60</div> <div>Nd</div> <div>NEODYMIUM</div>	<div>61</div> <div>Pm</div> <div>PROMETHIUM</div>	<div>62</div> <div>Sm</div> <div>SAMARIUM</div>	<div>63</div> <div>Eu</div> <div>EUROPIUM</div>	<div>64</div> <div>Tb</div> <div>TERBIUM</div>	<div>65</div> <div>Dy</div> <div>DYSPROSIUM</div>	<div>66</div> <div>Ho</div> <div>HOLMIUM</div>	<div>67</div> <div>Er</div> <div>ERBIUM</div>	<div>68</div> <div>Sb</div> <div>ANTIMONY</div>	<div>69</div> <div>Tm</div> <div>THULIUM</div>	<div>70</div> <div>Yb</div> <div>YTERBIUM</div>	<div>71</div> <div>Lu</div> <div>LUTETIUM</div>									
<div>89</div> <div>Ac</div> <div>ACTINIUM</div>	<div>90</div> <div>Th</div> <div>THORIUM</div>	<div>91</div> <div>Pa</div> <div>PROTACTINIUM</div>	<div>92</div> <div>U</div> <div>URANIUM</div>	<div>93</div> <div>Np</div> <div>NEPTUNIUM</div>	<div>94</div> <div>Pu</div> <div>PLUTONIUM</div>	<div>95</div> <div>Am</div> <div>AMERICIUM</div>	<div>96</div> <div>Bk</div> <div>BERKELIUM</div>	<div>97</div> <div>Cf</div> <div>CALIFORNIUM</div>	<div>98</div> <div>Es</div> <div>EINSTEINIUM</div>	<div>99</div> <div>Fm</div> <div>FERMIUM</div>	<div>100</div> <div>Bi</div> <div>BISMUTH</div>	<div>101</div> <div>Md</div> <div>MENDELEVIUM</div>	<div>102</div> <div>No</div> <div>NOBELIUM</div>	<div>103</div> <div>Lr</div> <div>LAWRENCIUM</div>									

GENERAL PROPERTIES OF ALKALINE EARTH METALS

All elements in group II are called Alkaline earth metals. They all have 2 valence electrons.

They readily ionize by losing 2 electrons and form divalent positive ions.

The metallic bonds in alkaline earth metals are stronger than those in alkali metals. Their ionization energies are higher than that of alkali metals but they are less reactive than

alkali metals. The atomic radius of alkaline earth metals increases and the ionization energies decreases down the group. The elements in this group are: Beryllium, Magnesium, Calcium, Strontium, Barium and Radium.

PHYSICAL PROPERTIES OF ALKALINE EARTH METALS

1. They all have two valence electrons. They readily ionize by losing two electrons and form divalent positive ions.
2. They are usually less soluble than the alkali metals.
3. They have higher melting points than the alkali metals.
4. Except for barium, the alkaline earth metals have closely packed metallic structures at room temperature.
5. They are better conductors of heat and electricity than alkali metals
6. The atomic radius of alkaline earth metals increases and the ionization energies decreases down the group.
7. When heated, three of the members produce flame colours
 - Calcium gives brick-red flame
 - Strontium gives crimson flame
 - Barium gives green flame
8. They exhibit some characteristics colour in appearance. beryllium is silvery-grey, magnesium, calcium, and radium are silvery-white, strontium and barium are silvery-yellow.

CALCIUM

Calcium is too reactive to occur as free metals in nature. Instead it occurs abundantly as:

1. Calcium trioxocarbonate (iv) (CaCO_3), in limestone, marble, chalk, aragonite, calcite and coral;
2. Calcium tetraoxosulphate (vi) (CaSO_4) in gypsum and anhydrite. Bones and teeth contain calcium tetraoxosulphate (vi)
3. Double trioxocarbonate (iv) $\text{CaCO}_3 \cdot \text{MgCO}_3$. In dolomite;

4. Calcium fluoride CaF_2 , in fluorspar; and
5. Various trioxosilicates (iv).

Limestone is found in the following places in Nigeria

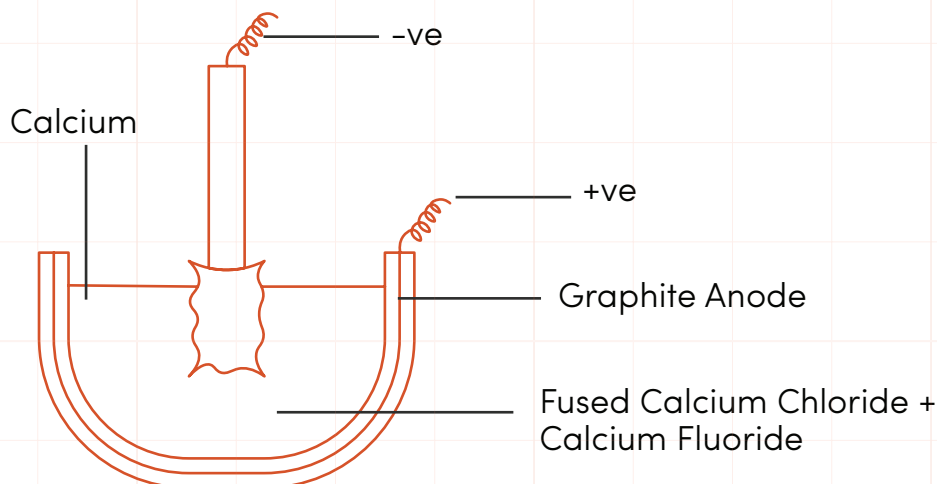
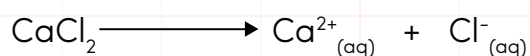
1. Ewekoro near Abeokuta, Ogun state.
2. Gongola River valleys in Benue
3. Nkalagu in Ebonyi
4. Ukpilla in Delta state
5. North of Calabar in cross-rivers state.
6. Near Sokoto in Sokoto state.

Limestone is quarried and is used locally in manufacturing cement.

EXTRACTION OF CALCIUM

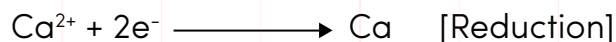
Since calcium compounds are very stable, metallic calcium is commonly extracted electronically from fused calcium chloride, a fluoride is usually added to the fused calcium chloride to lower the melting point from 850°C to about 650°C . The anode is a graphite vessel lined with iron. The cathode is an iron rod which is dipped just a little into the electrolyte. Calcium is deposited on the iron rod (i.e. at the cathode) while chlorine gas is liberated at the anode.

Fused calcium chloride contains calcium and chloride ions



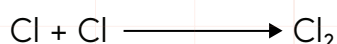
Extraction of calcium

At the cathode: The calcium ions receive two electrons each to become reduced to the metal.

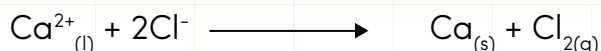


The calcium formed is collected at the bottom of the iron rod. When the calcium metal accumulates (forms an irregular stick), the iron rod is raised slowly.

At the anode: Two chloride ions give up an electron each to become chlorine atoms. The two chlorine atoms combine to form one chlorine molecule which is then liberated.



Overall electrolytic reaction:

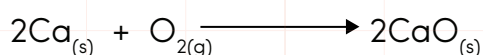


PHYSICAL PROPERTIES OF CALCIUM

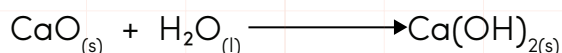
1. Calcium is a silvery-grey solid metal
2. it has a specific gravity of 1.55
3. it is malleable and ductile.
4. The melting point is 840°C.
5. It conducts heat and electricity.

CHEMICAL PROPERTIES OF CALCIUM

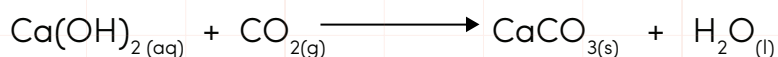
1. **Reaction with air:** Calcium readily loses its metallic lustre when exposed to air due to the formation of white film of calcium oxide (or quicklime) on the surface of the metal.



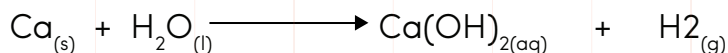
This Calcium oxide absorbs moisture to form calcium hydroxide (slaked lime).



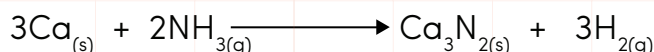
This calcium hydroxide then reacts with carbon (IV) oxide to form Calcium trioxocarbonate (IV)



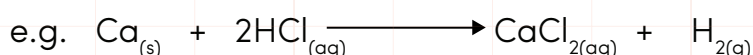
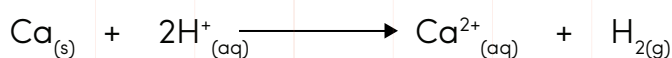
2. **Reaction with water:** Calcium reacts slowly with cold water and rapidly with warm water to form sodium hydroxide and hydrogen.



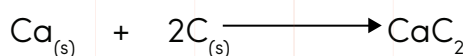
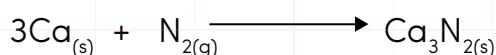
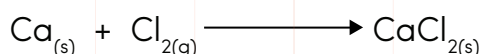
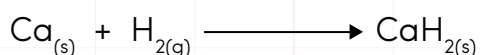
3. **Reaction with ammonia:** If ammonia is passed over heated calcium, calcium nitride is formed and hydrogen is given off.



4. **Reaction with Acids:** Calcium reacts vigorously to displace hydrogen from dilute acids



5. **Reactions with non-metals:** When heated, calcium combines directly with non-metals such as Sulphur, Hydrogen, Chlorine, Nitrogen and Carbon.

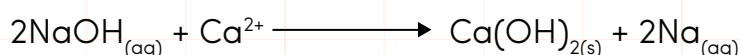


TEST FOR CALCIUM IONS

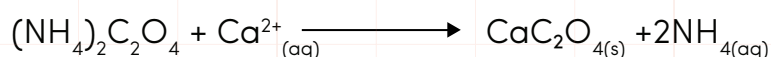
1. **Flame test:** calcium compounds give an orange-red colour to a non-luminous flame and produce a brick-red flame which appears green if view through a blue glass.

Note: Barium gives a pale green flame while strontium gives a bright red flame.

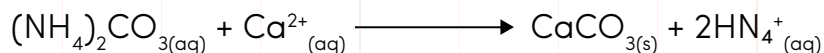
2. **With dilute sodium hydroxide:** Add a few drops of sodium hydroxide solution to an unknown salt solution. A formation of white precipitate, which is insoluble in excess sodium hydroxide, indicates the presence of calcium ions.



3. **With ammonium ethanedioate:** add a solution of ammonium ethanedioate to a solution of the unknown salt. The formation of a white precipitate, which is soluble in dilute hydrochloric acid but insoluble in ethanoic acid, indicates the presence of calcium ions,



Note: Ammonium trioxocarbonate (iv) may be used instead of using ammonium ethanedioate i.e.



Note: Barium and strontium salt undergo similar reactions with ammonium ethanedioate and ammonium trioxocarbonate (iv)

COMPOUNDS OF CALCIUM

Calcium is the most important of all the alkaline metals. Calcium forms ionic compounds but the compounds are less stable to heat than those of alkali metals. Our teeth and bones contain calcium tetraoxophosphate (VI), $\text{Ca}_3(\text{PO}_4)_2$ and calcium trioxocarbonate (IV), CaCO_3 . Calcium compounds are of great economic importance especially in the building industry and in the extraction of metals.

Other compounds of calcium are:

1. Calcium oxide (Quicklime), CaO
2. Calcium hydroxide, $\text{Ca}(\text{OH})_2$
3. Calcium Chloride, CaCl_2
4. Calcium trioxocarbonate (IV), CaCO_3
5. Calcium tetraoxosulphate (VI), CaSO_4

USES OF CALCIUM

1. It is used as oxidant in steel casting and copper alloys.
2. It is used in the manufacture of calcium fluoride.
3. It is used in the extraction of uranium.
4. Calcium oxide is used for the manufacturing of bleaching powder and caustic soda
5. Calcium oxide is used as desiccant in the laboratory
6. Calcium oxide is used in the production of mortar and cement.
7. calcium trioxocarbonate (iv) is used for the manufacture of cement
8. Calcium tetraoxosulphate (vi) is used for making plaster of Paris.
9. Calcium hydroxide is used for softening hard water.

ALUMINIUM

Aluminium- This is the third most plentiful elements in the earth crust, being found abundantly as trioxosilicate (iv) in rocks and clays.

The main source of aluminium is the mineral called bauxite, $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. other important minerals includes:

Kaolin, $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$

Cryolite, Na_3AlF_6

Corundum, Al_2O_3 etc.

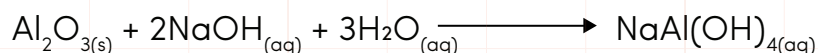
EXTRACTION OF ALUMINIUM

Aluminium is extracted by electrolysis of bauxite [$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$]. Two stages are involved in the extraction.

1. Purification of the crude bauxite

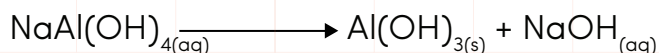
2. Electrolysis of aluminium oxide (Al_2O_3)

1. Purification of the crude bauxite: This involves heating the bauxite with NaOH solution (caustic soda) to form sodium aluminate (III) $\text{NaAl}(\text{OH})_4$ which is soluble.



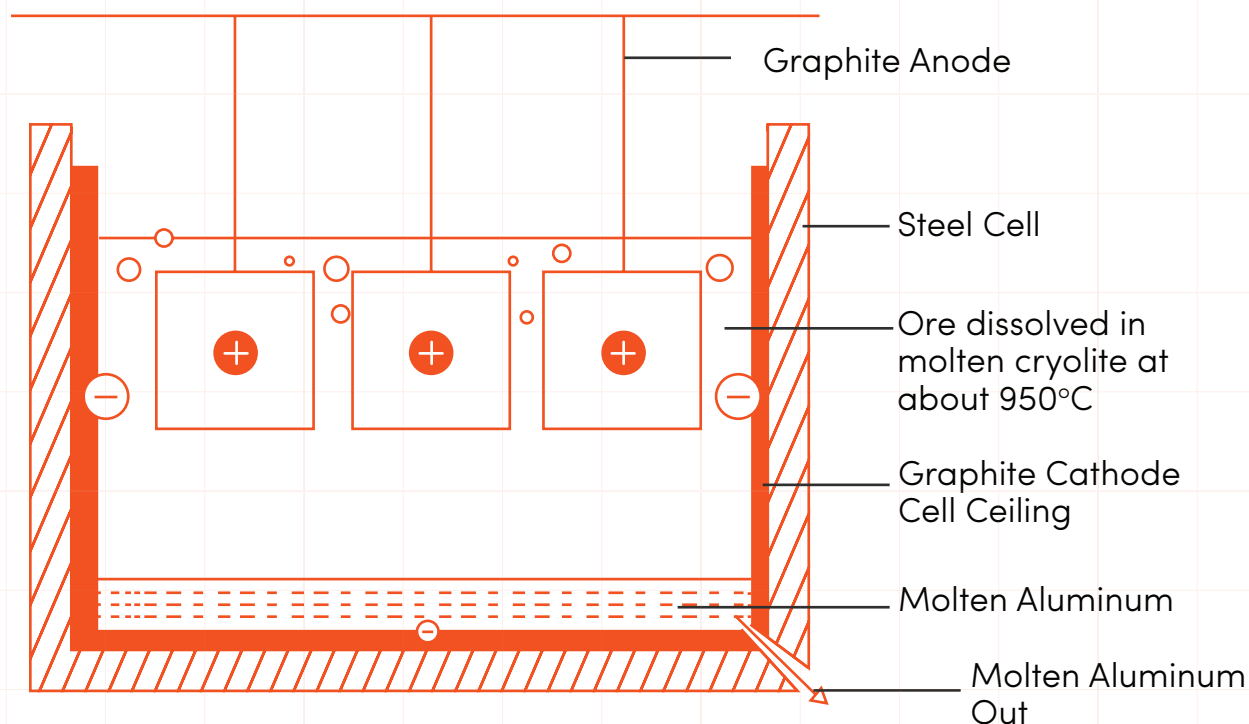
The impurities of the ore e.g. Iron (III) oxide, trioxosilicate (iv) can be filtered off as a sludge since they are neither soluble nor react with NaOH.

Precipitation of hydroxide is made possible by seeding the filtrate with aluminium hydroxide crystals.



$\text{Al}(\text{OH})_3$ crystals are filtered off. Washed dried and heated strongly to give pure aluminium oxide, Al_2O_3 . The NaOH left is concentrated and reused.

2. Electrolysis of aluminium oxide, Al_2O_3 :



A diagram showing the electrolysis of Aluminium oxide.

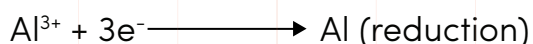
The cathode is an iron container lined with the graphite. The anode is a graphite rod dipped into the electrolyte.

A solution of pure alumina in molten cryolite Na_3AlF_6 is the electrolyte. Temperature of about 950°C maintained by the electrolyte is made possible by the heating effect of the large current supplied making the process very expensive. Oxygen is given off at the anode which in turn burns away gradually as carbon (iv) oxide (CO_2) hence the anode is replaced continuously during the process and this increases the cost.

Aluminium (molten form) which settles at the bottom of the cell is collected at intervals.

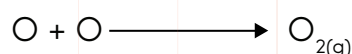
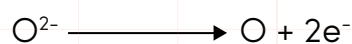
AT CATHODE

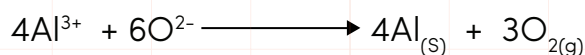
The aluminium ions gain three electrons each at the cathode to become deposited as metallic aluminium.



At anode

The oxygen ions donate two electrons each to form atomic oxygen which then pair off to form gaseous molecules

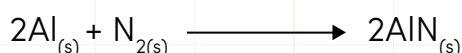
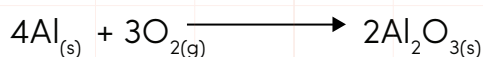


Overall reaction**Physical properties of Aluminium**

1. Aluminium is a silvery-white solid metal.
2. Aluminium is malleable and ductile. It can also be rolled into a foil.
3. It is a very good conductor of heat and electricity.
4. It possesses a moderate tensile strength.
5. It has a melting point of 660°C and a boiling point of 2450°C
6. It has a density of 2.70gcm^{-3}

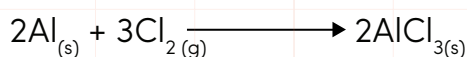
Chemical Properties of Aluminium**1. Reaction with air**

When a piece of aluminium sheet is exposed to moist air, a thin, continuous coating of aluminium oxide is formed which prevents further attack of the metal by atmospheric oxygen and water or steam under normal conditions. Aluminium sheets are thus said to be corrosion free. Aluminium metal burns in air at about 800°C to form aluminium oxide, Al_2O_3 and the aluminium nitride, AlN .

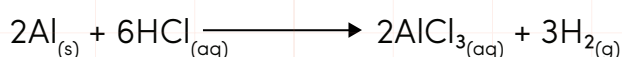


2. Reaction with non-metal: Heated aluminium combines directly with the halogen, sulphur, nitrogen, phosphorus and carbon, with the evolution of heat.

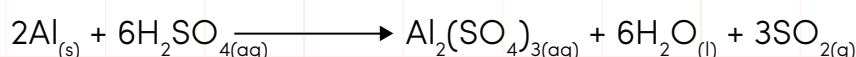
For example,



3. Reaction with acid: Aluminium reacts slowly with dilute hydrochloric acid but more rapidly with the concentrated acid to displace hydrogen.



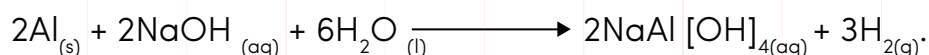
Aluminium does not react with tetraoxosulphate (vi) acid. However, the hot concentrated acid oxidizes it to liberate sulphur (iv) oxide.



Aluminium does not react with trioxonitrate (v) acid at any concentration due to the

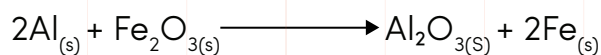
formation of protective layer of aluminium oxide. As a result, aluminium containers are frequently used to transport the acid.

4. Reaction with alkali: Aluminum dissolves in both sodium and potassium hydroxides to form a soluble aluminate (III) with evolution of hydrogen. For example



Thus, washing soda is never used to clean aluminum vessel

5. Reaction With Iron (III) Oxide: Aluminium reduces iron (III) oxide to form molten iron. This is the reaction used in the thermal process.

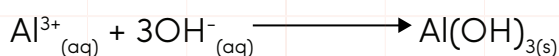


TEST FOR ALUMINUM IONS

1. With sodium hydroxide solution: To the unknown salt solution, add a few drops of sodium hydroxide solution. There is a formation of a white precipitate which is insoluble in excess sodium hydroxide solution.

The unknown solution may contain Zn^{2+} , Pb^{2+} or Al^{3+} .

2. With aqueous ammonia: Add a few drops of aqueous ammonium to the unknown salt solution. If a white gelatinous precipitate is formed and the precipitate is insoluble in excess aqueous ammonia, this confirms the presence of aluminum ions.



Note: lead II and zinc salt give similar reactions but lead II salt gives a white precipitate with concentrated hydrochloric acid, while aluminum salt do not. Zinc salt gives a white precipitate with aqueous ammonia but the precipitate dissolves in an excess of the reagent.

COMPOUNDS OF ALUMINUM

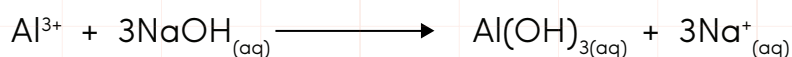
Aluminum compounds are mainly covalent e.g. AlCl_3 . Hydrated Aluminum are usually acidic in aqueous solution.

Some compounds of aluminium are

1. Aluminium oxide, Al_2O_3
2. Aluminium hydroxide, $\text{Al}(\text{OH})_3$
3. Aluminium hydride, AlH_3
4. Aluminium tetraoxosulphate (VI), $\text{Al}_2(\text{SO}_4)_3$

ALUMINIUM HYDROXIDE

Aluminium hydroxide is a white gelatinous precipitate formed when sodium hydroxide solution is added to a solution of an aluminium salt.



