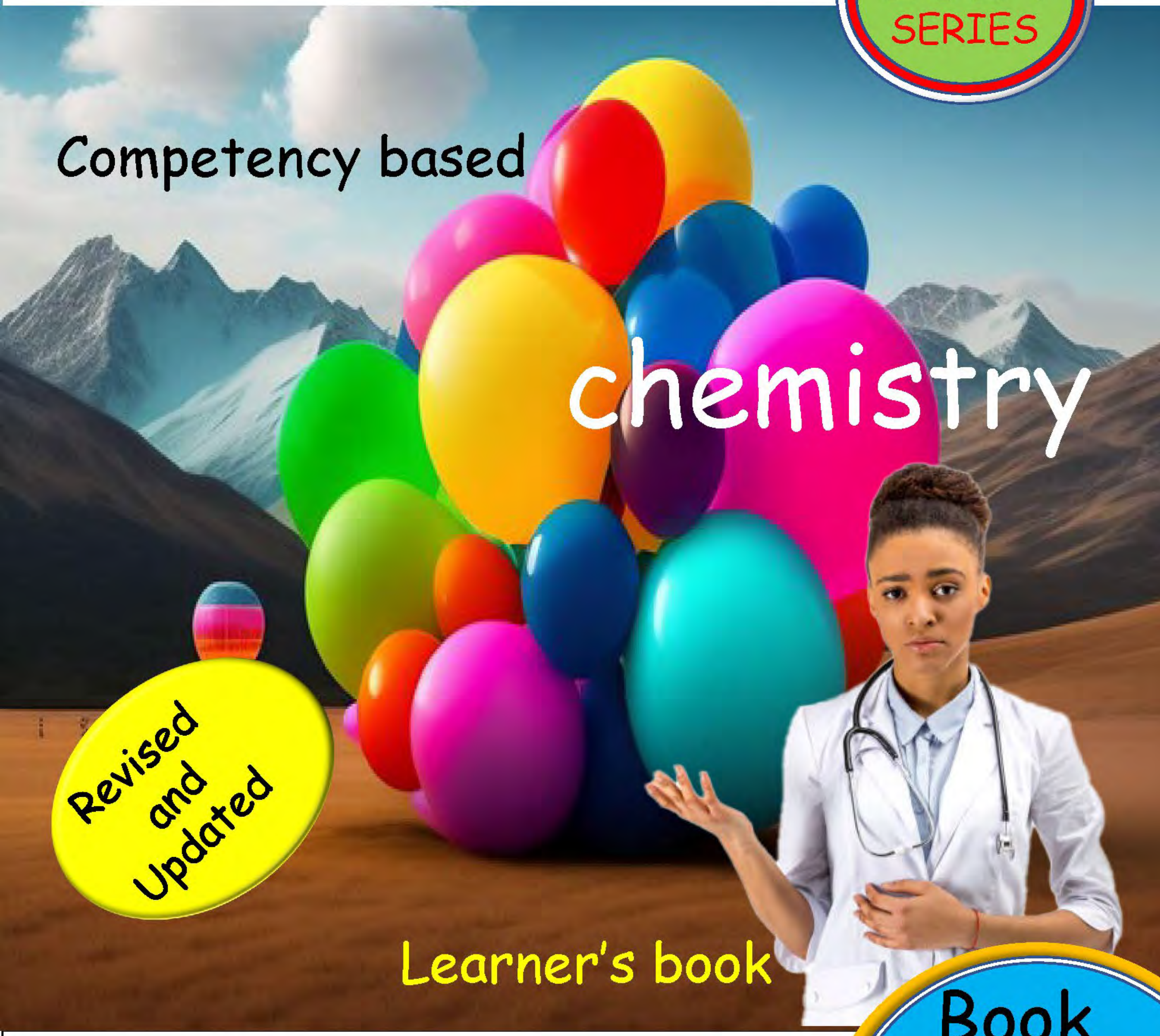
UTTERMOST

Harroan Uttermost

2024 SERIES



Competency based

chemistry

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Book 3

Unlock your full competency potential

2024 Series

HARROAN-UTTERMOST

chemistry S3

New curriculum learner's book for s.3

Student's information.