POTASH ALUM

Potash Alum is known as Aluminium potassium tetraoxophosphate (vi) dodecahydrate, $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$. This potash alum is very common and it is used in our homes and industries. It is used as a coagulant in water purification for removing particles. Some deodorants contain potash alum. Potash alum is used for washing snail before cooking. Potash alum is prepared by crystallizing solutions of potassium tetraoxosulphate (vi), K_2SO_4 and Aluminium tetraoxosulphate (vi), $\text{Al}_2(\text{SO}_4)_3$ in the correct mole ratios. The two salt crystallize out as one salt.

USES OF ALUMINIUM

1. Aluminum is used as an alloy such as duralumin (a mixture of Al, Cu, Mg and Mn) aluminum bronze (a mixture of Cu, Al). These alloys are used in cars, ships, aircraft and moving parts of machine. Duralumin is used in the construction of aircraft due to its light weight.
2. Aluminum is used for cooking utensils
3. It is used in manufacturing electrical cables
4. It is used as a component of paint and
5. It is used in making foils for packing.

TIN

Tin does not occur naturally as free element, the main source is the mineral cassiterite, SnO_2 .

Cassiterite is found in Malaysia, Indonesia and Bolivia. In Nigeria, tin was mined in Jos, plateau state in 1903. Nigeria is the current largest producer of tin and is presently exporting 13000 tonnes produced yearly.

EXTRACTION OF TIN

The stages involved in the extraction of tin are as follows

1. The ore, SnO_2 is first concentrated by crushing and washing with water.
2. Impurities like volatile oxides, sulphur, arsenic and antimony are removed by roasting the concentrated ore in air.
3. The molten tin obtained is impure. It contains impurities of iron, arsenic and lead. The molten tin is then refined (purified) by heating it gently on a sloping surface. As it flows down the surface, the impurities are exposed to air and become converted to oxides which are left behind as scum. The tin produced is about 99.9% pure.

PHYSICAL PROPERTIES OF TIN

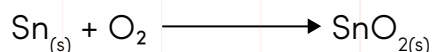
1. Tin is silvery-white solid with metallic luster.
2. Tin is malleable. It is soft and can be cut with knife.
3. Tin is a good conductor of heat and electricity.
4. Tin exist in three different allotropic forms with different densities. The allotropes are grey tin with density of 5.76gcm^{-3} , rhombic tin with a density of 6.6gcm^{-3} and white tin with a density of 7.2gcm^{-3} .

Note: Tin exist as white tin at room temperature.

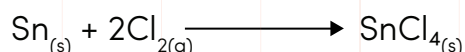
5. Tin is not ductile enough to be drawn into wire.
6. Tin has a melting point of 230°C and a boiling point of 227°C .

CHEMICAL PROPERTIES OF TIN

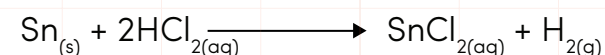
1. Reaction with oxygen: Tin is reactive and only combines with oxygen above 1200°C to form tin (IV) oxide. It does not combine with nitrogen and carbon.



2. Reaction with non-metals: Tin combines with chlorine when heated to give tin (IV) chloride



3. Reaction with acids: Tin reacts slowly with dilute hydrochloric acid and rapidly with the concentrated acid give tin (II) chloride

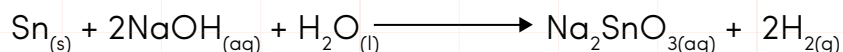


With dilute tetraoxosulphate (vi) acid hardly any reaction is observed, but with the hot concentrated acid, sulphate(iv) oxide is evolved



The reaction of tin with trioxonitrate (V) acid depends on the concentration and temperature of the acid.

4. Reaction with alkalis: Tin dissolves in concentrated solution of alkalis to give trioxostannate (IV) salts and hydrogen.

**USES OF TIN**

1. Tin is used for coating steel to prevent it from corrosion.
2. Because tin has low melting point and resistance to atmospheric corrosion, it is used in making sheet glass.
3. Steel coated with tin is used for food preservation because it is not poisonous.
4. Tin is used in making alloys e.g. type metal (Sn, Sb, Pb), bronze (Sn, Cu), and solder (Sn, Pb)

TRANSITION ELEMENTS

Transition elements are the elements that have partially filled d-orbitals. They are found between group 2 and 3 in the periodic table. They are in three rows with ten elements in each row. They are metals of economic importance.

A Comprehensive Periodic Table.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

1 H HYDROGEN

2 Li LITHIUM Be BERYLLIUM

3 Na SODIUM Mg MAGNESIUM

4 K POTASSIUM Ca CALCIUM Sc SCANDIUM Ti TITANIUM V VANADIUM Cr CHROMIUM Mn MANGANESE Fe IRON Co COBALT Ni NICKEL Cu COPPER Zn ZINC Ga GALLIUM Ge GERMANIUM As ARSENIC Se SELENIUM Br BROMINE Kr KRYPTON

5 Rb RUBIDIUM Sr STRONTIUM Y YTTRIUM Zr ZIRCONIUM Nb NIOBIUM Mo MOLYBDENUM Tc TECHNETIUM Ru RUTHENIUM Rh RHODIUM Pd PALLADIUM Ag SILBER Cd KADMIUM In INDIIUM Sn ZINN Sb ANTIMON Y Te TELLUR IODIN Xe KSENON

6 Cs CAESIUM Ba BARIUM La LANTHANUM Hf HAFNIUM Ta TANTALUM W WOLFRAM Re RHENIUM Os OSMIUM Ir IRIIDIUM Pt PLATINUM Au GOLD Hg QUECKSILBER Tl THALLIUM Pb BLEI Bi BISMUT Po POLONIUM At ASTATIN Rn RADON

7 Li LITHIUM Ra RADIUM Ac ACTINIUM Rf RUTHERFORDIUM Db DUBNIUM Sg SEABORGIUM Bh BOHRIUM Hs HASSIUM Mt MEITNERIUM Ds DARMSTADTIUM Rg ROENTGENIUM Cn COPERNICIUM Nh UNUNTRIUM Fl FERMIUM Mc UNUNPENTIUM Lv POLONIUM Ts UNUNSEPTIUM Og OGANESSON

8 9 10 11 12 13 14 15 16 17 18

19 K POTASSIUM 20 Ca CALCIUM 21 Sc SCANDIUM 22 Ti TITANIUM 23 V VANADIUM 24 Cr CHROMIUM 25 Mn MANGANESE 26 Fe IRON 27 Co COBALT 28 Ni NICKEL 29 Cu COPPER 30 Zn ZINC 31 Ga GALLIUM 32 Ge GERMANIUM 33 As ARSENIC 34 Se SELENIUM 35 Br BROMINE 36 Kr KRYPTON

37 Rb RUBIDIUM 38 Sr STRONTIUM 39 Y YTTRIUM 40 Zr ZIRCONIUM 41 Nb NIOBIUM 42 Mo MOLYBDENUM 43 Tc TECHNETIUM 44 Ru RUTHENIUM 45 Rh RHODIUM 46 Pd PALLADIUM 47 Ag SILBER 48 Cd KADMIUM 49 In INDIIUM 50 Sn ZINN 51 Sb ANTIMON 52 Te TELLUR 53 I IODIN 54 Xe KSENON

55 Cs CAESIUM 56 Ba BARIUM 57 La LANTHANUM 58 Ce CERIUM 59 Pr PRASEODYMIUM 60 Nd NEODYMIUM 61 Pm PROMETHIUM 62 Sm SAMARIUM 63 Eu EUROPIUM 64 Tb TERBIUM 65 Dy DYSPROBIUM 66 Ho HOLMIUM 67 Er ERBIUM 68 Yb YTERBIUM 69 Lu LUTETIUM

89 Ac ACTINIUM 90 Th THORIUM 91 Pa PROTAKTIUM 92 U URANIUM 93 Np NEPTUNIUM 94 Pu PLUTONIUM 95 Am AMERIUM 96 Bk BERKELIUM 97 Cf CALIFORNIUM 98 Es EINSTEINIUM 99 Fm FERMIUM 100 Bk BISMUTH 101 Md MENDELEVIUM 102 No NOBELIUM 103 Lr LAWRENCIUM

Alkali Metals
Alkaline Earth Metals
Transition Metals
Other Metals
Halogens
Noble Gases
Rare Earth Elements
Actinoid elements
Other Non-Metals

THE PERIODIC TABLE SHOWING THE FIRST TRANSITION SERIES

The periodic table is color-coded to show the order of orbital filling:

- S Block (Red):** Groups 1 and 2, plus Helium (Group 18). Labeled with "4s orbital filling".
- d block (Blue):** Groups 3 through 10. Labeled with "3d orbital filling".
- P block (Green):** Groups 13 through 18. Labeled with "4p orbital filling".

THE ELECTRONIC CONFIGURATION OF THE FIRST TRANSITION SERIES.

The first transition series consists of the elements with the atomic numbers 21 to 30. The atoms of these elements have one or two 4s electrons like Group 1 and 2 metals in the same period. They have partially filled 3d-orbitals and these are responsible for the special properties of the transition metals.

Arrangement of 3d electrons (e⁻) in the first series of transition elements

Element	Orbital							
	1s	2s	2p	3s	3p	3d		4s
Sc	2	2	6	2	6	↑ [3d ¹]		2
Ti	2	2	6	2	6	↑ ↑	2	2
V	2	2	6	2	6	↑ ↑ ↑	3	2
Cr	2	2	6	2	6	↑ ↑ ↑ ↑ ↑	5	1
Mn	2	2	6	2	6	↑ ↑ ↑ ↑ ↑	5	2
Fe	2	2	6	2	6	↑ ↓ ↑ ↑ ↑ ↑	6	2
Co	2	2	6	2	6	↑ ↓ ↑ ↓ ↑ ↑ ↑	7	2
Ni	2	2	6	2	6	↑ ↓ ↑ ↓ ↑ ↓ ↑ ↑	8	2
Cu	2	2	6	2	6	↑ ↓ ↑ ↓ ↑ ↓ ↑ ↓ ↑ ↓	10	1
Zn	2	2	6	2	6	↑ ↓ ↑ ↓ ↑ ↓ ↑ ↓ ↑ ↓	10	2

In forming simple ions, 4s e⁻ are removed before 3d e⁻

Element	Z	e ⁻ Configuration of Atom	Common ions(s)	e ⁻ Configuration of Ion
Sc	21	[Ar] 4s ² 3d ¹	*Sc ³⁺	[Ar] 4s ⁰ 3d ⁰
Ti	22	[Ar] 4s ² 3d ²	Ti ²⁺	[Ar] 4s ⁰ 3d ²
V	23	[Ar] 4s ² 3d ³	V ²⁺	[Ar] 4s ⁰ 3d ³
Cr	24	[Ar] 4s ¹ 3d ⁵	Cr ³	[Ar] 4s ⁰ 3d ³
Mn	25	[Ar] 4s ² 3d ⁵	Mn ²⁺	[Ar] 4s ⁰ 3d ⁵
Fe	26	[Ar] 4s ² 3d ⁶	Fe ²⁺ , Fe ³⁺	[Ar] 4s ⁰ 3d ⁶ , [Ar] 4s ⁰ 3d ⁵
Co	27	[Ar] 4s ² 3d ⁷	Co ²⁺	[Ar] 4s ⁰ 3d ⁷
Ni	28	[Ar] 4s ² 3d ⁸	Ni ²⁺	[Ar] 4s ⁰ 3d ⁸
Cu	29	[Ar] 4s ¹ 3d ¹⁰	*Cu ⁺ , Cu ²⁺	[Ar] 4s ⁰ 3d ¹⁰ , [Ar] 4s ⁰ 3d ¹⁰
Zn	30	[Ar] 4s ² 3d ¹⁰	*Zn ²⁺	[Ar] 4s ⁰ 3d ¹⁰

* Sc³⁺, Cu⁺ and Zn²⁺ are not typical transition metal ions because they have empty or complete d-sub-shells eg. Sc³⁺ and Zn²⁺ compounds all white: one oxidation state only

From the table above, we can deduce that:

1. Zinc atom (Zn), Zinc ion (Zn^{2+}), copper atom (Cu) and copper (I) ion (Cu^+) are not transitional because they have completely filled d-orbitals; and
2. Scandium ion (Sc^{3+}) is non-transitional because it does not have any electrons in its 3d-orbitals.
3. Chromium and copper atoms have only one electron in the 4s-orbital. This is because a special stability is associated with the $3d^5$ and $3d^{10}$ electronic configurations.

PHYSICAL PROPERTIES OF TRANSITION ELEMENTS

1. All transition elements are typical metals. They are all solids, hard, tough, malleable and ductile.
2. They are good conductors of heat and electricity.
3. They have high melting and boiling points.
4. They have high densities.
5. They have low atomic volumes.
6. They are paramagnetic in nature.

CHEMICAL PROPERTIES OF TRANSITION ELEMENTS

The chemical properties in which transition elements differ from a typical s-block and p-block elements are:

1. variable oxidation states
2. Formation of complex ion.
3. Formation of coloured compounds.
4. catalytic property

VARIABLE OXIDATION STATES

Transition metals exhibit variable oxidation states because 3d-electrons are available for bond formation (i.e. formation of many compounds.)

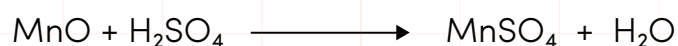
For example, manganese with the electronic configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$ can lose:

1. 4s electrons to give +2 oxidation state as in MnO ;

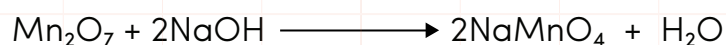
- Two 4s and two 3d electrons to give +4 oxidation state as in MnO_2
- Two 4s and four 3d electrons to give a +6 oxidation state as in MnO_4^{2-}
- Two 4s and five 3d electrons to give +7 oxidation state as in MnO_4^-

Lower oxidation state of the transition metals occur in ionic compounds and tended to form reducing agents e.g. chromium (II) salts and oxides like Manganese (II) oxide. Higher oxidation states are found in covalent compounds and tend to form oxidizing agent e.g. potassium heptaoxodichromate (VI) and potassium tetraoxomanganate (VII). Oxides of transition elements in low oxidation states tend to be basic. E.g., MnO , but oxides in high oxidation states tend to be acidic e.g. Mn_2O_7 .

Oxides of transition elements with intermediate oxidation states form amphoteric oxides. E.g. Chromium (III) oxides (Cr_2O_3).



Basic oxide



Acidic oxide

All transition elements except scandium exhibit oxidation state of +2.

Variable oxidation states and their oxides

Elements	Oxides	Oxidation numbers
Sc	Sc_2O_3	+3
Ti	TiO , Ti_2O_3 , TiO_2	+2, +3, +4
V	VO , V_2O_3 , VO_2 , V_2O_5	+2, +3, +4, +5
Cr	CrO , Cr_2O_3 , CrO_3	+2, +3, +6
Mn	MnO , Mn_2O_3 , MnO_2 , K_2MnO_4 , KMnO_4	+2, +3, +4, +6, +7
Fe	FeO , Fe_2O_3 ,	+2, +3
Co	CoO , Co_2O_3	+2, +3
Ni	NiO , Ni_2O_3 , NiO_2	+2, +3, +4
Cu	Cu_2O , CuO	+1, +2
Zn	ZnO	+2

FORMATION OF COMPLEX ION

Transition elements have the ability to form complex ions. A complex ion or compound consists of a central metal atom or ions to which several other atoms, ions or molecules called ligands are bonded. The bond between the central metal ion and the ligands is either electrovalent or co-ordinate.

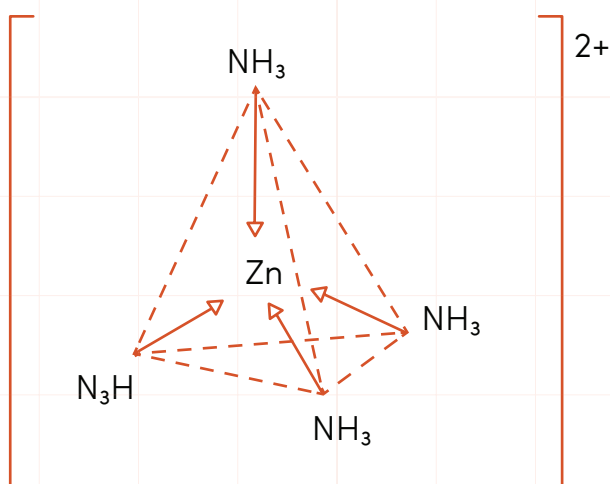
An example of a complex ion is the blue tetraamine copper (II) ion, $[\text{Cu}(\text{NH}_3)_4]^{2+}$ in which the central copper (II) ion is linked by coordinate bonding to four ammonia molecules. Transition metal complex usually have four or six ligands. When the complex ion has six ligands, the ligands are arranged octahedrally around the central metal ion as in the case of hexacyanoferrate (III) ion, $[\text{Fe}(\text{CN})_6]^{3-}$, or at the corners of a square as in tetraamine copper (II) ion.

The electrons donated by the ligands usually fill up the incomplete d-orbitals and the 4s and 4p orbitals in the central transition metal ion.

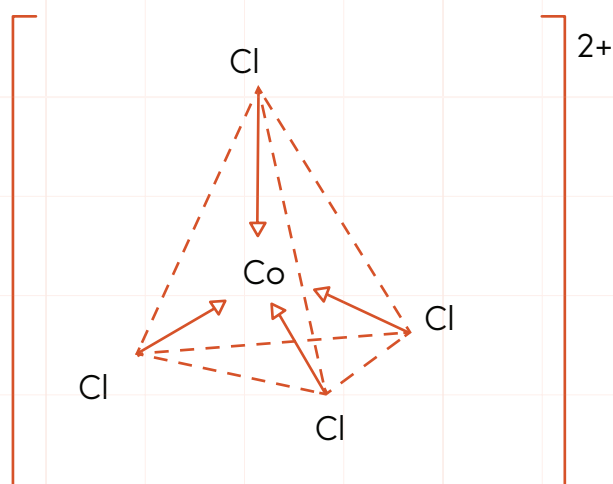
All transition metal ions tend to form complex ions with water. These hydrated ions are usually unstable.

EXAMPLES OF COMPLEX IONS ARE:

1. tetraamine zinc (II) ion
2. tetrachlorocobaltate (II) ion



tetraaminezinc (II) ion
 $[\text{Zn}(\text{NH}_3)_4]^{2+}$



tetrachlorocobaltate (II) ion
 $[\text{CoCl}_4]^{2-}$

FORMATION OF COLOURED IONS

Transition metals give coloured ions because of the partially filled 3d orbitals. Zinc and scandium are colourless since they do not have partially filled 3d-orbitals. In the complex ion, the nature of the ligands also contribute to the colour.

The colour of some transition metal ions in aqueous solution

	Ion	d-electrons	Color
1.	Sc ³⁺	3d ⁰	Colourless
2.	Ti ³⁺	3d ¹	Purple
3.	V ³⁺	3d ²	Green
4.	Cr ³⁺	3d ³	Violet
5.	Mn ³⁺	3d ⁴	Violet
6.	Mn ²⁺	3d ⁵	Pink
7.	Fe ³⁺	3d ⁵	Yellow
8.	Fe ²⁺	3d ⁶	Green
9.	Co ²⁺	3d ⁷	Pink
10.	Ni ²⁺	3d ⁸	Green
11.	Cu ²⁺	3d ⁹	Blue
12.	Zn ²⁺	3d ¹⁰	Colourless

CATALYTIC ACTIVITY:

Transition metals and their compounds are used extensively as catalyst particularly in the industrial process because of the ease with which their ions change their oxidation states. For example, in the catalytic decomposition of hydrogen peroxide, (H₂O₂) to oxygen and water, the catalyst used to speed up the reaction is manganese (IV) oxide. The Haber process, the contact process and hydrogenation of vegetable oil are examples of industrial processes where transition metals are used as catalyst.

COPPER

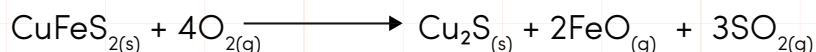
Copper belongs to the group of elements known as noble metals which include silver and gold. Copper is very reactive, stable in air and can be found in the free metallic form in a few places. The principal source of copper is copper pyrites, CuFeS_2 . Other sources of copper are:

1. Cuprite, Cu_2O
2. Malachite, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$
3. Chalcocite, Cu_2S
4. Bornite, $\text{Cu}_2\text{S} \cdot \text{CuS} \cdot \text{FeS}$

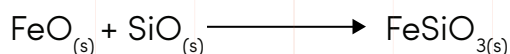
EXTRACTION OF COPPER

Copper is extracted from any of its sulphide ores e.g copper pyrite, CuFeS_2 . The extraction procedures are as follows:

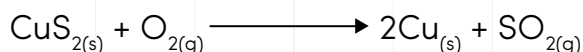
1. The ore is first concentrated by froth floatation. It is then roasted in a limited supply of air. The iron and some of the sulphur in the ore are oxidised to iron (II) oxide and Sulphur (IV) oxide respectively



2. Silicon (IV) oxide (SiO_2) is added and the mixture is heated in the absence of air to convert iron (II) oxide to iron(II) trioxosilicate (IV) which floats on copper (I) sulphide as slag and is removed.



3. Copper (I) sulphide left is heated in controlled quantity of air to produce copper which is about 97% to 99% pure.



The copper obtained can be made purer by the process of electrolysis.

The electrolyte is copper (II) tetraoxosulphate (VI). The impure copper is the anode while pure copper is used as the cathode. The impure copper goes into the solution, while pure copper (99.95% pure) is deposited at the cathode, leaving the impurities in the solution. Some silver and gold are collected at the anode as valuable impurities.

PHYSICAL PROPERTIES

1. It is a soft, red-brown solid with metallic lustre.
2. It has a relative density of 8.95gcm^{-3} .
3. It has a melting point of 1080°C and boiling point of 2300°C
4. It is very malleable and ductile.
5. It is an excellent conductor of heat and electricity.

TEST FOR COPPER (II) ION

1. **Flame Test:** All copper (II) salts impart a characteristic bluish-green colour to a non-luminous flame.
2. **Sodium Hydroxide:** Add a few drops of sodium hydroxide to the unknown salt solution. If a blue gelatinous precipitate is formed and the precipitate is insoluble in excess sodium hydroxide solution, this confirms the presence of copper (II) ions.
3. **Aqueous Ammonia:** Add a few drops of ammonia solution to the unknown salt solution. The formation of a blue precipitate of copper (II) hydroxide which dissolves in excess aqueous ammonia to give a deep blue solution indicates the presence of copper (II) ions.

USES OF COPPER

1. Copper has the best electrical conduction properties after silver. It is used for making electric wires because of its excellent ductility.
2. It is used in roofing and also in other metal works due to its attractiveness.
3. It is used to make water pipes and boilers because of its resistance to chemical attack.
4. Copper is used in the production of wide range of important alloys like bronze (Cu and Sn) brass (Cu, Zn) and cupronickel (Cu, Ni)
5. Copper is used in making cooking utensils and calorimeters
6. Finely divided copper is used industrially as a catalyst in the oxidation of methanol.
7. Copper is used for ornamental work as it is not attacked by air.

SUMMARY

So far, we have learnt how to

1. List the materials made of metals around us.
2. List metal ores and their location in Nigeria.
3. List the metals in the periodic table.
4. Give the general physical properties of metals.
5. State the chemical properties of metals.
6. Explain the activity series of metals.
7. List the compounds formed by metals
8. Explain the general principles of extractions of metals
9. List the alkali metals and give the general physical properties of alkali metals.
10. Describe sodium and explain how it is extracted.
11. State physical properties of sodium and explain its chemical properties
12. Test for sodium, list its compounds and uses
13. List alkaline earth metals and give the general properties of alkaline earth metals.
14. Describe and explain the extraction of calcium
15. List the physical and chemical properties of calcium
16. Test for calcium
17. List the various compounds of calcium and highlight the uses of calcium
18. Describe aluminum and explain how it is extract
19. List physical properties of aluminum
20. test for aluminum and state its chemical properties
21. List the compounds of aluminium and also give the various uses of aluminum
22. Describe tin
23. Explain the extraction of tin, list physical and chemical properties of tin and lastly, state the uses of tin
24. Define transition elements
25. List the elements of the first transition series.

26. Write the electronic configurations of the elements of the first transition series.
27. State the physical properties of transition elements
28. Explain the chemical properties of transition elements.
29. Describe copper
30. Explain how to extract copper
31. Give the physical properties of copper
32. Explain the chemical properties of copper.
33. Test for copper.
34. State the uses of copper.

INTERACTIVE ASSESSMENT QUESTIONS

1. Which of the following metals is the strongest reducing agent?

A Sodium
B Silver
C Potassium
D Copper
E Gold
2. Metals can be stretched to wires because they are

A Ductile
B Good conductors
C Lustrous
D Malleable
E Sonorous
3. Which of the following arrangements is in order of increasing metallic property?

A $\text{Li} < \text{Na} < \text{K}$
B $\text{Na} < \text{Li} < \text{K}$
C $\text{K} < \text{Na} < \text{Li}$
D $\text{K} < \text{Li} < \text{Na}$
E $\text{Na} < \text{K} < \text{Li}$

4. The following substances are ores of metals except.

- A Bauxite
- B Cuprite
- C Cassiterite
- D Graphite
- E Magnetite

5. Which of the following is the main compound used for removing impurities from bauxite?

- A NaOH
- B CaCO_3
- C Na_3AlF_6
- D H_2SO_4
- E MgSO_4

6. Zinc displaces copper from an aqueous solution of copper (II) salt because.

- A Copper is a transition element
- B Copper is a moderately reactive metal
- C Zinc is more reactive than copper
- D Zinc reacts with both acids and alkalis.
- E Zinc and Copper have reducing properties

7. A metal that is widely used in the manufacture of paints and overhead electric cables is

- A Aluminum
- B Copper
- C Iron
- D Lead
- E Sodium

8. The following transition metal ions would be coloured in aqueous solution except

- A Cr^{3+}
- B Fe^{3+}
- C Mn^{3+}
- D SC^{3+}
- E Fe^{2+}

9. The following are characteristics of transition elements except

- A Formation of complex ions
- B Fixed oxidation states
- C Formation of coloured compounds
- D Catalytic abilities
- E Variable oxidation states

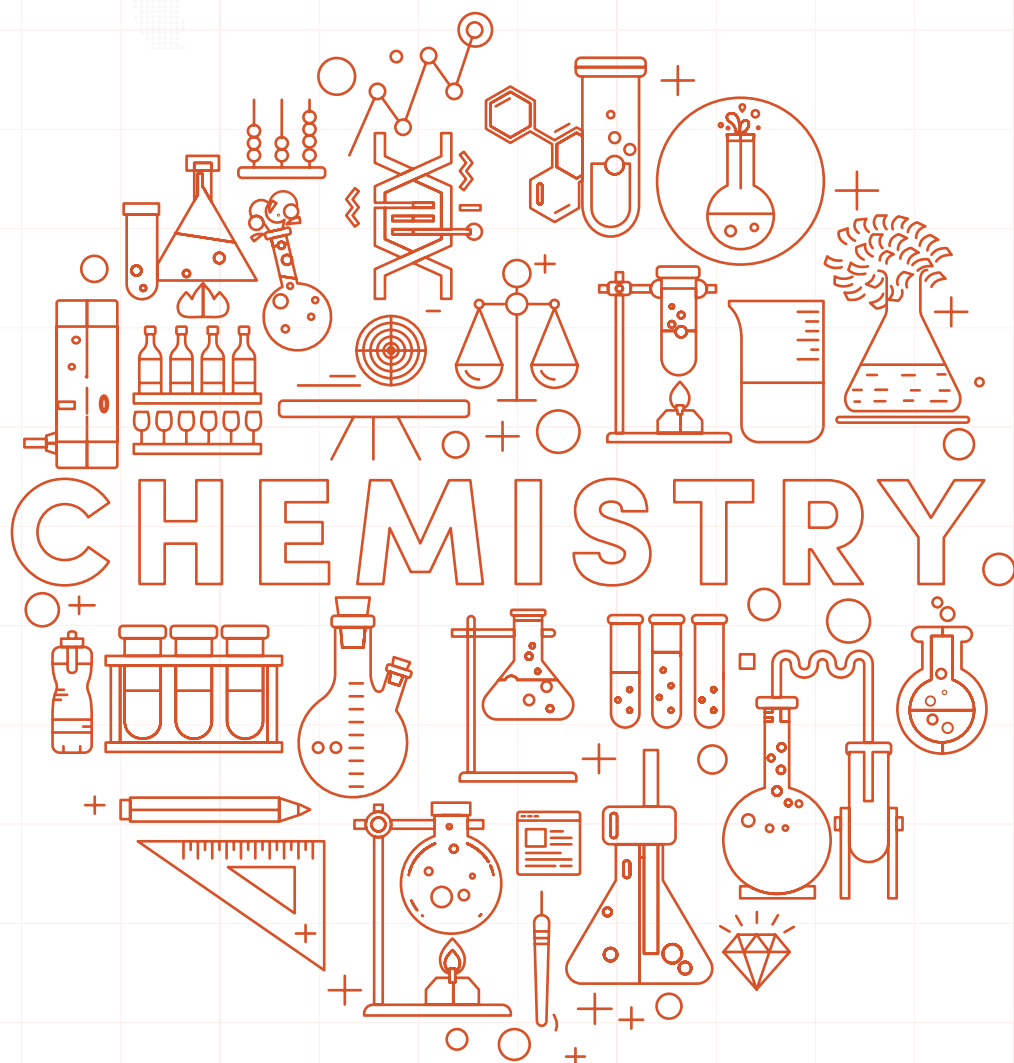
10. One of the characteristics of transition metal is

- A Reducing ability
- B Ductility
- C Ability to conduct electricity
- D Formation of coloured ions
- E Sonorous

IRON

PERFORMANCE OBJECTIVES

1. Mention and list some ores of iron
2. List where iron ores are found in Nigeria.
3. Explain the extraction of iron in the blast furnace.
4. List the types of iron and state the physical and chemical properties of iron
5. Explain the properties of iron
6. Test for iron (II) ion. and Iron (III) ion
7. Explain rusting of iron and give the method of preventing iron rust.
8. Describe and prepare iron (III) chloride



INTRODUCTION

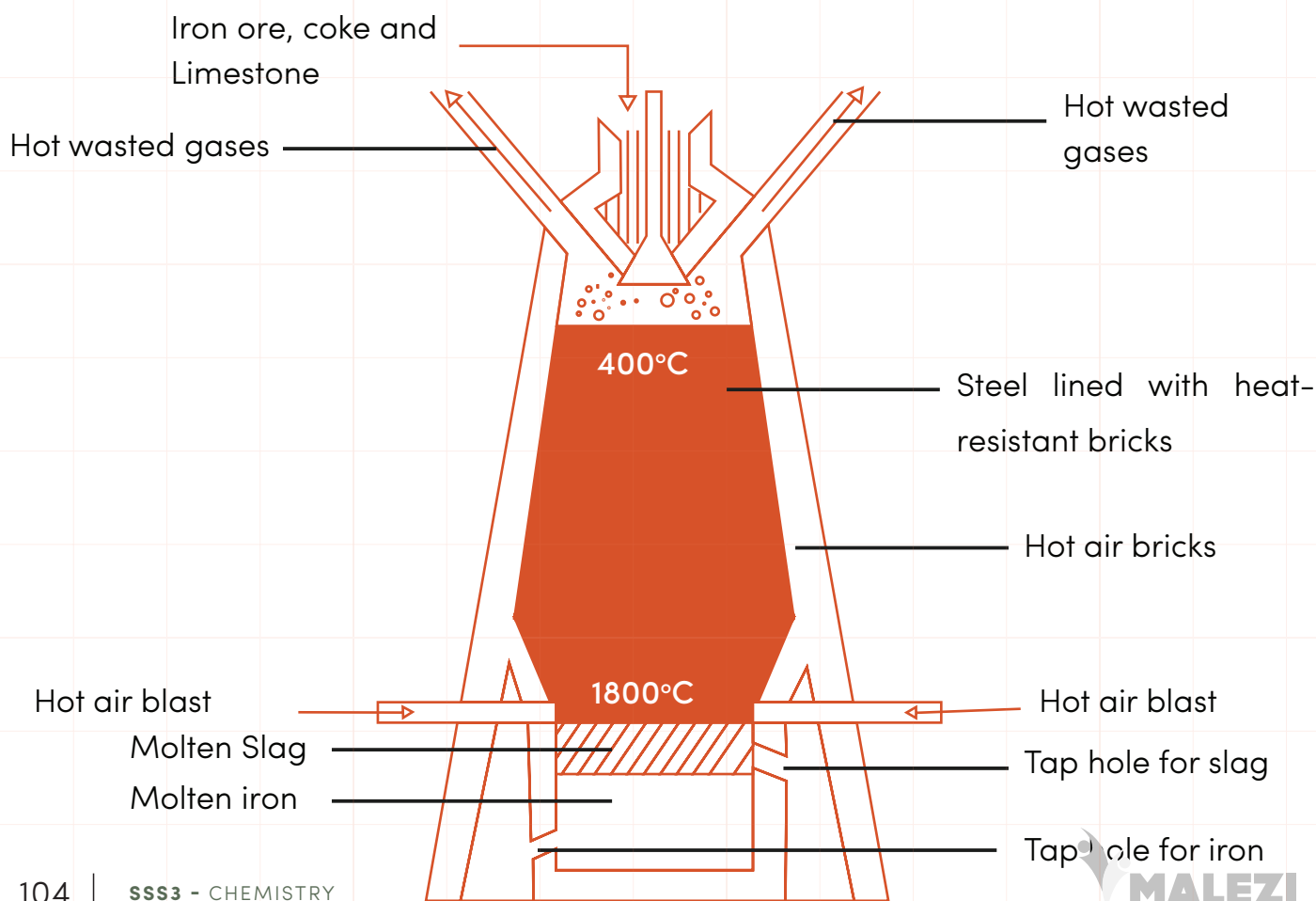
The relative abundance of iron in nature

Iron is the second most plentiful metal in the earth's crust after aluminum. It is not found free except in meteorites. The most common ores are:

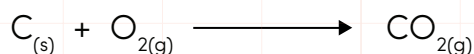
1. haematite (Iron (III) oxide), Fe_2O_3
2. magnetite(iron (II) diiron oxide), Fe_3O_4
3. Iron pyrites (Iron disulfide), FeS_2
4. Siderite or spathic iron ore (Iron (II) trioxocarbonate (IV)), FeCO_3
5. Limonite (hydrated iron (III) oxide), $\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$

Iron is also present as trioxosilicates (IV) in clay soils. This is a constituent of the pigments haemoglobin in animals and chlorophyll in plants. Iron ores are available in commercial quantities in Anambra and Edo state. The most important iron ore areas are in Itakpe, Ajaokuta, Jebba, and Lokoja in Kogi state. Steelworks are in Adja in Edo state and Ajaokuta in Kogi state.

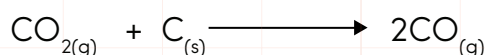
EXTRACTION OF IRON



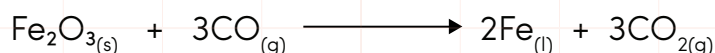
The iron ore is roasted in the air so that Iron (III) oxide is produced. The Iron (III) oxide produced is then mixed with limestone and coke and heated to a high temperature of about 1800°C in a blast furnace. These solid minerals are fed into the furnace from the top, while a blast of hot air enters near the base through small pipes called tuyeres. The temperature inside the furnace varies from about 2000°C near the bottom to about 200°C at the top. In the lower part, the white-hot coke is oxidized by the oxygen in the hot air blast to liberate carbon (IV) oxide. This is an exothermic reaction and much heat is evolved.



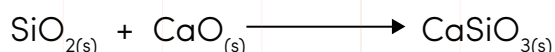
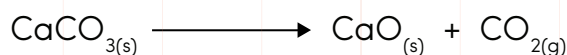
As the gas mixture moves up, the oxygen present in the air lessens and the carbon (IV) oxide becomes reduced by the white-hot coke to carbon (II) oxide.



The carbon (II) oxide then reacts with the iron (III) oxide, which reduces it to iron.



The high temperature causes the limestone to decompose into calcium oxide and carbon (IV) oxide. The calcium oxide then combines with silicon (IV) oxide (impurity) to give calcium trioxosilicate (IV).



The molten iron formed sinks to the bottom level of the furnace and is tapped off. It is run into moulds where it is being set as pig iron. It may also be used directly to make steel or further purified to produce wrought iron. The calcium trisilicate (IV) and other earthy impurities form a molten slag which floats on the molten iron and can be removed separately. The waste gas mixture that comes out of the furnace contains mainly nitrogen, 30% carbon (II) oxide, and 10% carbon (IV) oxide, and the waste gas is used for pre-heating the air blast and iron ore.

The whole process is continuous, and a blast furnace is normally kept going continuously for months or years until the lining needs to be replaced.

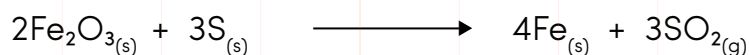
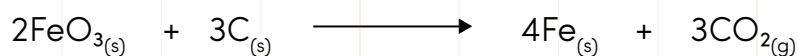
TYPES OF IRON AND THEIR USES

1. **Pig Iron:** Pig iron is obtained directly from the blast furnace. It is an impure form of iron because it contains many impurities like Sulphur, phosphorous, silicon, and manganese in varying proportions depending on the ores used and the operating temperature. The presence of these impurities lowers the melting point of iron from 1530°C to about 1200°C . It is hard and brittle.
2. **Cast Iron:** Cast iron is obtained from pig iron which has been re-melted and runs into moulds. Its melting point is lower than that of pure iron, it contains a lower percentage of impurities than pig iron.

At 1200°C , it can be melted and used to produce castings which do not need machining and which do not have to bear much strain such as kitchen stores, drain pipes, Bunsen burner, retort stand bases as well as radiators. Cast iron is brittle but can be welded or forged.

3. **Wrought Iron:** This is the purest kind of iron and it is obtained by heating cast iron in a furnace with haematite (Iron (III) oxide), Fe_2O_3 by a process known as puddling.

During the process, the impurities like carbon and Sulphur which cast iron contains are oxidized and removed as gaseous oxides. Any phosphorus and silicon (IV) oxide from trioxosilicates and phosphates are also removed in form of slag from the semi-molten mass iron.



The semi molten mass is hammered and rolled so that the slag is squeezed out and a mass of almost pure iron remains.

Wrought iron is malleable and can be welded when hot. It is very tough and fibrous and can withstand many strains.

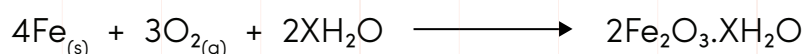
It is used to make iron nails or gates, ornamental work, horse-shoes, and agricultural implements.

PHYSICAL PROPERTIES OF IRON

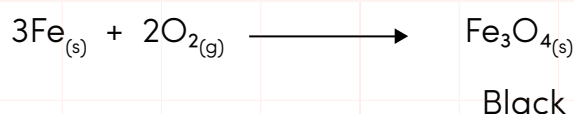
1. Iron is a gray metal with a density of 7.8gcm^{-3}
2. Its melting point is 1535°C
3. Its boiling point is 2800°C .
4. It is malleable and ductile.
5. It is a good conductor of heat and electricity.
6. It can easily be magnetized.

CHEMICAL PROPERTIES OF IRON

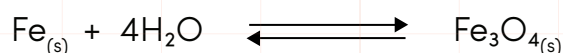
1. Reaction with air: Iron burns in air to form reddish hydrated iron (III) oxide of variable composition



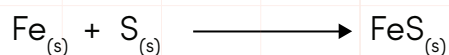
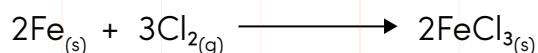
2. Finely divided iron burns at a high temperature when heated in the air. to form magnetic iron oxide.



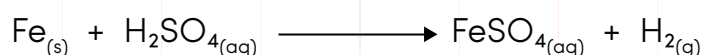
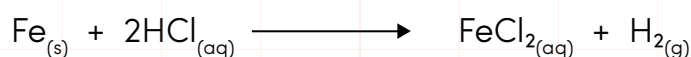
3. Reaction with steam: Passing steam over hot iron filings, tri-iron tetraoxide and hydrogen are produced. This reaction is reversible.



4. Reaction with non-metals: Iron combines directly with non-metals like Sulphur, chlorine, carbon, phosphorus, and silicon. It forms iron (III) chloride with chlorine and iron (II) sulfide with Sulphur.

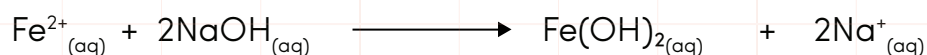


5. Reaction with Acids: Iron reacts readily with dilute mineral acids producing hydrogen and the appropriate iron (II) salt, e.g. iron reacts with hydrochloric acid and tetraoxosulphate (VI acid).

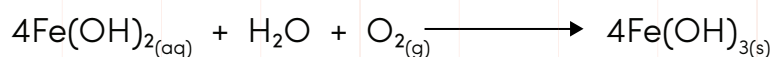


TEST FOR IRON (II) ION

With sodium hydroxide: Add sodium hydroxide solution in drops and then in excess to an unknown salt solution, a dirty green precipitate which is insoluble in excess sodium hydroxide solution is formed. This means that iron (II) ion is present. If after some time, the green precipitate turns reddish-brown when it is exposed to air, this means that the iron (II) ion has been oxidized to Iron (III) hydroxide.



Dirty green precipitate



Reddish brown precipitate

TEST FOR IRON (III)

With sodium hydroxide: Add sodium hydroxide solution in drops and then, in excess to the unknown salt solution. A reddish-brown precipitate is formed and the precipitate is insoluble in excess sodium hydroxide solution. This means that iron (III) ions are present.

RUSTING OF IRON

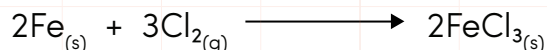
Rusting of iron results from the actions of oxygen and water in the atmosphere. If the rusted surface is scraped off or removed, the exposed part will also begin to corrode (rust) if left exposed to moist air.

PREVENTION OF RUSTING

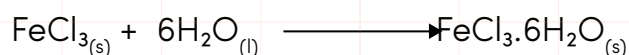
1. Coating or alloying with another metal like chromium that will not rust or corrode quickly. Galvanization of iron means coating of iron with zinc.
2. Putting grease or oil on iron and steel parts of a machine
3. Painting exposed parts of machines and vehicles.

PREPARATION OF IRON (III) CHLORIDE, FeCl_3

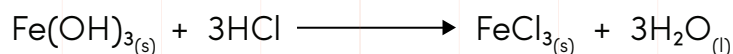
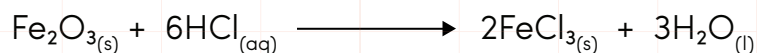
The anhydrous salt is prepared by heating iron in steam of dry chlorine gas. The chloride which sublimes at 315°C condenses as very dark-green crystals.



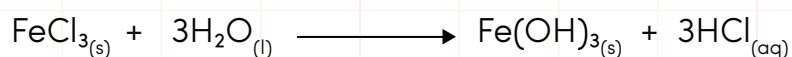
The dark green crystals can be dissolved in water and recrystallized as a brownish-yellow hexahydrate, $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$



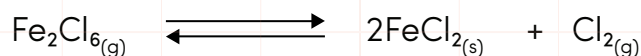
This hydrated chloride is prepared by the action of dilute hydrochloric acid on iron (III) oxide or hydroxide.

**PROPERTIES IRON (III) CHLORIDE**

1. Anhydrous iron (III) chloride is deliquescent.
2. It is a covalent compound which also hydrolyses in excess water like aluminum chloride. The product is a colloidal acidic solution, containing hydrated iron (III) hydroxide.



The vapour exists as a dimer, Fe_2Cl_6 at low temperatures, the dimer dissociates to form iron (III) chloride and chlorine.



SUMMARY

So far, we have learnt how to

1. Mention and list some ores of iron
2. List where iron ores are found in Nigeria.
3. Explain the extraction of iron in the blast furnace.
4. List the types of iron and state the physical and chemical properties of iron
5. Explain the properties of iron
6. Test for iron (II) ion. and Iron (III) ion
7. Explain rusting of iron and give the method of preventing iron rust.
8. Describe and prepare iron (III) chloride

INTERACTIVE ASSESSMENT QUESTIONS

1. Iron is extracted from which of the following ores?
I. Haematite, II Bauxite, III Magnetite, IV Cassiterite

A I and II only
B I and III only
C I, II, and III only
D I, II, III, and IV
E II and III only
2. An element that would produce colored ions in aqueous solutions is?