This book belongs to:

Name ....

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Chapter one

Carbon in life

By the end of this chapter, you should be able to;

- Classify carbon compounds into groups
- Understand that the environment contains a variety of carbon compounds
- Show practically that a material contains carbon
- Explain the importance of organic compounds in daily life
- Name hydrocarbons using the IUPAC nomenclature system.
- Draw and name structures of organic compounds
- Understand the process of making soapy detergents
- Understand how ethanol is made

1.1 Diversity of carbon compounds

Key question: How can you show that a material contains carbon?

Introduction.

The environment consists of several substances which are made from organic compounds. Plants, animals, plastics, textiles, and drugs are examples of substances which are organic. The knowledge of organic chemistry helps to understand how these substances are made. The major constituent elements of organic compounds are carbon and hydrogen. Other important elements commonly found in organic compounds include oxygen, nitrogen, sulphur, phosphorus, halogens, and few metals such as magnesium and lithium. It should be noted that not all carbon containing compounds are organic; some compounds such as carbon dioxide, carbides, hydrogen carbonates, and carbonates are inorganic. In this chapter, you will learn about the concept of organic chemistry, and basic descriptions of hydrocarbons, alcohols, and carboxylic acids.

Classifying carbon-based compounds

A huge number of chemical compounds are known. Just as biologists group plants and animals to show their fundamental similarities, Chemists group carbon-based compounds to show patterns and trends in the physical and chemical properties of substances. Until the 19th century, chemists classified compounds basing on their sources as organic and inorganic. They classified compounds obtained from living organisms as organic compounds and compounds obtained from constituents of the earth (minerals) as inorganic compounds

Friedrich Wohler

The term "organic" was originally used by chemists of the 18th century to describe compounds obtained from living sources (plants and animals). These chemists believed that nature possessed a certain force which occurs only in living things. According to their thought, only living things could produce organic compounds. This believe was disproved in 1828 by Friedrich Wohler, a German Chemist who prepared urea, an organic compound from the reaction between solutions of inorganic compounds ammonium chloride and silver cyanate.

Today, organic chemistry is defined as the study of carbon containing compounds except oxides of carbon, metal carbides, carbonates, and cyanides. Nearly all compounds found in living organisms are organic. Besides this, the vast majority of compounds encountered in our daily lives are organic. Inorganic chemistry is the study of non – carbon containing compounds and oxides of carbon, carbonates, hydro carbonates, metal carbides and cyanides.

The name carbon is derived from the Latin word "carbo" meaning coal. Carbon is found in nature in free state as well as compound state. Carbon in free state is found as graphite and diamond and in combined state as;

- carbon dioxide
- carbonates such as calcium carbonate
- fossil fuels such as coal, petroleum, natural gas
- natural fibers such as cotton, wool, silk
- carbonaceous nutrients such as carbohydrates


Diamond


Graphite rod


Carbohydrates


Cotton

In the earth's crust, carbon is present to the extent of approximately 0.27% in the form of carbonate, coal, petroleum. In the atmosphere, the proportion of carbon in the form of carbon dioxide is approximately 0.03%. some types of plants which grow on the ocean floor convert carbon in marine water into calcium carbonate

Group activity:

Group activity: **showing that materials we use in everyday life contain carbon.**

1. carry out the activity below to show the presence of carbon in common materials and substances.

What you need: Heat source, plastic bottles, sugar, cotton wool, dry leaves, seeds, maize flour, test tubes, spatula and test tube holders

Caution; Be careful when using the heat source such that you don't burn yourself.