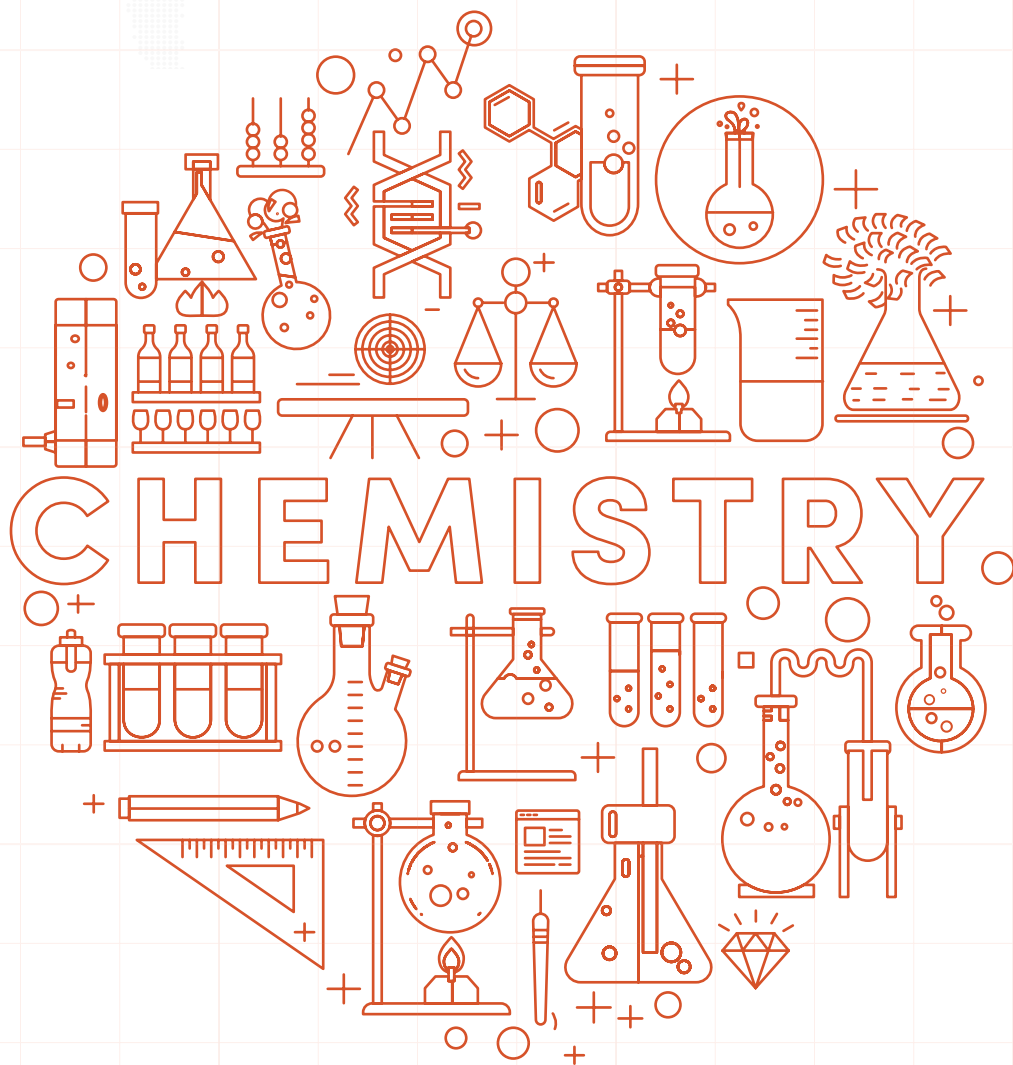
A Calcium
B Magnesium
C Sodium
D Iron
E Potassium

3. During the extraction of iron, the limestone which is fed into the blast furnace produces CaO which removes
- A Excess air
 - B Unburnt Coke
 - C Earthy impurities
 - D Molten Iron
 - E Marbles
4. Metals which only react with steam when they are red hot include
- A Copper
 - B Sodium
 - C Calcium
 - D Gold
 - E Iron
5. Pig-iron is brittle because it contains
- A A high percentage of carbon as an impurity
 - B Calcium trisilicate (iv)
 - C Unreacted haematite
 - D Undecomposed limestone
 - E Steel
6. Iron is often galvanized to
- A Make it more malleable
 - B Remove the impurities in it
 - C Protect it against corrosion
 - D Render it passive
 - E Melt it.

ETHICAL, LEGAL AND SOCIAL ISSUES

PERFORMANCE OBJECTIVES

1. List some sources of chemical waste.
2. Mention some industrial pollutants.
3. State the roles of government in preventing chemical degradation.



INTRODUCTION

Human activities and industrialization have led to the occurrence of wastes in our environment today. These wastes pollute the air and negatively affect respiration and photosynthesis process. Water and land are also affected by the generation of chemical wastes resulting in various health hazards and at times death. Mostly affected are cities and highly industrialized environment. It is therefore important for government to put to check environmental pollution by laws and regulations that will guide industries and individuals in waste generation, disposal and management. These laws and regulations should be enforced to the letter so as to have a good environment and healthy citizens.

CHEMICAL WASTE

Unwanted materials that are generated from homes, offices, industries, factories and are chemical in nature are called Chemical Waste. They are categorized into two namely:

1. Wastes from combustion.
 2. Other sources of waste.
-
1. **Waste from combustion.** This includes:
 - a. Tobacco smoke produced by smoking tobacco products.
 - b. Combustion of coal and solid fuel which generates SO_2 and polycyclic aromatic hydrocarbon as smoke.
 - c. Combustion of liquid petroleum generating carbon (II) oxide (CO), oxides of nitrogen etc.
 - d. Industry and incineration can generate oxides of sulphur and nitrogen.
 - e. Combustion products generated from home such as NO_2 from gas cookers and formaldehyde from building materials.
 2. **Other sources of waste:** These include:
 - a. Addition of fluorides to water. Adding fluorides to water has a negative effect like fluorosis of the teeth.
 - b. Soft water damages lead pipes.

- c. Fertilizer leaching by water which increases the risk of methemoglobinemia (blue babies) due to the presence of nitrates in water.
- d. Deposition of solid hazardous waste.

INDUSTRIAL POLLUTANTS

Industrial pollutants are agents of pollution generated from different industries. These pollutants include: CO, NO₂, CO₂, ground level, Ozone (O₃), particulate matter, SO₂, hydrocarbon and lead.

1. **CO:** Carbon monoxide is a colourless and poisonous gas. About 80% of the gas is generated from road transport. It affects oxygen transportation round the body by the blood thus, resulting in heart diseases
2. **NO₂:** Oxides of nitrogen emitted from vehicle exhaust is very harmful to the health. NO₂ at high levels, causes irritation and inflammation on the lungs airways. NO₂ dissolves rain water to form acid rain.
3. **Lead:** Petrol combustion is the main source of lead in the air. However, this is reduced by gradually stopping leaded petrol. Lead dust causes lead poisoning
4. **Ground Level Ozone:** Ground level ozone is very harmful to health unlike the upper level ozone which protects the earth. High level of the ground level irritate and inflame the lungs; it causes migraine and coughing and attack rubber, pigments and vegetation.
5. **Particulate Matter:** Sources of particulate matter in air include sand, coal burning sea spray, construction dust or soot, etc. Finer particles in the air are more dangerous than larger ones. This is because we can easily and deeply breathe these finer particles into our lungs thereby having more toxic effects.
6. **SO₂:** This gas evolve when we burn fuel and materials that contain Sulphur. Sulphur (IV) oxide dissolves in rain water in the air to form acid rain. Acid rain causes skin irritation and attack buildings. A short-term exposure to high level SO₂ may cause coughing, tightening of the chest and lung irritation.

- 7. Hydrocarbons:** There are hydrogen and carbon compounds. Such compounds include: 1,3 butadiene (primarily from vehicle exhaust) and benzene (from the combustion of petrol. Longer term exposure to these compounds is often linked to leukemia and other form of cancer.

ROLES OF LOCAL GOVERNMENT IN PREVENTING CHEMICAL DEGRADATION

The following measures are taking by government to prevent chemical degradation.

1. Legislation by law makers by examining various degradation forms and suggesting possible way.
2. Setting of minimum standards, minimum standards of waste generation and management are set for citizens and industries by government bodies.
3. Government should also ensure the passage into law of the minimum standards set for citizens and, the legislation and, their subsequent enforcement. Industries and citizens should be made to abide by these laws.

SUMMARY

So far, we have learnt how to

1. Mention and list some ores of iron
2. List where iron ores are found in Nigeria.
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8. Describe and prepare iron (III) chloride

INTERACTIVE ASSESSMENT QUESTIONS

1. The following are major industrial pollution except.

A	CO ₂
B	CO
C	SO ₂
D	NO ₂
E	Lead
2. The following diseases are caused by industrial pollutants except.

A	Cancer
B	Lead poisoning
C	Leukemia
D	Irritation
E	Polio

3. Which of the following gases can cause blood poisoning?

- A NO_2
- B CO_2
- C SO_2
- D CFC
- E CO

4. The un-covered raw food that is sold along major road is likely to contain some amounts of.

- A Lead
- B Copper
- C Argon
- D Sodium
- E Iron

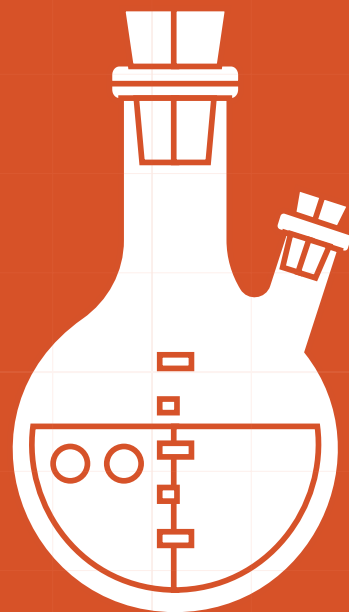
5. The gas that is most useful in protecting humans against solar radiation is

- A Chlorine
- B Ozone
- C CO_2
- D H_2S
- E NO_2



THEME

03



Chemical World.

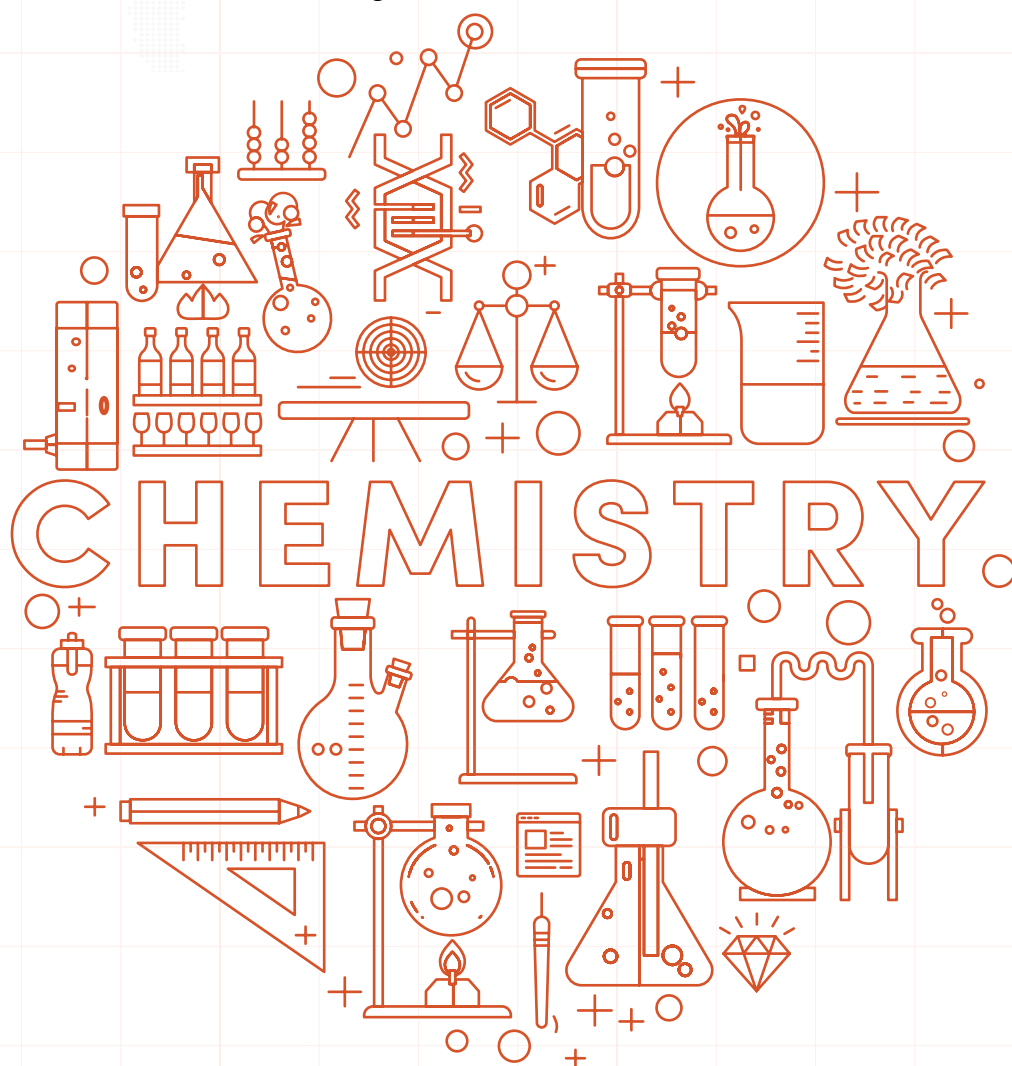
Chemistry and Industry.

_____ Chemistry of life.

FATS AND OIL

PERFORMANCE OBJECTIVES

1. Describe the occurrence of fats and oil.
2. Give the IUPAC name and the molecular formula of some fatty acids
3. List the sources of fats and oil
4. Differentiate between fats and oil.
5. State the physical properties of fats and oil.
6. Explain the physical properties of fats and oil.
7. Test for fats and oil and also give the uses of fats and oil.

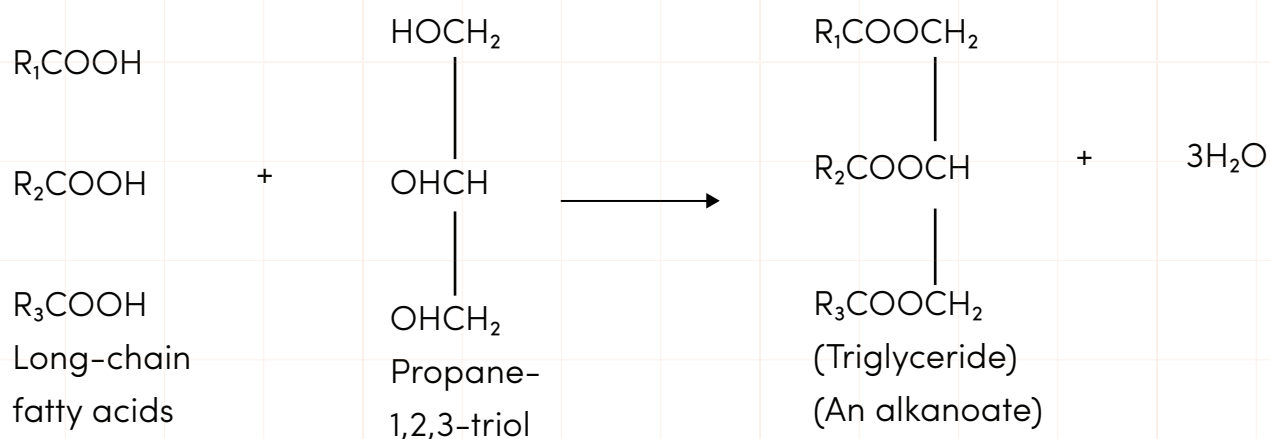


INTRODUCTION

Fats and oils are members of a group of compounds called lipids. The fats are solids of animal origin. The oils are liquids of plant origin.

Lipids are esters occurring naturally in plants and animals. They are a mixture of esters formed from different fatty acids. The acids may be saturated or unsaturated. There are no double bonds in the long hydrocarbon chains of saturated fatty acids. There are one or more double bonds in long hydrocarbon chains of unsaturated fatty acids. Fats are esters produced from saturated fatty acids. While oils are esters produced from unsaturated fatty acids.

Fats and oils are the products obtained from long-chain fatty acids with trihydric alcohol e.g. propane-1,2,3-triol (glycerol). They are alkanoates of higher fatty acids and propane-1,2,3-triol (glycerol.)



The R groups e.g. R_1 , R_2 , and R_3 in the fatty acids may be the same or different.

Examples of saturated and unsaturated fatty acids

IUPAC Name	Old Name	Source	Molecular formula
Hexadecenoic acid	Palmitic acid	Palm oil	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
Octadecanoic acid	Stearic acid	Animal fats	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$
Octa-9-enoic acid	Oleic acid	Peanut oil Olive oil	$\text{CH}_3\text{C}(\text{CH}_2)_7\text{CH}=\text{CHCHCH}=\text{CH}(\text{CH}_2)_7\text{COOH}$
Octadeca-9,12-dienoic acid	Linoleic acid	Vegetable oil	$\text{CH}_3\text{C}(\text{CH}_2)_4\text{CH}=\text{CHCHCH}=\text{CH}(\text{CH}_2)_7\text{COOH}$

SOURCES OF FATS AND OILS

Fats and oils occur naturally in living things. There are two main sources.

1. Tissues of Animals. Marine (water) animals, such as fish, produce fish oil and cod-liver oil, while terrestrial (land) animals produce butter, lard, and tallow.
2. Fruits and seeds of plants: They contain edible fat and oil such as cocoa butter, fat, palm oil, cottonseed oil, coconut oil, corn oil, groundnut oil, olive oil, sunflower seed oil and soya bean oil. They are called vegetable oils.

DIFFERENCES BETWEEN FATS AND OILS

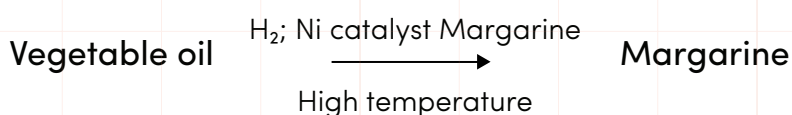
1. Fats are solids while oils are liquids.
2. Fats are usually from animals while oils are from plants.

PHYSICAL PROPERTIES OF FATS AND OILS.

1. Pure lipids are coloured or white and with little odour.
2. They do not have sharp boiling or melting points because they are complex mixtures of some different triglycerides (esters).
3. They do not dissolve in water but dissolve in organic solvents such as alcohols.
4. When heated to temperatures above 300°C, fats and oils decompose to give irritating fumes

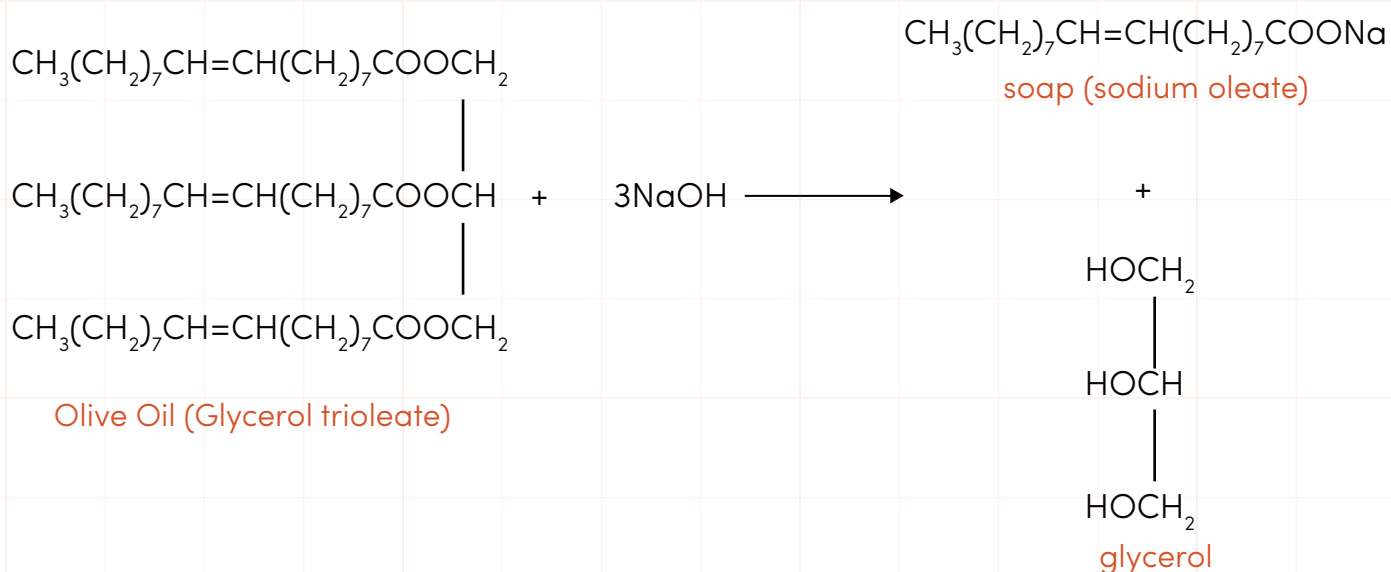
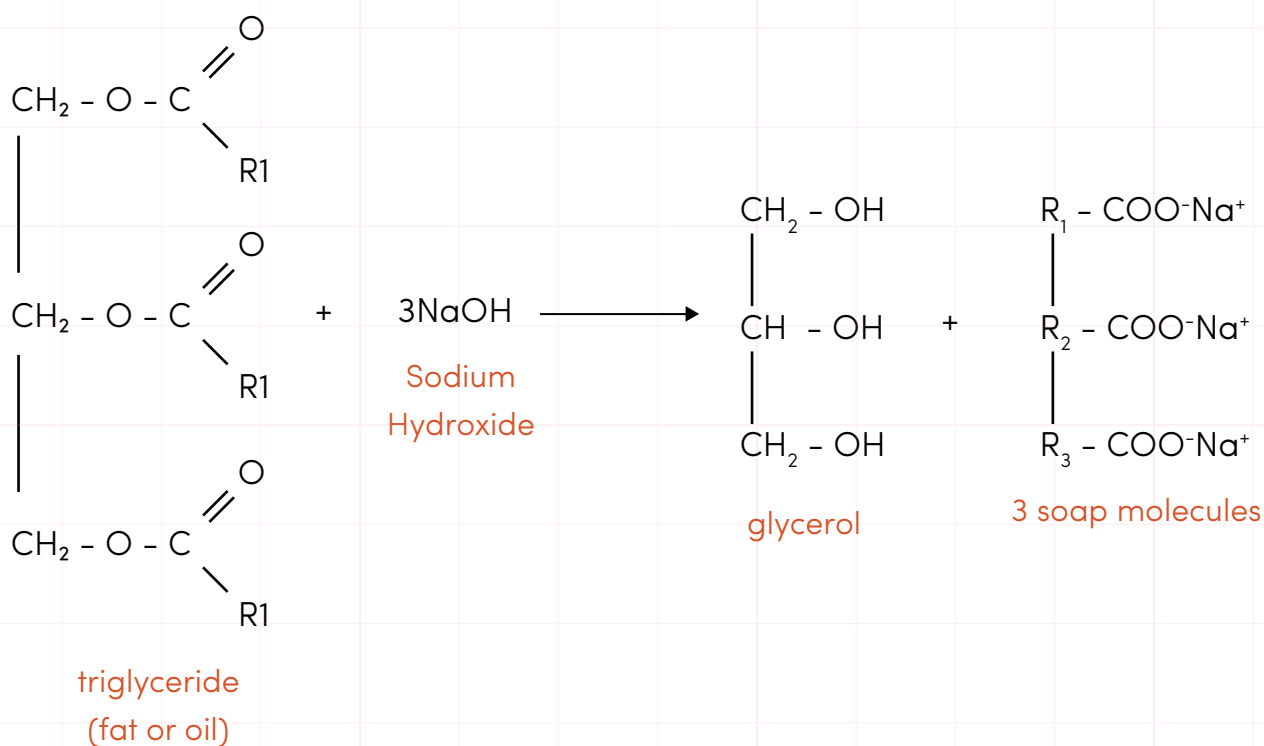
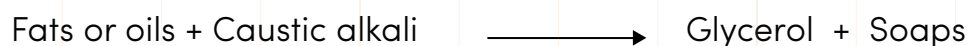
CHEMICAL PROPERTIES OF FATS AND OILS

1. **Hydrogenation of oils:** Hydrogenation of oil is known as the hardening of oils to produce solid fats. This is achieved by passing hydrogen into an unsaturated oil at about 200°C and 3 atmospheric pressure by using finely divided Nickel as a catalyst. The unsaturated part of the oil is saturated and the oil becomes hardened into fat. The hardened oils are mixed with salts, vitamins, skimmed milk, and various fat to form margarine.



2. Formation of soap (Saponification of fats and oils):

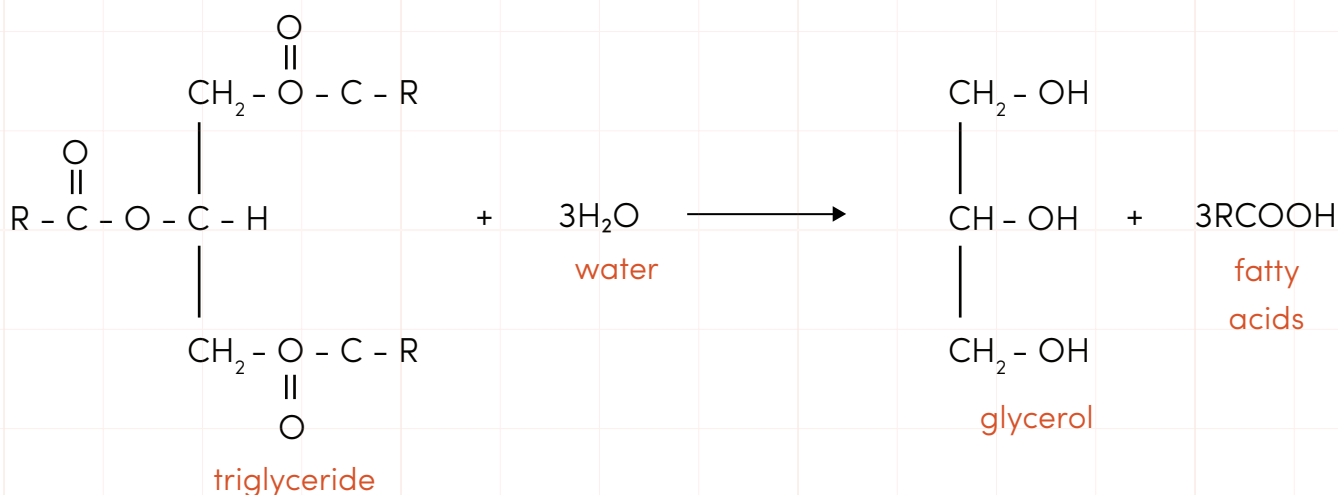
Saponification is the alkaline hydrolysis of fats and oils to give a mixture of salts of fatty acids (soaps) and propane-1,2,3-triol (glycerol)



Hard soaps are produced if caustic soda (NaOH) is used for the reaction. Soft or liquid soaps are produced if caustic potash (KOH) is used. The fats and oils that can be used for soap making include olive oil, coconut oil, palm kernel oil, palm oil, and goat tallow.

3. ACID HYDROLYSIS OF FATS AND OILS

When natural fats or oils are boiled with water in the presence of concentrated H_2SO_4 , the products obtained are propane-1,2,3-triol (a trihydric alkanol, glycerol) and a mixture of saturated and unsaturated fatty acids which can be separated by using fractional distillation.



TESTS FOR FATS AND OILS

1. A drop of oil or melted fat on a piece of paper forms a translucent grease spot.
2. To a little amount of the substance in a test-tube, add a few drops of Sudan (III) reagent. A red coloration indicates the substance is fat or oil.

USES OF FATS AND OILS

1. Fats and oils are widely present in foods. When eaten, they provide good nutrients for body building and they are oxidized in the body to provide energy for metabolic processes, which are accompanied by a release of CO_2 .
2. Fats and oils are used in the production of soaps, propane-1,2,3-triol (glycerol), and margarine
3. As solvents for production of candle vanishers, paints etc.

SUMMARY

So far, we have learnt how to

1. Describe the occurrence of fats and oil.
2. Give the IUPAC name and the molecular formula of some fatty acids
3. List the sources of fats and oil
4. Differentiate between fats and oil.
5. State the physical properties of fats and oil.
6. Explain the physical properties of fats and oil.
7. Test for fats and oil and also give the uses of fats and oil.

INTERACTIVE ASSESSMENT QUESTIONS

1. The following oils can serve as a raw material for the production of margarine except.

A	Palm kernel oil
B	Sunflower
C	Coconut oil
D	Olive oil
E	Paraffin oil
2. We can change oil into fat by using nickel as catalyst at 180°C through a process called

A	Polymerization
B	Alkylation
C	Hydrogenation
D	Substitution
E	Decomposition

3. Which of these solvents cannot be used to dissolve fats?

- A Tetrachloromethane
- B Ethoxyethane
- C Chloroform
- D Water
- E Benzene

4. The alkanol obtained when soap is produced is

- A Dihydric alkanol
- B Monohydric alkanol
- C Trihydricalkanol
- D Tertiary alkanol
- E Secondary alcohol

5. The boiling of fats and an aqueous solution of caustic soda is called ?

- A Acidification
- B Hydrolysis
- C Saponification
- D Esterification
- E Neutralization

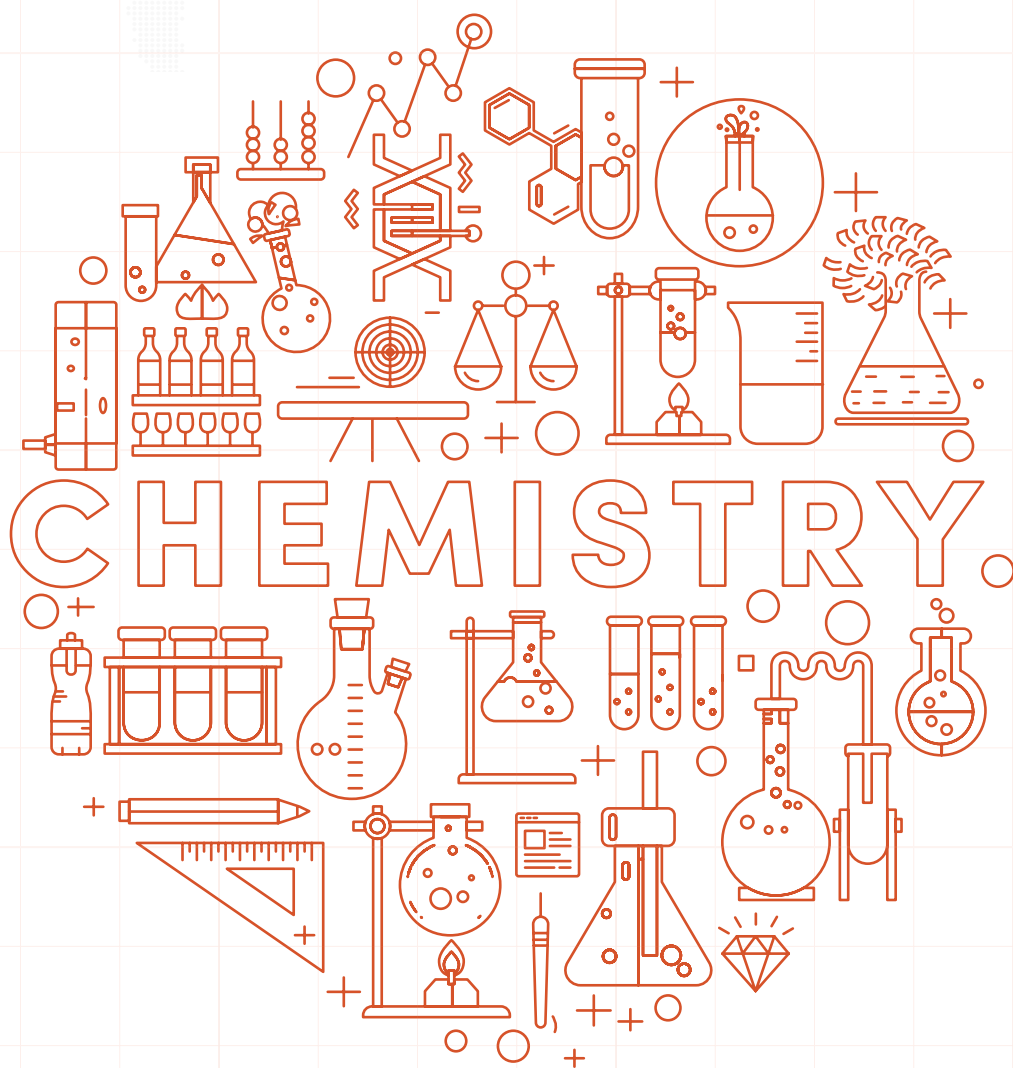
6. A liquid that will dissolve fat is

- A Kerosene
- B Hydrochloric acid
- C Calcium hydroxide
- D Water
- E Tetraoxosulphate (IV) acid

SOAP AND DETERGENTS

PERFORMANCE OBJECTIVES

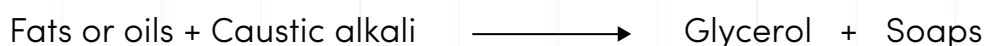
1. Describe and prepare soap
2. Explain the action of soap as an emulsifying agent.
3. Explain the cleansing action of soap.
4. Define detergent.
5. List the types of soap and prepare detergents.
6. Differentiate between soap and detergents



INTRODUCTION

SOAP

Soap (a salt of fatty acid) is one of the products obtained when fats or oil is being hydrolyzed with an alkali. Soaps are sodium salts of fatty acids. They are usually referred to as soapy detergents.



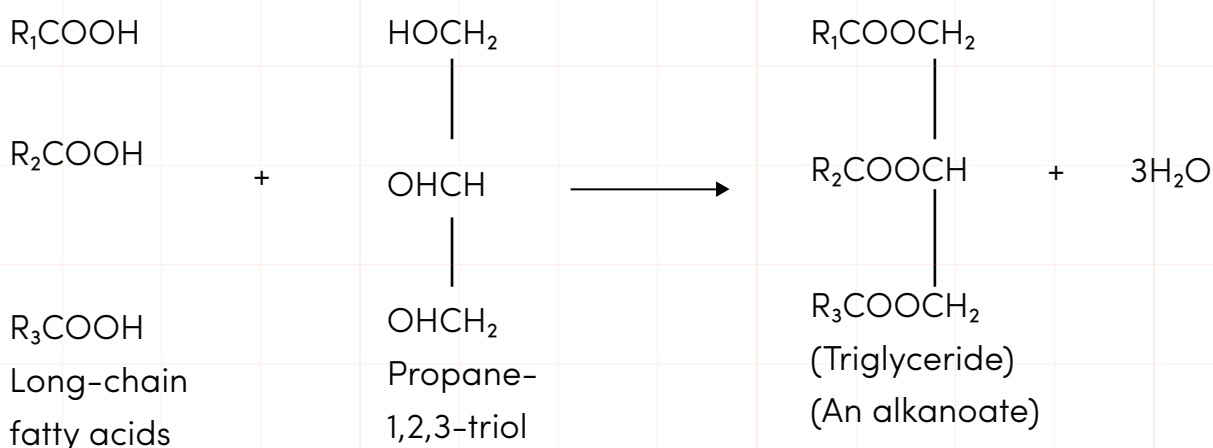
This process of obtaining soap is known as saponification.

Fats and oils are the products obtained from long-chain fatty acids with trihydric alcohol e.g. propane-1,2,3-triol (glycerol). They are alkanoates of higher fatty acids and propane-1,2,3-triol (glycerol.)

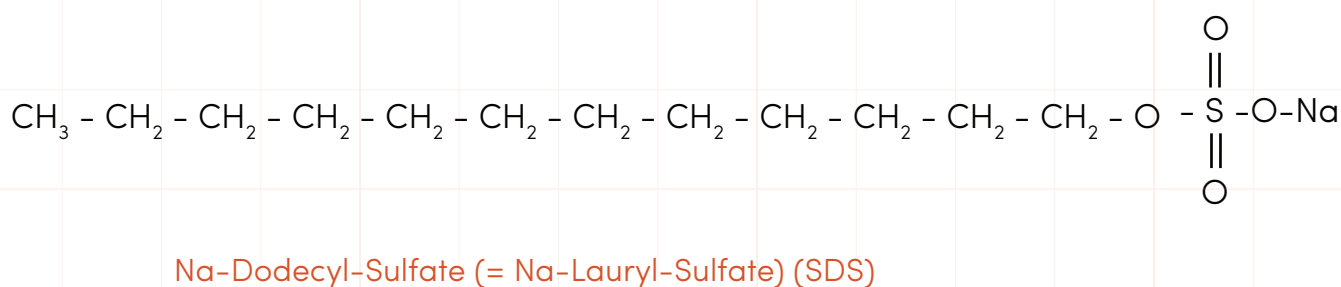
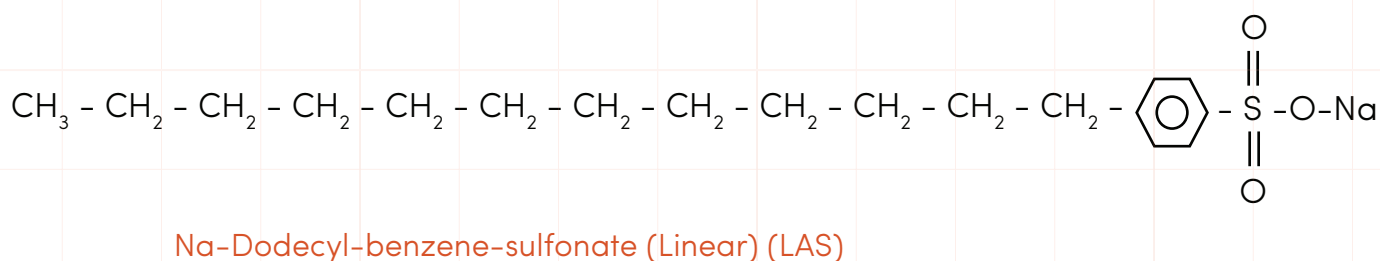
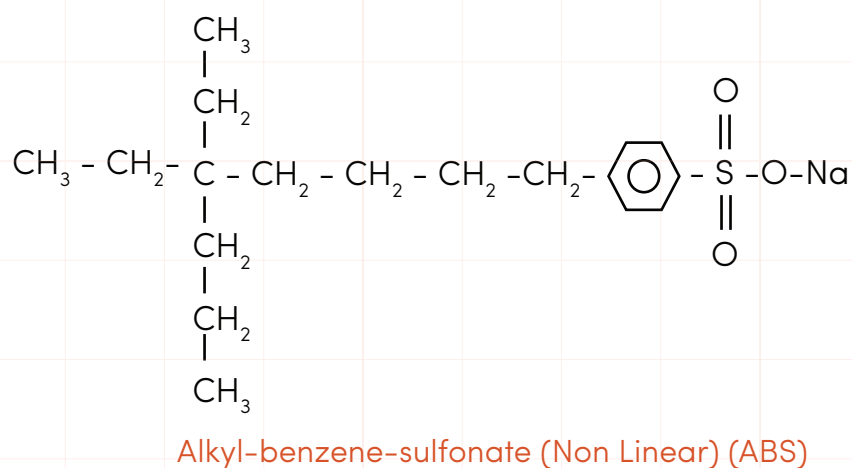
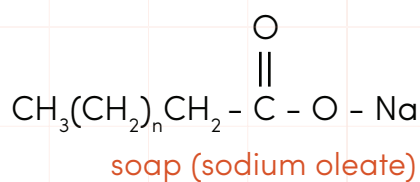
The soap contains the potassium or sodium salts of long-chain alkanoic acids. Such as sodium hexadecanoic (sodium palmitate) and sodium octadecanoic (sodium stearate). Soap is a potassium or sodium salts of an alkanoate and each contains two parts: (RCOONa⁺) for sodium soap and (RCOOK⁺) for potassium soap.

(i) R – alkyl radical is a non – water-soluble hydrocarbon

(ii) COONa⁺ and COOK⁺ soluble in water

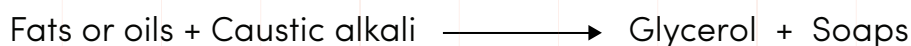


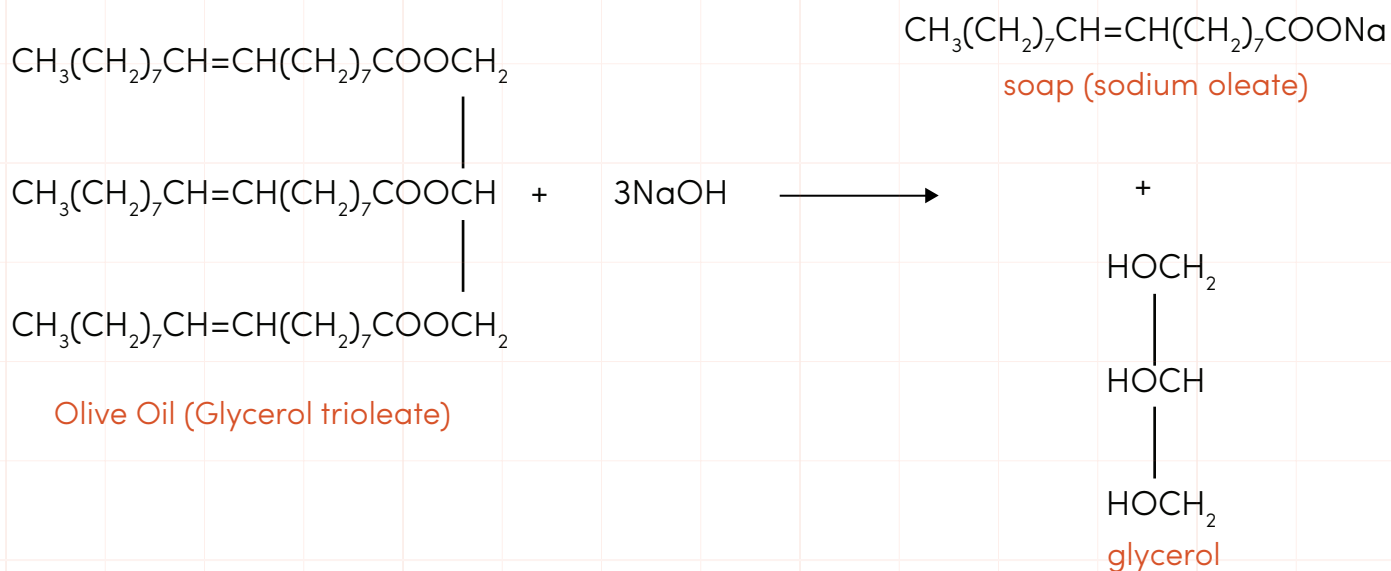
The R groups e.g. R₁, R₂ and R₃ in the fatty acids may be the same or different.