What to do:

- Put part of each of the materials in separate test tubes.
- Heat each test tube and observe the changes in the substances. Use a test tube holder to hold the test tube when heating. For a piece of a plastic bottle, you can heat directly without placing it in a test tube. Use a pair of tongs when holding the plastic.
- Observe what happens when heating each of the substance

TASK;

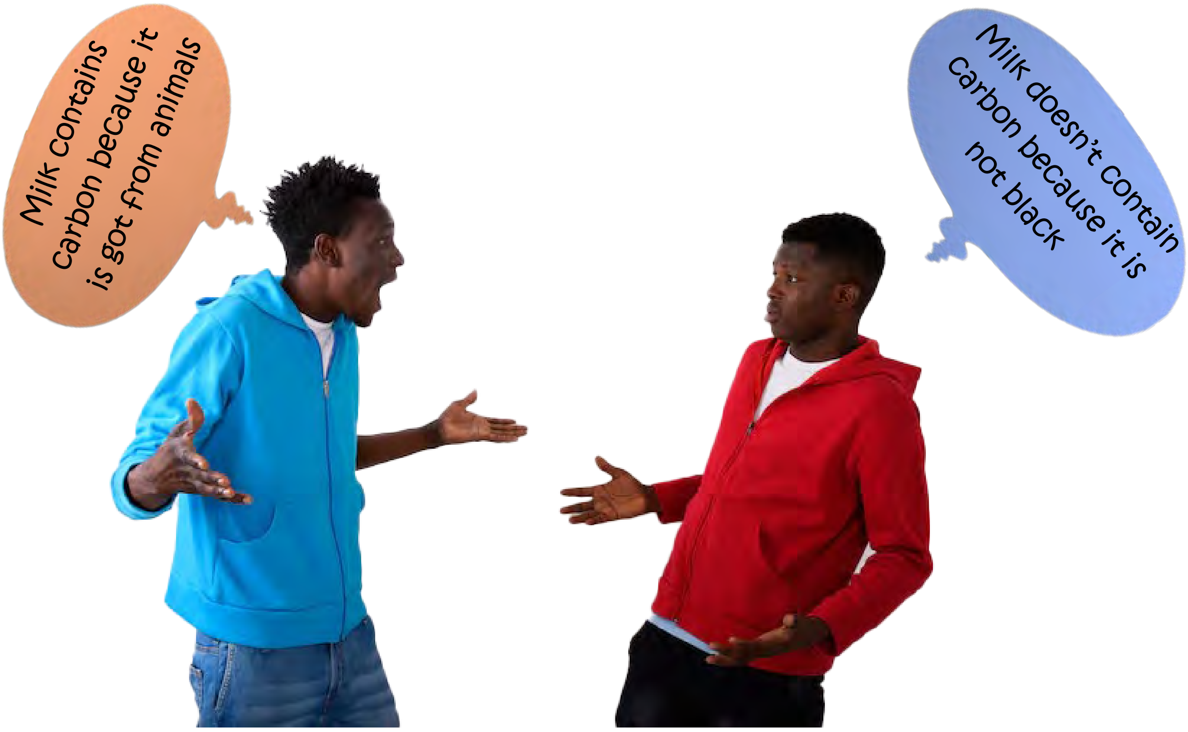
a) Draw a table on the answer space provided showing the name of materials and observations. Fill in the observations for each material.

b) Outline the similarity from burning different materials

c) What conclusion can you make from your observations.

Use your brain power!

Two of your siblings are having an argument about the composition of milk. One says milk contains carbon and another says milk doesn't contain carbon.



By using a practical scientific approach, how would you end their argument? Hint: use the scientific method (come up with a hypothesis and test it). Write your report in the answer space provided.

1.2 Importance of organic chemistry

Key question: How is organic chemistry important in daily life?

Concept of organic chemistry

Many organic compounds are found in the environment where they were formed as a result of various chemical reactions. The study of organic chemistry involves preparation methods, structures, properties, composition, and reactions of organic compounds. More than three quarters of the global compounds contain carbon. Carbon is unique in its chemical properties as it can form many compounds due to its ability to catenate and forms multiple bonds which are single, double, and triple bonds. *Catenation* is the bonding of atoms of the same element to form a chain. Carbon forms stable bonds with itself and other elements. It can make straight chains and branched chains. Carbon can form simple and complex molecules that contain many numbers of carbon atoms.

Substances made from organic compounds

Organic compounds include different types of substances such as oils, dyes, pharmaceuticals, papers, inks, paints, plastics, fuels, rubbers, and textiles. These substances can be grouped into different categories based on their sources as follows:

- Those derived from fossil fuels such as petroleum, coal and natural gas.
- Those derived from plants such as carbohydrates, oils, vitamins, textiles, and rubbers.
- Those derived from animals such as proteins and fats.

Organic compounds can also be categorised as natural and synthetic compounds. Natural organic compounds are those which occur naturally, such as carbohydrates, essential oils, and coal. Synthetic organic compounds are man made compounds such as plastics and dyes.

Substances made from organic compounds

Differences between organic chemistry and inorganic chemistry

Organic compounds	Inorganic compounds
Most organic compounds contain carbon-hydrogen bond(s) with the exception of some compounds such as carbon tetrachloride, and urea,	Inorganic compounds include compounds that lack carbon-hydrogen bond(s) such as carbonates, sulphates, oxides, hydroxides, and chlorides.

Most of the organic compounds are covalent in nature.	They can be covalent or ionic in nature.
Have low melting and boiling points.	Most have high melting and boiling points except gases.
There are many classes based on functional groups such as alkanes, alkenes, alkynes, and alcohols.	They exist in few classes only as salts, acids or bases.
They are soluble in organic solvents such as benzene, cyclohexane, alcohol, and ethers.	They are mostly soluble in water and other inorganic solvents such as ammonia, sulphuric acid, and nitric acid.
They are poor conductors of heat and electricity.	Most of them are good conductors of heat and electricity.
Reactions of most organic compounds generally proceed slowly.	Reactions of most inorganic compounds are generally fast.

Importance of organic chemistry

Organic chemistry is important both in life and in industrial processes. The following are some areas where organic chemistry is applied.

- **Body anatomy, functioning, and physiology:** All organisms are made of millions of organic compounds categorised as carbohydrates, lipids, proteins, nucleic acids, enzymes, and hormones. Body tissues such as muscles and blood, are made up of the combinations of these groups. For example, carbohydrates are a class of important organic molecules that provide the body with energy and structure
- **Medicines and drugs:** Several careers (engineers, dentists, pharmacologists, and chemists) apply the knowledge of organic chemistry in their technical innovations. Dentists use potassium citrate to combat sensitive toothache. Doctors use the knowledge of organic processes in the body to treat illnesses. The study of drugs (pharmacology) relies on organic chemistry synthetic pathways. These drugs are used for treating various illnesses. For example, artemisinin is for treatment of malaria, streptomycin is an antibiotic for tuberculosis (TB), clotrimazole is for treatment of fungal infections, and paracetamol is an analgesic (painkiller).

Drugs made from organic compounds

potassium citrate combats teeth pain and sensitivity

Group activity:

Group activity:

Importance of organic chemistry in everyday life

1. Describe the importance of organic chemistry in the following;
   a) Textile industries   b) energy and fuels   c) polymers   d) agricultural sector
2. Describe other importance of organic chemistry in daily life.

Use your brain power!

1. Sarah loves cooking and experimenting with different flavors in her dishes. She wants to understand how different spices and herbs contribute to the taste and aroma of her dishes. How can an understanding of organic chemistry help Sarah in enhancing the flavors in her cooking?

2. Lisa is concerned about the pollution caused by plastic waste and wants to find alternative packaging materials. How can an understanding of organic chemistry help Lisa in identifying and designing sustainable packaging solutions using biodegradable materials?