PREPARATION OF SOAP

Saponification is the alkaline hydrolysis of fats and oils to give a mixture of salts of fatty acids (soaps) and propane-1,2,3-triol (glycerol)

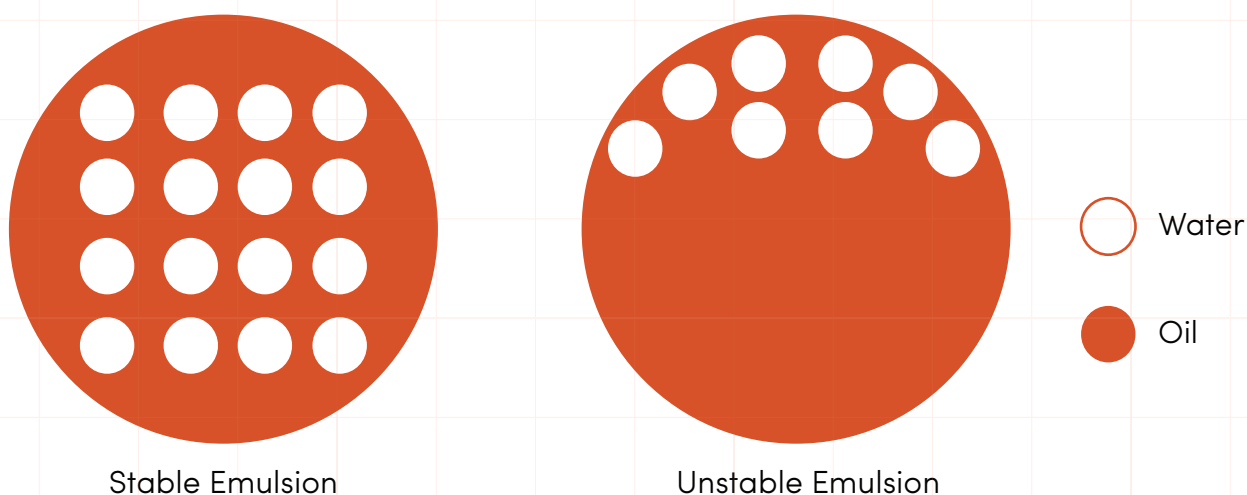


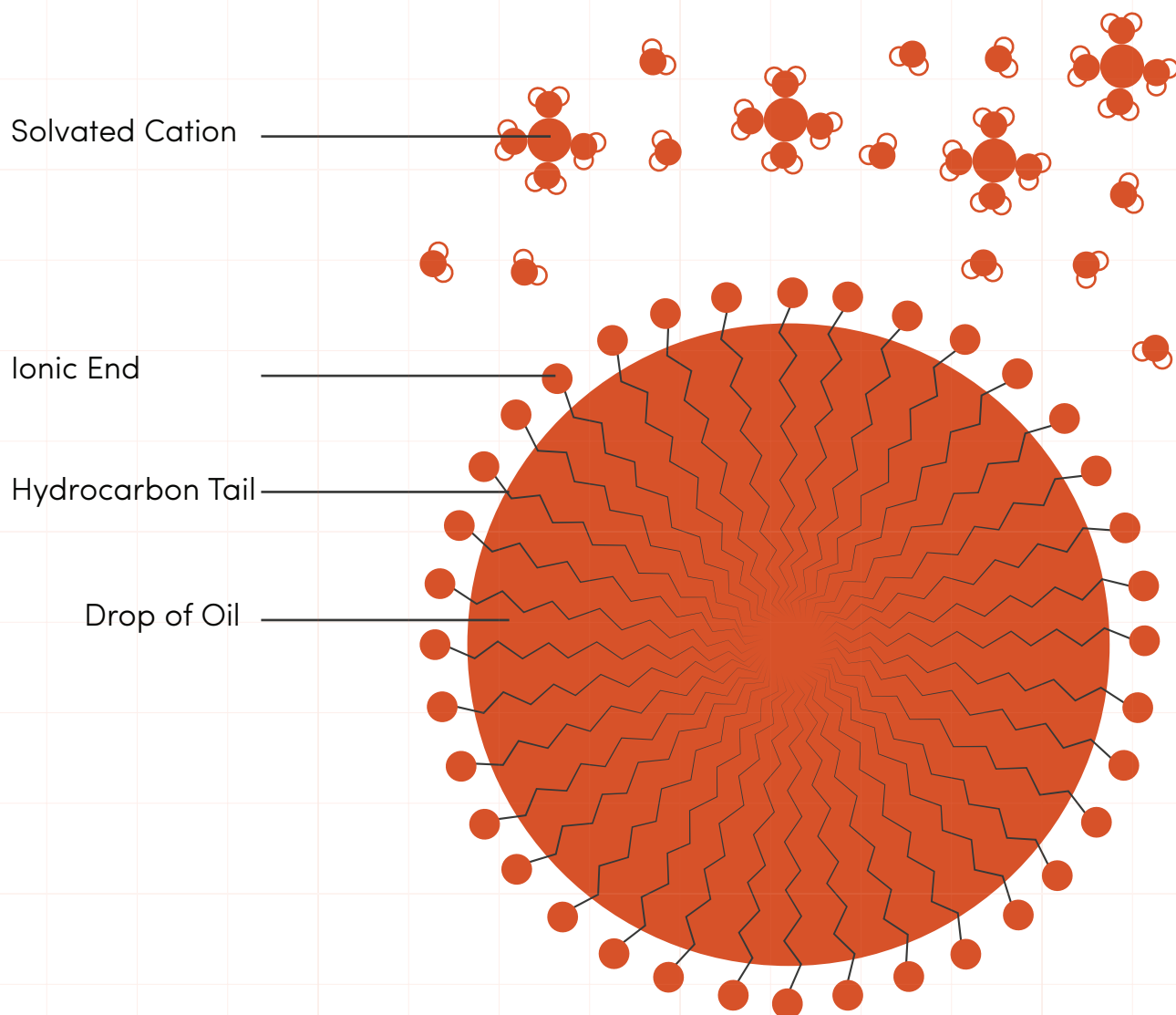


Hard soaps are produced if caustic soda (NaOH) is used for the reaction. Soft or liquid soap is produced if caustic potash (KOH) is used. The fats and oils that can be used for soap making include olive oil, coconut oil, palm kernel oil, palm oil, and goat tallow.

THE ACTION OF SOAP AS AN EMULSIFYING AGENT

If some oil is poured into a beaker of water, the oil will float on the water surface as a separate layer. If the oil-water mixture is shaken vigorously, the oil will be suspended as tiny droplets in the aqueous layer. This is an oil-water emulsion. The emulsion formed in this case is an unstable one. On standing, the droplets will coalesce to form the same oil layer again. If some soap solution is added to the oil-water emulsion, the molecules of the soap gather around each oil droplet. The hydrocarbon chains dissolve in the oil, while the ions project into the surrounding water. Electrostatic repulsion prevents the coalescing of the droplets into larger droplets, thus forming a stable emulsion of oil in water. Soap, therefore, acts as an emulsifying agent





THE CLEANSING ACTION OF SOAP

When a solution of soap is applied to a grease-coated piece of fabric, the soap molecules first approach the grease spot. At the interphase of grease and water, the hydrophilic heads dissolve in the water while the hydrophobic tails of the soap particles dissolve in grease. The water molecules attract the ionic heads of the soap molecules. This action helps to lift the grease spot upwards and enabling more soap particles to dissolve in the grease. Eventually, with mechanical scrubbing, the greased patch is emulsified. On rinsing the fabric, the grease is removed.

DETERGENTS

Detergents are substances that can clean an object. These include soap powders, soap, dishwashing liquids as well as water

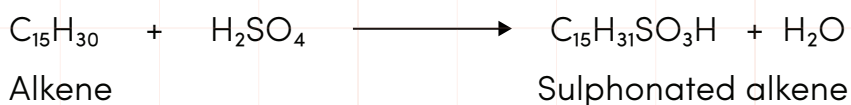
TYPES OF DETERGENTS

1. Soapy detergents: These are soaps. They are the saponification products of fats and oil i.e. the sodium salts of fatty acids.
2. Soapless Detergents: These are better cleaning agents than soap because they are not affected by the hardness of the water.

PREPARATION OF SOAPLESS DETERGENTS

Soapless detergents are synthesized from petroleum products e.g. alkenes having C_{12} to C_{20} atoms in the main chain. Soapless detergents can also be made from benzene and its derivatives.

A long chain alkene is made to react with tetraoxosulphate (VI) acid in the presence of HCl as a catalyst. The sulfonated alkene is treated with sodium hydroxide to form the salt of the sulfated alkene or detergent

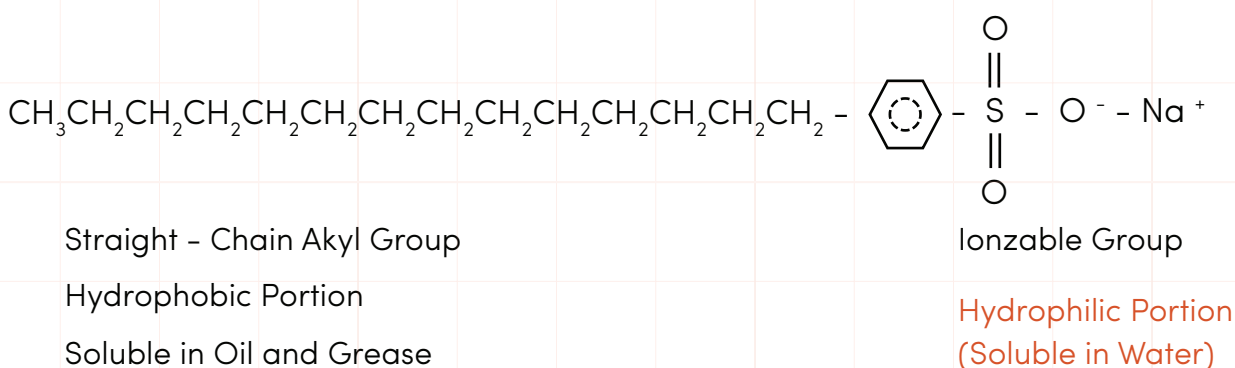


The resulting sulfonated alkene is treated with sodium hydroxide solution to convert it to the sodium salt of the sulfonated alkene, which is the detergent.



STRUCTURE OF DETERGENTS

The detergent molecule has a hydrophilic head and a hydrophobic tail. The presence of $SO_3^- Na^+$ in the molecules of soapless detergents is responsible for their high solubility in water.



Note: Detergent possesses the same cleansing action as that of soap.

DIFFERENCES BETWEEN SOAP AND DETERGENTS

1. Soaps form scum with hard water while detergents are not affected by the hardness of the water.
2. Soap is not as soluble as detergents in water.
3. Soap cannot be well utilized under alkaline and acidic conditions, whereas detergents can be used fully well under such conditions.
4. Soap has a cleansing group of RCOO^- while that of detergents is RSO_3^- .
5. Soap is produced from vegetable oils while detergents are produced from petroleum products.

SUMMARY

So far, we have learnt how to

1. Describe and prepare soap
2. Explain the action of soap as an emulsifying agent.
3. Explain the cleansing action of soap.
4. Define detergent.
5. List the types of soap and prepare detergents.
6. Differentiate between soap and detergents

INTERACTIVE ASSESSMENT QUESTIONS

1. Which of the following is a soapless detergent?

- A $\text{C}_{12}\text{H}_{25}\text{OSO}_3\text{Na}$
- B $\text{C}_{17}\text{H}_{35}\text{COONa}$
- C $\text{C}_6\text{H}_5\text{OH}$
- D $\text{C}_4\text{H}_9\text{COOC}_2\text{H}_5$
- E $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

2. By shaking a detergent solution with -----, an emulsion is produced.

- A Water
- B Palm oil
- C Ethanoic acid
- D Palm wine
- E Sand

3. "Lux" "Omo" washing liquids are all

- A All contain synthetics and oils
- B Emulsifying and curdy agents
- C Detergents
- D Soaps
- E Alkanol

4. The structural component that makes detergent dissolve in quickly in water than soap is

- A $\text{SO}_4^- \text{Na}^+$
- B $\text{COO}^- \text{K}^+$
- C $\text{COO}^- \text{Na}^+$
- D $\text{SO}_3^- \text{Na}^+$
- E $\text{SO}_4^{2-} \text{K}^+$

5. The saponification of alkanoate for the production of soap and alkanol involves

- A Hydrolysis
- B Esterification
- C Dehydration
- D Oxidation
- E Neutralization

6. In the production of soap, concentrated sodium chloride is added to

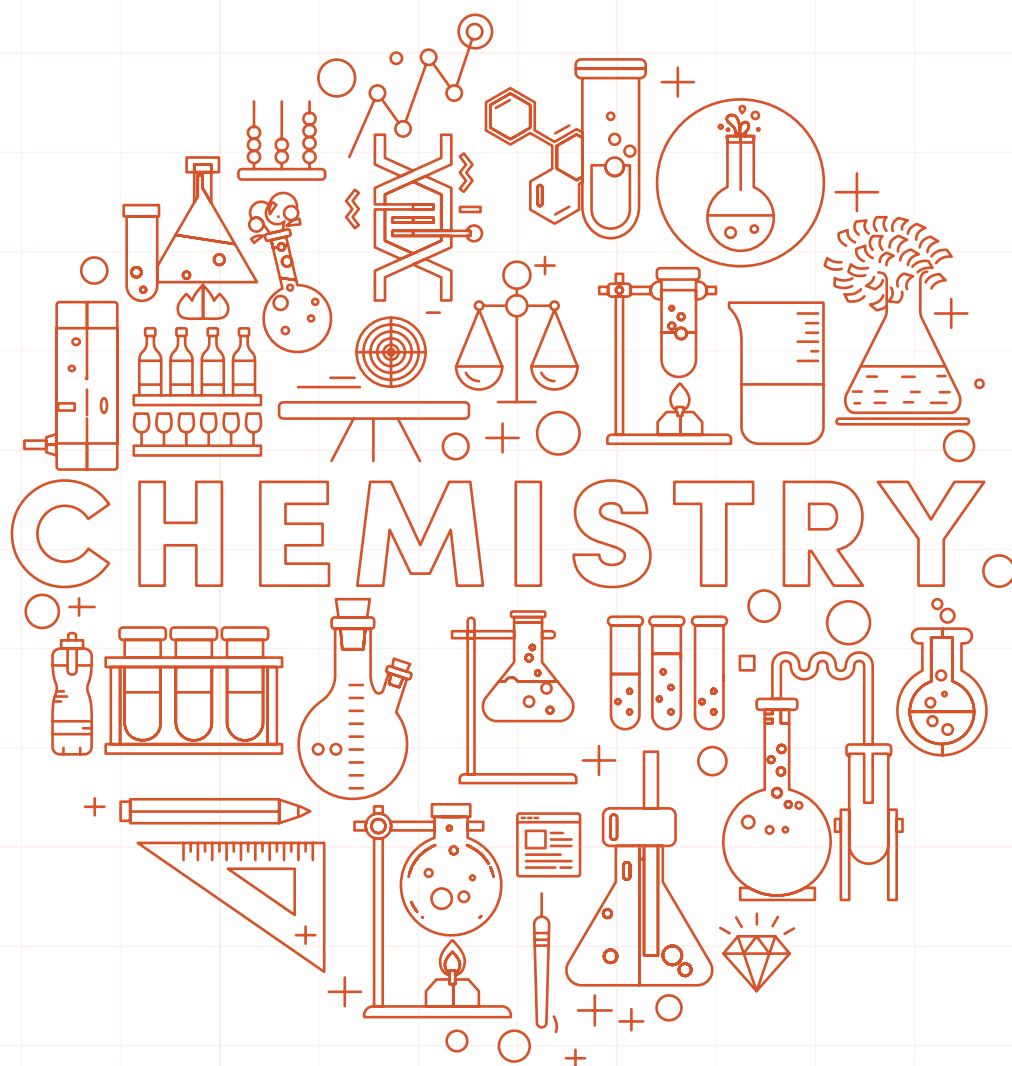
- A Saponify the soap
- B Decrease the solubility of the soap
- C Increase the volume of the soap
- D Increase the solubility of soap
- E Emulsify the soap

GIANT MOLECULES: CARBOHYDRATES

PERFORMANCE OBJECTIVE

1. Describe carbohydrates
2. List the sources of carbohydrates
3. Explain the classes of carbohydrates
4. Describe monosaccharides
5. List examples of monosaccharides
6. Describe and prepare glucose
7. State the properties of glucose
8. Test for glucose
9. Explain the uses of glucose
10. Describe fructose
11. Explain the term 'disaccharides'
12. Describe and prepare sucrose
13. State and explain the chemical properties of sucrose
14. State and explain the physical properties of sucrose
15. Test for sucrose
16. Give the uses of sucrose
17. Differentiate between reducing and non-reducing sugars.
18. Explain the term 'polysaccharides'
19. Describe and prepare sugar.

20. State the physical properties of sugar.
21. Explain the chemical properties of sugar.
22. Test for sugar
23. Give the uses of sugar.



INTRODUCTION

Carbohydrates

Carbohydrates are a family of organic compounds. They contain carbon, hydrogen, and oxygen. They have a general formula of $C_x(H_2O)_y$ or $C_xH_{2y}O_y$. Where x and y are integers (i.e. whole numbers).

Sources of carbohydrates

Rice, bread, cassava, yam, cocoyam, potato etc.

Classes of carbohydrates

Carbohydrates can be classified into

1. Simple sugars; and
2. Complex sugars.

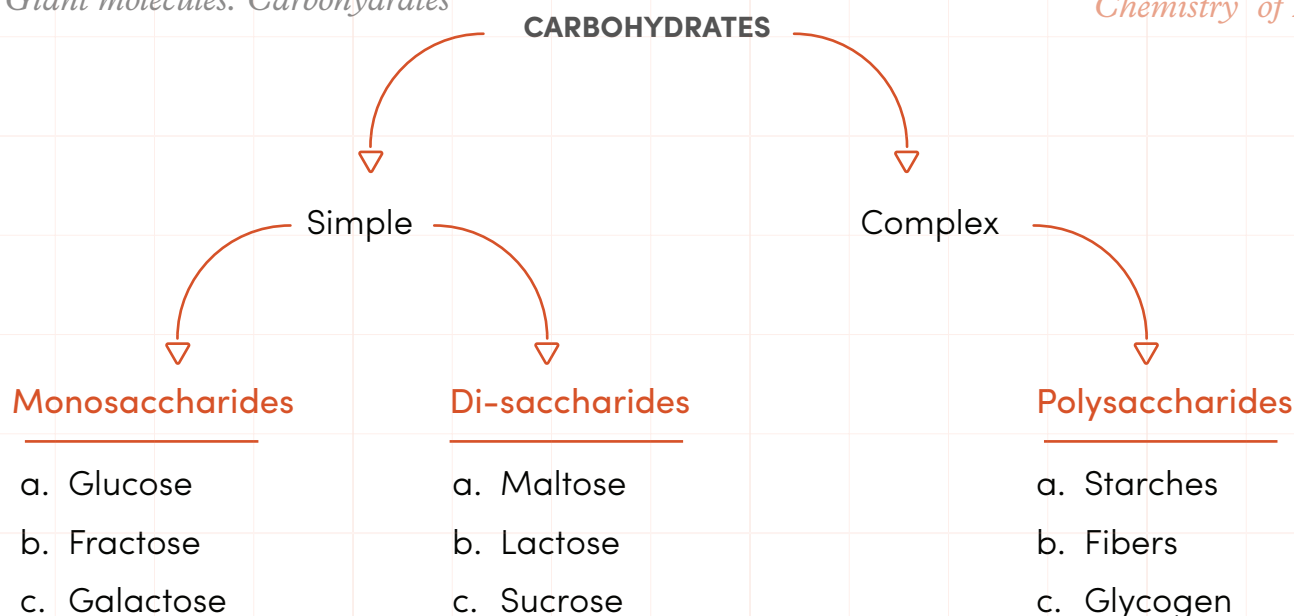
The simple sugars:

These are classified into monosaccharides and disaccharides. The monosaccharides are simple carbohydrates which are crystalline, soluble in water and they have a sweet taste. Some examples of monosaccharides include glucose, fructose, and galactose.

The disaccharides are derived from two molecules of monosaccharides. They are maltose, sucrose, and lactose.

The complex sugars:

These are also known as polysaccharides. They are non-crystalline, insoluble (except in glycogen), and tasteless. Their general molecular formula is $(C_6H_{10}O_5)_n$. Examples of complex sugars are starch and cellulose. They have very high relative molecular masses. They are polymers derived from monosaccharides.



MONOSACCHARIDES

These are the simplest members of the family of carbohydrates. They are simple sugars. They contain three–six carbon atoms per molecule.

They are:

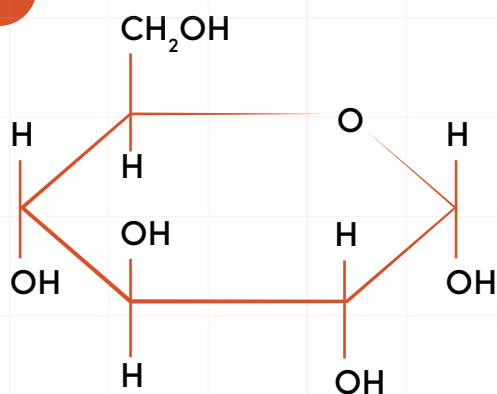
1. trioses with three carbon atoms per molecule.
2. pentoses with five carbon atoms per molecule.
3. hexoses with six carbon atoms per molecules.

The most common and important monosaccharides are the ones containing six carbon atoms per molecule and they are called hexoses. Examples of hexoses are glucose, fructose, mannose, and galactose. All hexoses have the same molecular formula of $C_6H_{12}O_6$ but possess different spatial arrangements.

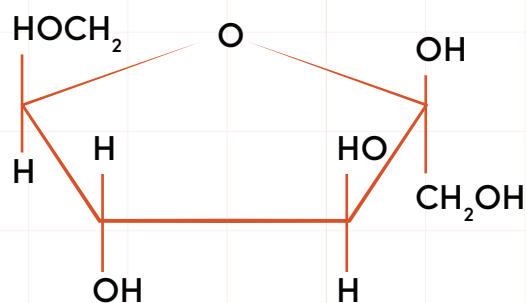
Hexoses exist in both open–chain and cyclic forms in solution. In solid crystals, they exist in the ring form.

Sugars are called aldoses if they contain the alkanol ($-CHO-$) group and ketoses if they have the alkenone ($-CO-$) group. Glucose is known to be an aldose but fructose is a ketose.

A

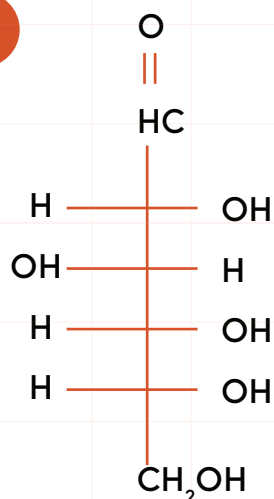


Glucose

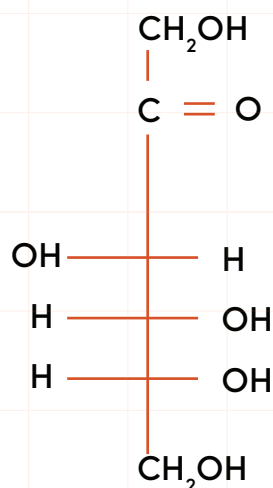


Fructose

B



Glucose



Fructose

Trioses and pentoses are also important monosaccharides. Trioses ($C_3H_6O_3$) are important in muscle metabolism. Examples of trioses are:

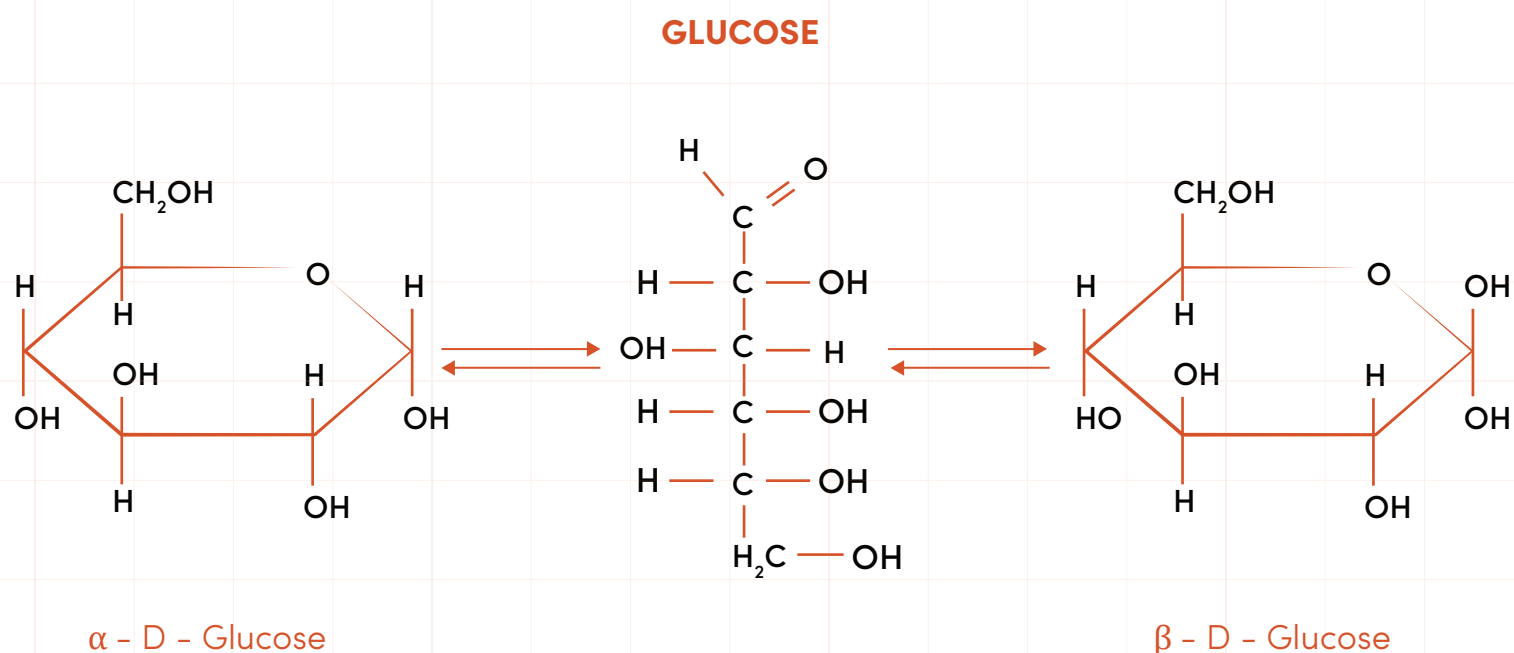
1. 2,3-dihydroxypropanol (glyceraldehyde); and
2. 1,3-dihydroxypropanone (dihydroxyacetone)

EXAMPLES OF IMPORTANT PENTOSES ARE

1. ribose and deoxyribose (important constituents of the cell nuclei);
2. arabinose (obtained from gum Arabic and cherry tree gum); and
3. xylose (obtained from the hydrolysis of wood, straw, and corn cobs).

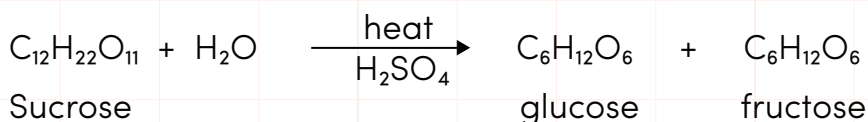
GLUCOSE

Glucose is the most important simple sugar. It is commonly called grape sugar or dextrose. Glucose is present in fruits such as grapes. It is also present in honey and the sap of plants. Little quantity of glucose can also be found in human urine. Glucose is the chief source of energy for animal tissues and is present in the blood of animals. Glucose is synthesized by plants during photosynthesis. Glucose exists in two forms- an open chain and a cyclic form.



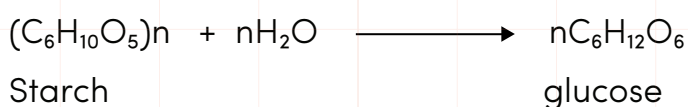
PREPARATION OF GLUCOSE

Glucose is prepared in the laboratory by the hydrolysis of sucrose with dilute tetraoxosulphate (vi) acid in the presence of ethanol.



The ethanol dissolves the fructose but the glucose separates as catalysts and is filtered off.

In the industry, glucose is prepared by the hydrolysis of starch using dilute acid under pressure.

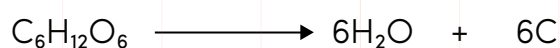


The starch is boiled with dilute tetraoxosulphate (VI) acid for about two hours, replenishing the water as it evaporates.

After hydrolysis, the acid is neutralized by adding the solid sodium trioxocarbonate (IV). The glucose solution is then filtered off, decolorizes with animal charcoal, and concentrated by evaporation. The concentrated solution known as molasses is left to cool and solidify.

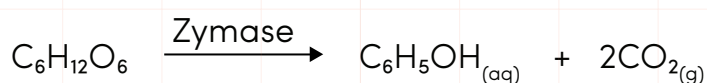
Properties of glucose

1. Glucose is a strong reducing agent because of the presence of $-CHO$ group. It reduces Fehling's solution to a red precipitate of copper (I) oxide on boiling.
2. When glucose is heated with concentrated tetraoxosulphate (VI) acid, a black residue of carbon is formed.



This dehydration reaction with concentrated tetraoxosulphate (VI) acid is characteristic of all carbohydrates.

Glucose solution is readily fermented to ethanol and carbon (iv) oxide by the enzymes.



Test for glucose

Test	Observation	Inference
To the unknown solution, add a few drops of Fehling's solution then heat.	There is a formation of a brick-red precipitate.	The unknown solution is glucose

Uses of glucose

1. Glucose is used in the manufacture of jam and sweets.
2. It is used as an immediate source of energy for sick people and sportsmen.

FRUCTOSE

Fructose is commonly called fruit sugar or laevulose. It is usually found together with glucose in fruit juices and honey. Fructose resembles its isomer, glucose in many ways.

Disaccharides

Disaccharides are produced by the condensation of two molecules of monosaccharides and the elimination of one molecule of water. The two monosaccharides may be the same or different.

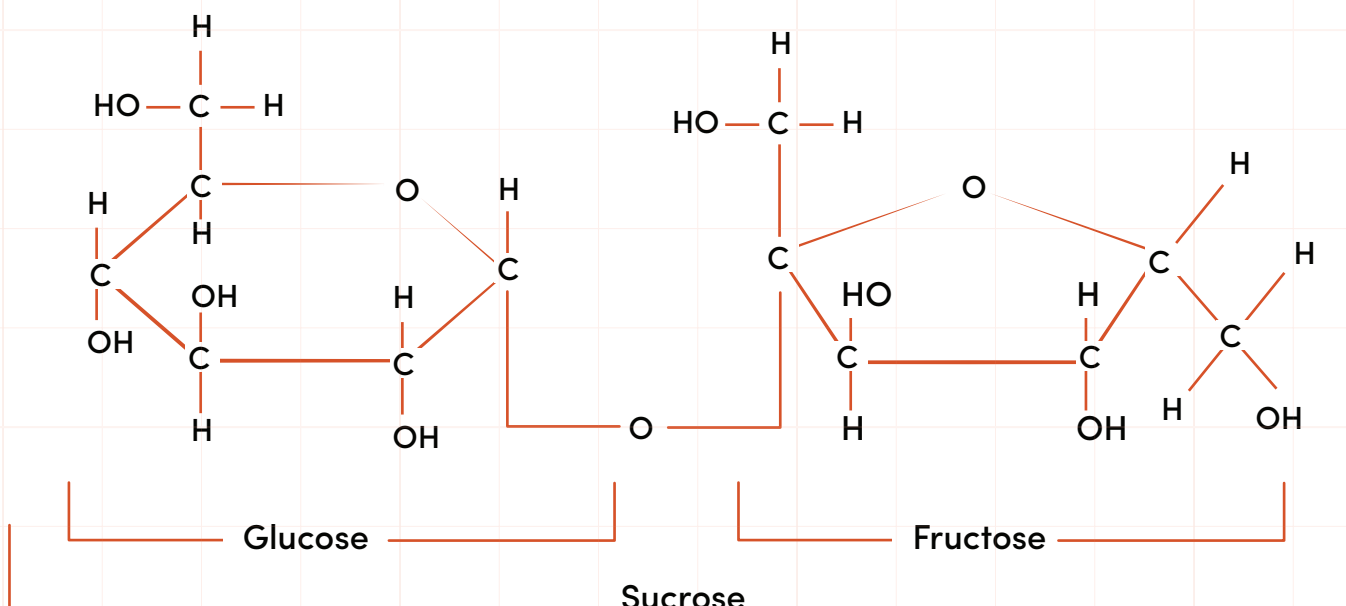
Example

Monosaccharides	Disaccharides
Glucose + fructose	Sucrose (Cane Sugar)
Glucose + galactose	Lactose (Milk sugar)
Glucose + glucose	Maltose (Malt sugar)

SUCROSE

Sucrose is a disaccharide. It is the ordinary sugar we eat every day. It is extracted from the juice of sugar cane. It has a molecular formula of $C_{12}H_{22}O_{11}$.

The structure of sucrose is



PREPARATION OF SUCROSE

Sucrose is prepared from the juice of sugar cane or sugar beet. The juice from the sugar cane or sugar beet is extracted with water warmed to about 80°C. This is followed by the purification by treatment with slaked lime and carbon (IV) oxide.

The purified solution is concentrated by evaporation. On cooling, the concentrated solution, brown crystals of impure sugar separate. The remaining liquids called molasses still contain a reasonable amount of sugar and is used for ethanol production by fermentation.

The brown sugar is refined by treatment with slaked lime and carbon (iv) oxide and decolorized with carbon (IV) oxide.

PHYSICAL PROPERTIES OF SUCROSE

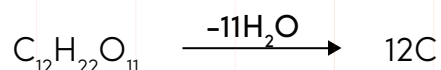
1. Sucrose is a colourless crystalline solid with a very sweet taste.
2. It does not dissolve in ethanol but dissolves readily in water.

CHEMICAL PROPERTIES OF SUCROSE

1. When sucrose is boiled with dilute tetraoxosulphate (VI) acid or hydrochloric acid, it is hydrolyzed to an equal mixture of glucose and fructose. This reaction is known as inversion. It can be affected by the enzyme invertase obtained from yeast.

Sucrose + water \longrightarrow glucose + fructose.

2. Sucrose does not have any carbonyl group, so it is not a reducing sugar. It does not have any positive effect on Fehling's solution.
3. Sucrose chars on strong heating or warming with concentrated tetraoxosulphate (VI) acid.



4. When sucrose is heated to a temperature of about 210°C, a yellowish-brown substance called caramel is obtained.

Test for sucrose

Test	Observation	Inference
To 1cm ³ of the unknown solution, add selivanoff reagent, then warm in a water bath.	The mixture turns red after 10 minutes.	The unknown solution is sucrose.

USES OF SUCROSE

1. Sucrose is used for sweetening foods.
2. It is used for food preservation.
3. Caramel is used for flavouring and in fermentation.
4. Sucrose is used for the production of ethanol by fermentation.

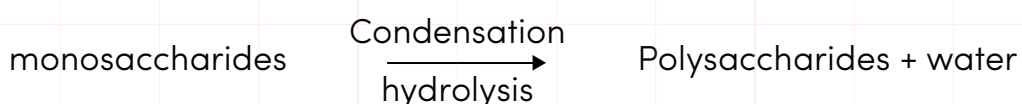
REDUCING AND NON-REDUCING SUGARS

Sugars are classified into reducing sugars and non-reducing sugars. Reducing sugars can be subdivided into monosaccharides e.g. glucose, fructose, galactose, mannose, etc., and disaccharides e.g. maltose, lactose, etc. Sucrose is a non-reducing sugar,

POLYSACCHARIDES

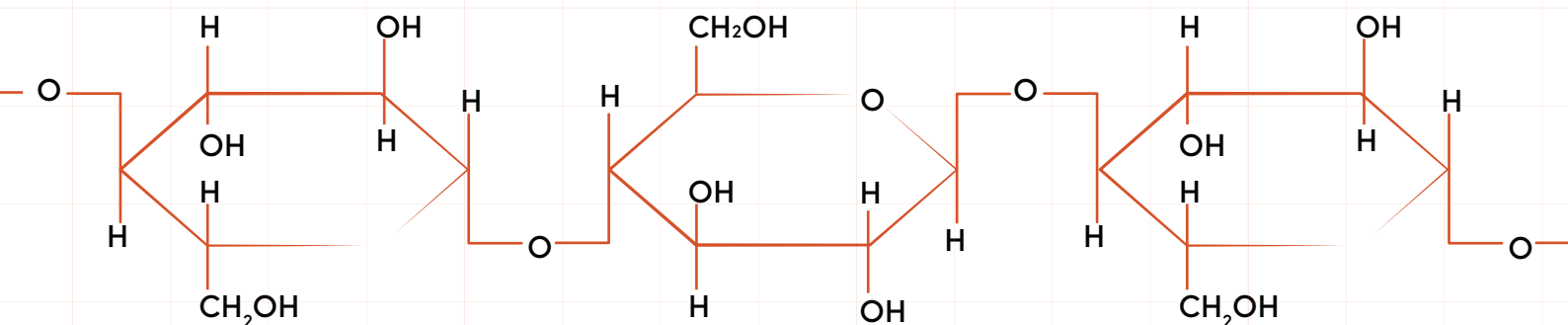
Polysaccharides are a group of carbohydrates that are composed of very long chains of monosaccharides linked together by condensation (i.e. by the elimination of one molecule of water for every bond formed between two monosaccharide molecules. The general molecular formula of polysaccharides is $(C_6H_{10}O_5)_n$ where n is a large number. Polysaccharides are polymers of hexoses.

Examples of polysaccharides are cellulose, starch, glycogen, and inulin. Polysaccharides can be hydrolyzed step by step with dilute acids to yield the component monosaccharides as the final products.



STARCH

Starch occurs naturally in most plants as a storage carbohydrate e.g. maize (corn), cassava, yam and cocoyam tubers, potatoes, rice, wheat, barley, and other cereals. The molecular formula of starch is $(C_6H_{10}O_5)_n$. Its structure consists of many units of a glucose molecule.



PREPARATION OF STARCH

The raw materials (e.g. potato or cassava tubers) are peeled and then crushed to break the plant cells and release the starch granules. Water is then mixed with the crushed pulp to extract the starch. This forms suspension which will be allowed to stand for some time, leaving behind the white starch residue, and the water above is decanted.

PHYSICAL PROPERTIES OF STARCH

1. Starch is a white odourless, tasteless powder.
2. Starch is insoluble in cold water but soluble in hot water to form a viscous solution
Which sets into jelly on cooling.

CHEMICAL PROPERTIES OF STARCH

1. Starch gives a characteristic deep blue colour with iodine solution.
2. Hot dilute acids hydrolyze starch into glucose and maltose.
3. Starch does not reduce Fehling's solution
4. starch decomposes when heated in the presence of the enzyme diastase to produce maltose sugar

Test for starch

Test	Observation	Inference
To the unknown substance, add a few drops of Iodine solution, then heat the mixture.	Formation of a dark-blue colouration which disappears on heating and re-appears on cooling.	The unknown substance is starch.

USES OF STARCH

1. Starch is mainly used as food.
2. It is used for stiffening linen.
3. It is used for the production of ethanol and glucose.

SUMMARY

So far, we have learnt how to

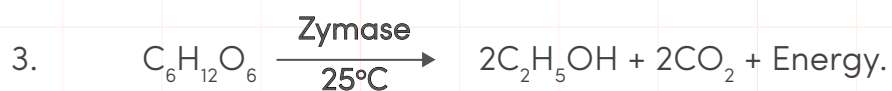
1. Describe carbohydrates
2. List the sources of carbohydrates
3. Explain the classes of carbohydrates
4. Describe monosaccharides
5. List examples of monosaccharides
6. Describe and prepare glucose
7. State the properties of glucose
8. Test for glucose and explain its uses.
9. Describe fructose
10. Explain the term 'disaccharides'
11. Describe and prepare sucrose

12. State and explain the chemical and physical properties of sucrose
13. Test for sucrose and give its uses
14. Differentiate between reducing and non-reducing sugars.
15. Explain the term 'polysaccharides'
16. Describe and prepare sugar
17. State the physical properties of sugar
18. Explain the chemical properties of sugar
19. Test for sugar and list its uses

INTERACTIVE ASSESSMENT QUESTIONS

1. The following are hexoses except,
 - A Glucose
 - B Cellulose
 - C Fructose
 - D Galactose
 - E Mannose

2. Glucose will be dehydrated to _____ if it is heated with concentrated tetraoxosulphate (VI) acid
 - A Carbon
 - B Carbon (IV) oxide
 - C Ethene
 - D Ethanol
 - E Ethanoic acid



The reaction represented by the equation above is useful in the production of

- A Ethanol
- B Propanol
- C Butanol
- D Methanol
- E Pentanol

4. Cellulose and starch can be classified as one of the following

- A Sugars
- B Sucrose
- C Hydrocarbons
- D Carbohydrates
- E Isomers

5. An example of a polysaccharide is

- A Dextrose
- B Starch
- C Glucose
- D Mannose
- E Fructose

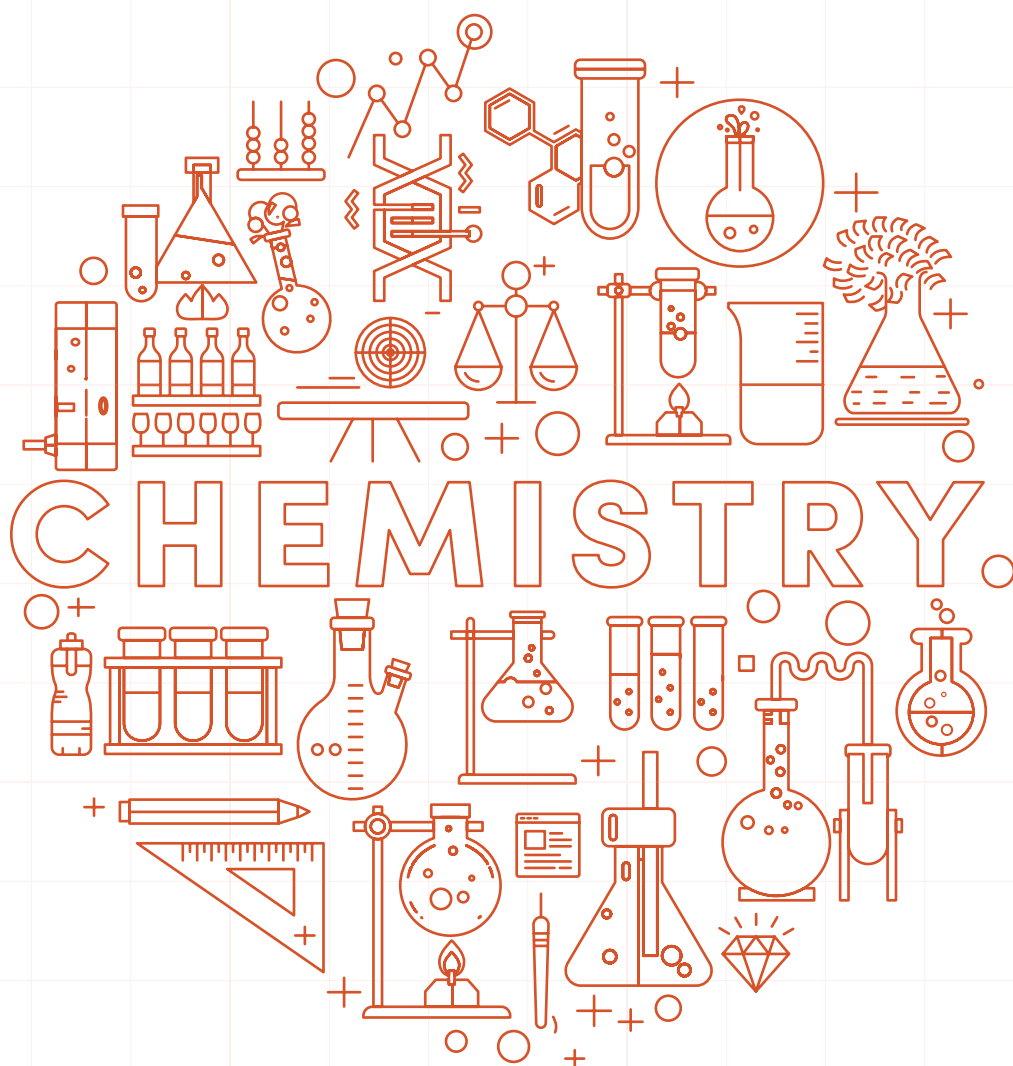
6. Sucrose is made up of

- A Glucose and glucose
- B Fructose and fructose
- C Galactose and glucose
- D Glucose and fructose
- E Fructose and galactose

GIANT MOLECULES: PROTEIN

PERFORMANCE OBJECTIVE

1. Define protein.
2. Give some examples of protein and list its composition
3. Define amino-acids.
4. Give the IUPAC name of some amino-acids
5. List the two classes of protein and give some of its sources
6. Explain one physical and one chemical property of protein
7. Test for protein and list some of its uses



INTRODUCTION PROTEINS

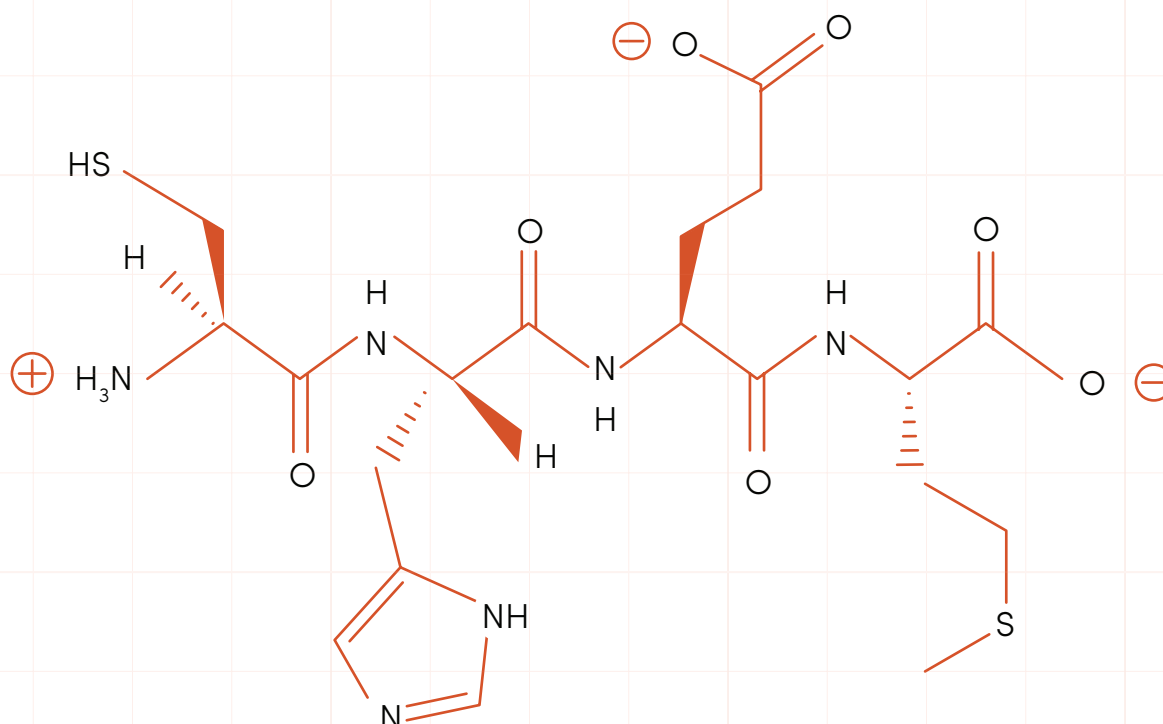
Proteins may be regarded as the products of successive condensation between the amino group of amino acid and the carbonyl group of another amino acid. proteins are complex combinations of amino acids which are essential constituents of living cells, being responsible for the growth and the maintenance of all tissues.

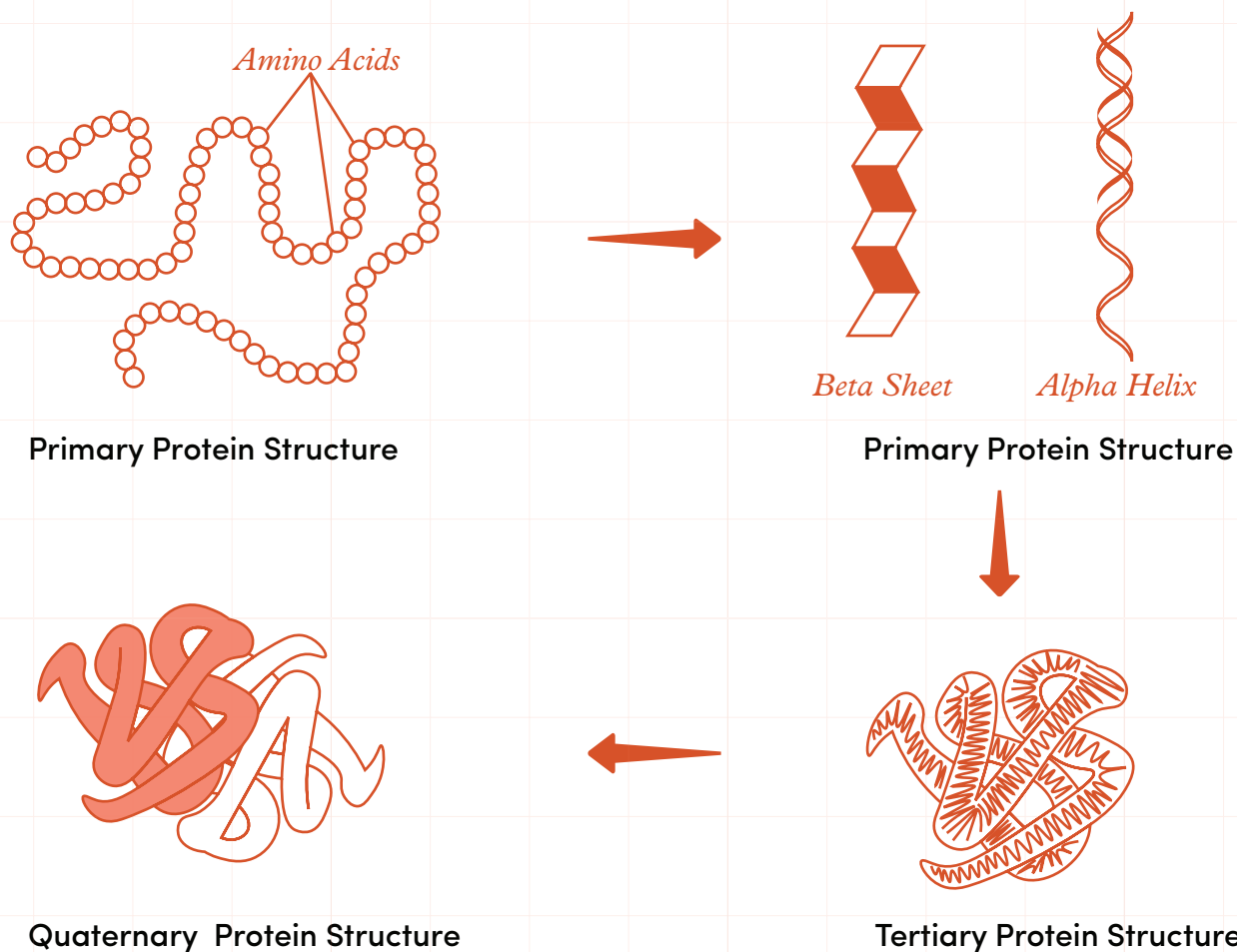
EXAMPLES OF PROTEINS

1. Insulin (a hormone)
2. Haemoglobin (oxygen-carrying pigment in blood),
3. Ribonuclease (an enzyme), and
4. Collagen (a muscle protein)

COMPOSITION OF PROTEINS.

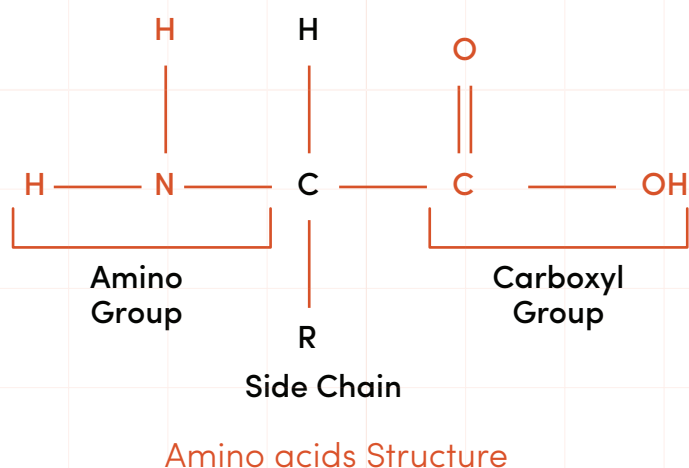
Protein contains carbon, hydrogen, oxygen, nitrogen, and sometimes phosphorus and sulphur



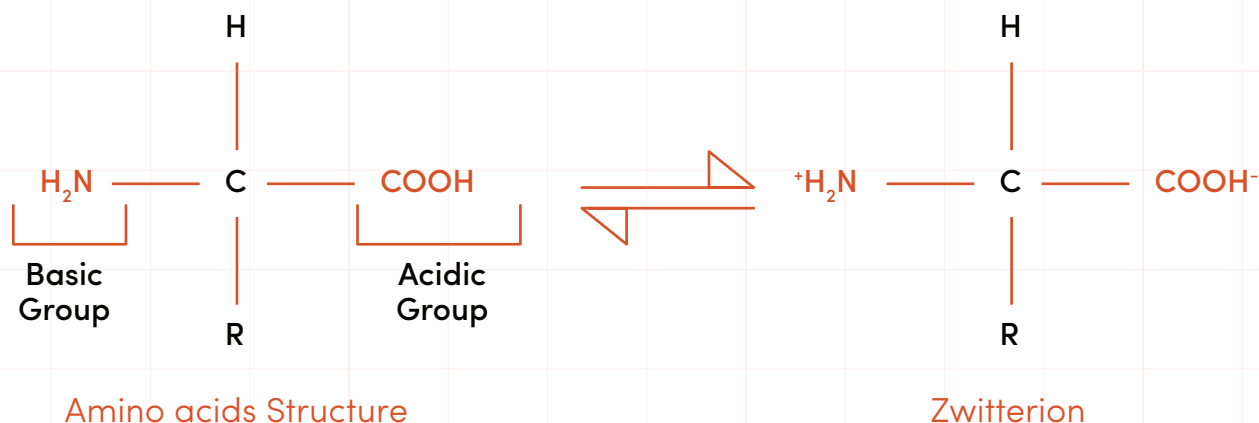


AMINO-ACIDS

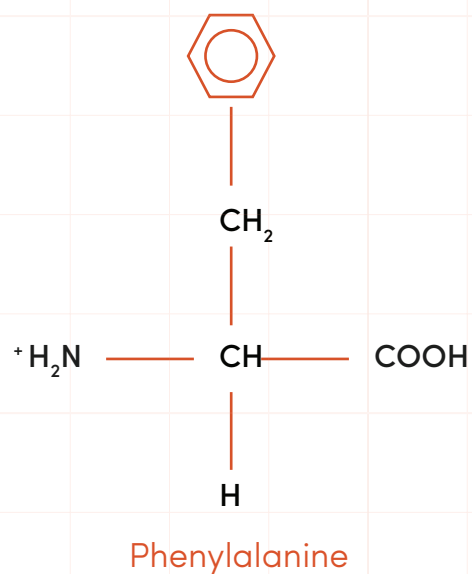
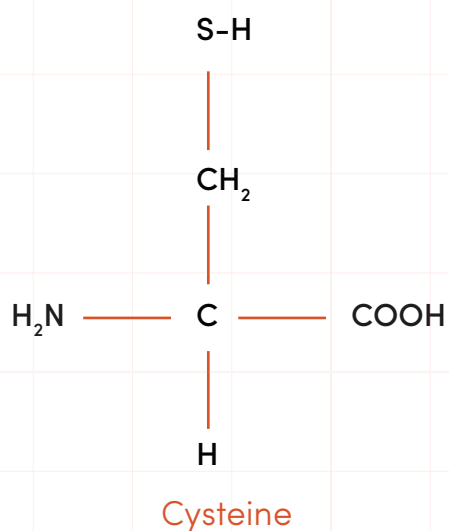
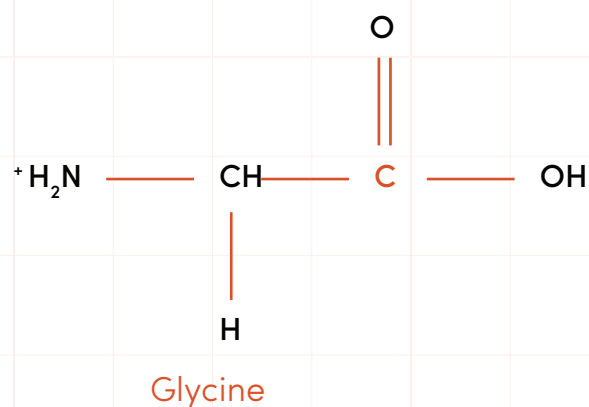
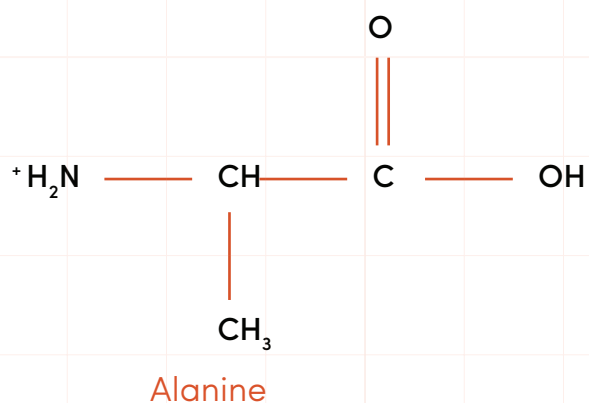
Amino acids are the basic structural units of proteins. Each amino acid contains an amino group ($-\text{NH}_2$) and a carboxyl group ($-\text{COOH}$) in its molecule. Its general structure is as follows:



The carbon atom of the amino acid to which the functional groups are attached is known as α -carbon. In a neutral solution, amino acids are in the form of dipolar



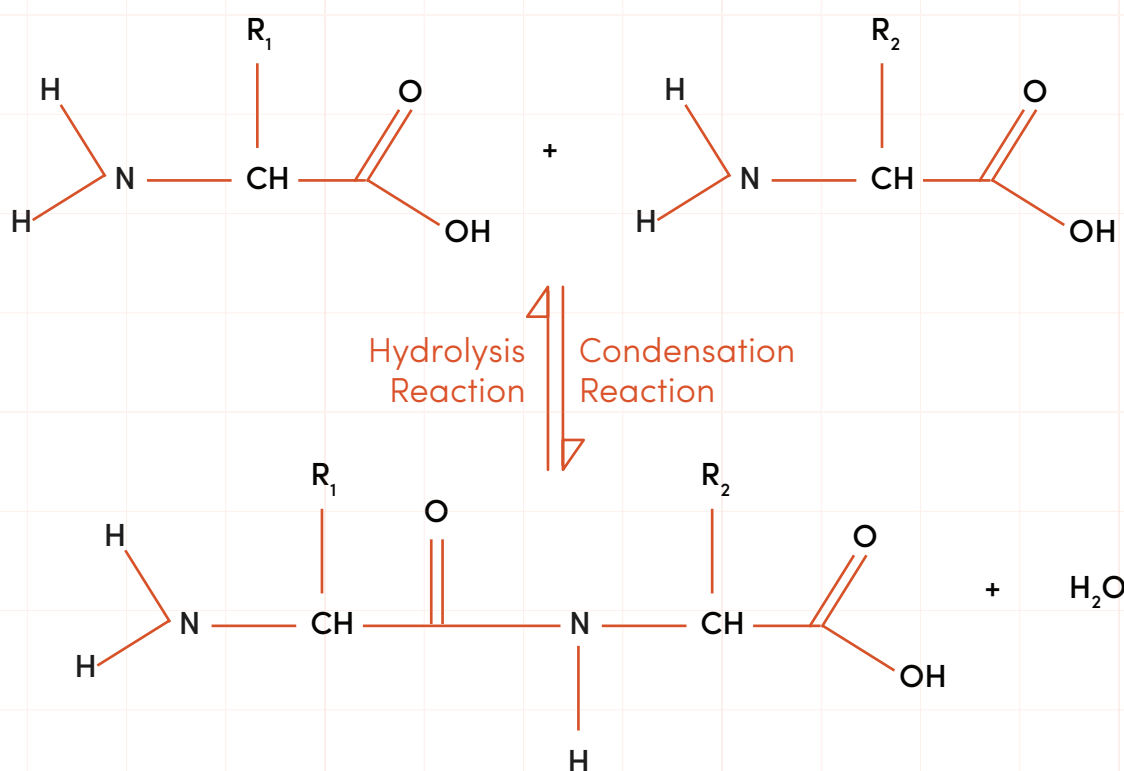
There are twenty naturally occurring amino acids. All proteins found in living organisms are combinations of these amino-acids. Some of these amino acids are called essential amino acids because they cannot be synthesized in our body. Therefore, these amino acids must be present in our dietary proteins. Some examples of amino acids are as follows:



PEPTIDES

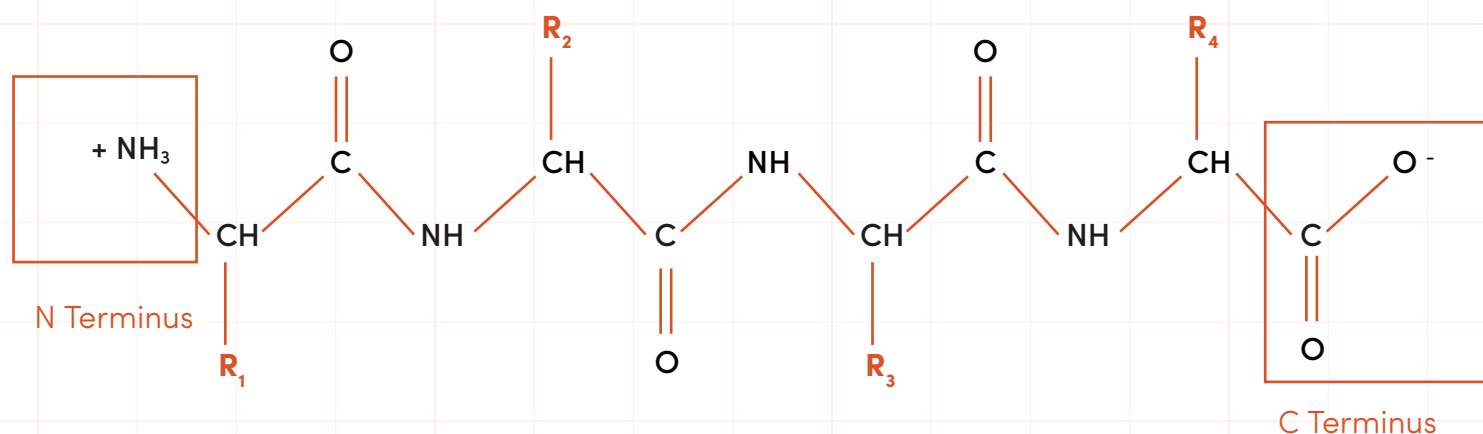
Peptides are amides formed by the interaction between carboxyl groups and amino groups. The bond joining the α -amino group of one amino acid and the α -carboxyl group of another amino acid is known as a peptide bond.

Two amino acids react to form a dipeptide; three amino acids form tripeptide; and so on.



If some amino acids are linked by peptide bonds, a polypeptide is formed. A polypeptide chain has a carboxyl end and an amino end. It consists of a regular repeating part or main chain and a variable part (indicated by **R**) or side chain.

NOTE: R will be different depending on the amino acids which make up the polypeptide.



OCCURRENCE OF PROTEINS

Proteins in our food are classified into first-class proteins and the second class proteins. The first-class proteins: These contain essential amino acids. They are mainly of animal origin. Examples are meat, fish, eggs, milk, and cheese.

The second class proteins are vegetables which are found in vegetables such as peas and beans.

Sources Of Protein: Milk, Egg, Fish, Meat, Chicken, Cheese. While plant sources are: Beans, groundnut, soya beans, cowpea e.t.c

THE PHYSICAL PROPERTY OF PROTEINS

Denaturation: When proteins are exposed to drastic conditions such as high temperature (above 40°C), extreme pH, and chemical reagents, they tend to lose biological activity and undergo other changes in properties. This is due to irreversible changes in the molecular shapes of the proteins and the protein is said to be denatured.

THE CHEMICAL PROPERTY OF PROTEINS

Hydrolysis: Proteins can be hydrolyzed to give amino acid by boiling them with solutions of hydrochloric acid or sodium hydroxide. Hydrolysis can also be carried out by using suitable enzymes. Proteins undergo some specific confirmatory tests.

Test for Proteins

1. Biuret Test

Test	Observation	Inference
Add about 1cm^3 of dilute caustic soda solution into a test tube containing some dilute egg white solution. Then add 1% copper(II) tetraoxosulphate(vi) solution drop by drop and shake thoroughly.	There is a formation of a violet colouration.	This confirms the presence of protein.

2. Million's Test

Test	Observation	Inference
Add a few drops of million's reagent to some egg-white solution in a test tube	A white precipitate is formed. The white precipitate formed turns brick – red on heating.	This shows the presence of protein.

3. Trioxonitrate (v) acid test

Test	Observation	Inference
Add a few drops of concentrated hydrogen trioxonitrate(v) acid to 2cm^3 of egg – white solution.	There is a formation of a yellow colouration.	This shows that protein is present

USES OF PROTEIN

1. Proteins is needed in the growth of young ones
2. It is used for repairing worn-out tissues or cells
3. Protein aids reproduction
4. It is used to produce enzymes
5. It is also used for the production of hormones
6. It is used for tissue and cell formation (bodybuilding).

SUMMARY

So far, we have learnt how to

1. Define protein.
2. Give some examples of protein and list its composition
3. Define amino-acids.
4. Give the IUPAC name of some amino-acids
5. List the two classes of protein and give some of its sources
6. Explain one physical and one chemical property of protein
7. Test for protein and list some of its uses

INTERACTIVE ASSESSMENT QUESTIONS

1. Proteins in acid solution undergo
 - A Substitution
 - B Fermentation
 - C Hydrolysis
 - D Polymerization
 - E Neutralization
2. Amino acids are obtained from proteins by
 - A Hydrolysis
 - B Oxidation
 - C Polymerization
 - D Reduction
 - E Heating

3. When protein is heated to a high temperature it undergoes
- A Condensation
 - B Denaturation
 - C Hydrolysis
 - D Polymerization
 - E Neutralization
4. The following are examples of protein except?
- A Haemoglobin
 - B Sucrose
 - C Collagen
 - D Insulin
 - E Ribonucleus
5. Sources of proteins include the following except
- A Rice
 - B Fish
 - C Milk
 - D Cheese
 - E Meat
6. What is observed when a millon's reagent is treated with an egg-white solution in a test-tube.
- A A blue precipitate is formed
 - B A green precipitate is formed
 - C A yellow precipitate is formed
 - D A formation of a white precipitate which turns brick-red on heating.
 - E Formation of a black precipitate which turns white after a while



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