1.3 Classifying organic compounds.

Key question: How do we name Hydrocarbons?

Classifying organic compounds.

Organic compounds can be classified into several groups namely; Hydrocarbons (alkanes, alkenes, alkynes), Alcohols, Esters, Carboxylic acids, Amines, Ketones, Ethers. These groups are differentiated from each other by functional groups.

A functional group is a group of atoms or bonds with a characteristic chemical reactivity. Examples of functional groups include; C=C, C≡C, –OH, and –COOH. Functional groups are common to a given homologous series

Homologous series is a series of organic compounds with the same functional group and similar chemical properties in which members differ from each other by CH_2 group. The following are the characteristics of homologous series;

- All members of a particular homologous series can be represented by the same general formula
- All members of a homologous series can be prepared using the same general methods.
- Members of the same homologous series have the same chemical properties
- The physical properties of members change gradually with increase in molecular mass e.g melting points, boiling points and density increase with increase in molecular mass.
- All members in each homologous series differ from another by a methylene (CH_2) group

Hydrocarbons

Hydro carbons are organic compounds consisting of only hydrogen and carbon atoms. They are classified into three groups namely alkanes, alkenes and alkynes.

General formula; is a general rule used to calculate the number of atoms of each element e.g

- C_nH_{2n+2} for alkanes
- C_nH_{2n} for alkenes
- C_nH_{2n-2} for alkynes
- $C_nH_{2n+1}OH$ for alcohols
- $C_nH_{2n+1}COOH$ for carboxylic acid

Where n is the number of carbon atoms in a molecule.

Naming hydrocarbons.

The naming of organic compounds is according to the International Union and Applied Chemistry (IUPAC) nomenclature system which gives systematic names to organic compounds. The names given using this system have two parts i.e the parent name/root name/ prefix and the primary suffix.

The prefix indicates the nature of the basic carbon chain making up the hydrocarbon. Chains with 1 to 4 carbon atoms are known by special root words. Chains with 5 or more carbon atoms are known by their respective Greek numbers.

Parent names/prefix name of hydrocarbons

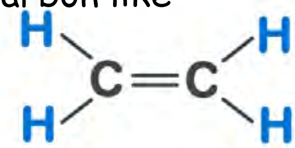
Number of carbon atoms	Prefix names
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-
7	Hept-
8	Oct-
9	Non-
10	Dec-

Primary suffixes are added to show whether the hydrocarbon is saturated or not

Primary suffixes for hydrocarbons

family	Type of bonds	Suffix
Alkanes	Single C-C	-ane
Alkenes	Double C=C	-ene
alkynes	Triple C≡C	-yne

When naming a hydrocarbon like



It has two carbon atoms therefore its prefix is eth-

It has double bonds between carbon atoms therefore its suffix is -ene

The name of the hydrocarbon is ethene. Its molecular formula is C_2H_4

Group activity:

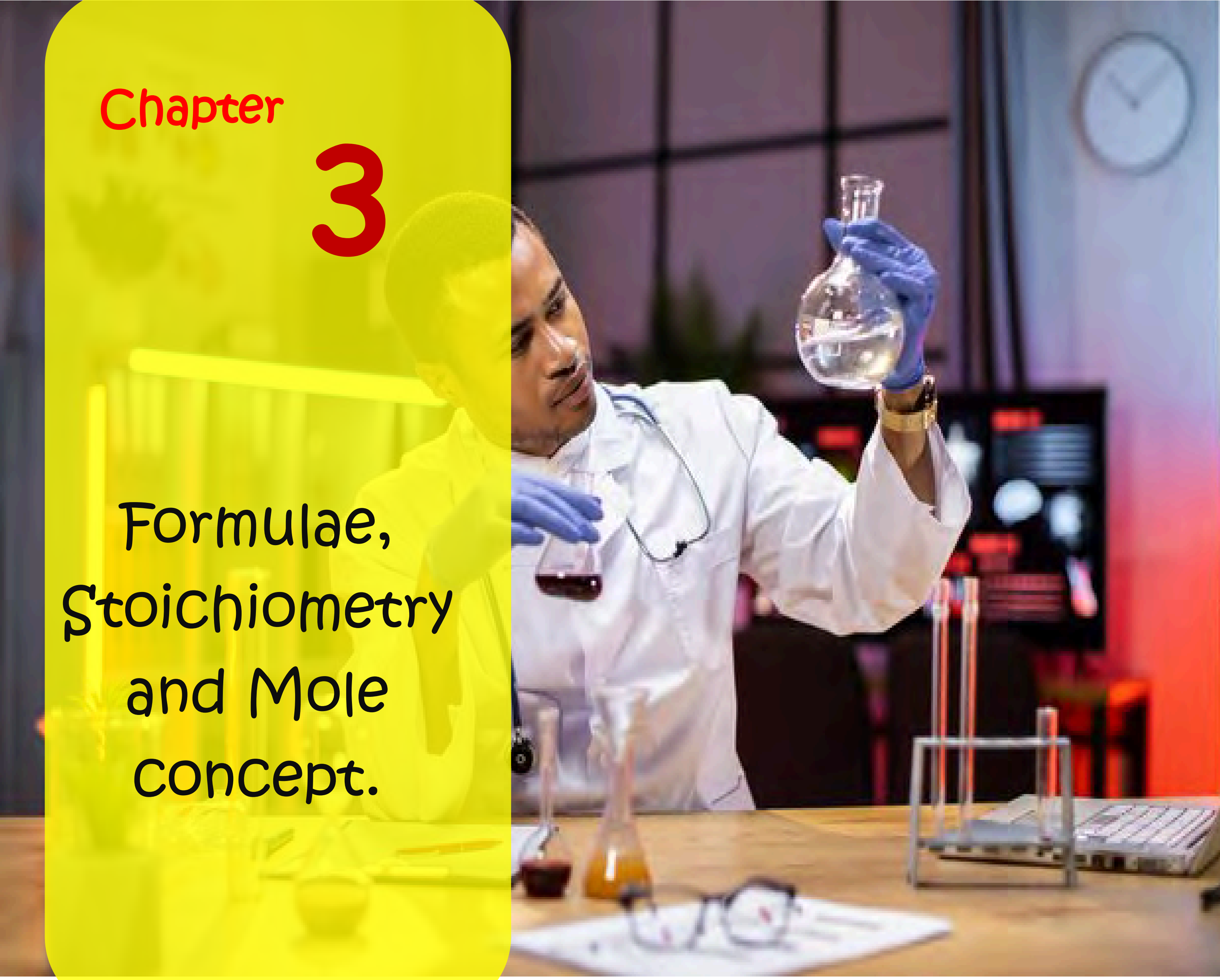
1. Consider the compound C_5H_{12}. What are the steps involved in naming this hydrocarbon, and what is the significance of each step?

1. Consider the compound C_5H_{12}. What are the steps involved in naming this hydrocarbon, and what is the significance of each step?
2. Why is it important to have a standardized system for naming hydrocarbons?
3. Consider a hydrocarbon C_7H_{16}. How would you determine its systematic name using the IUPAC rules? Show how you have arrived to your answer
4. Complete the table below

Number of carbon atoms (n)	Formula of alkane (C_nH_{2n+2})	Name of alkane	Formula of alkene (C_nH_{2n})	Name of alkene	Formula of alkyne (C_nH_{2n-2})	Name of alkyne
1	CH_4	methane	-	-	-	-
2						
3						
4						
5						
6						
7						
8						
9						
10						

Use your brain power!

5. You are a chemist working in a laboratory. Your colleague accidentally spills a liquid hydrocarbon on the floor, but the label got damaged, making it impossible to identify the compound. Your task is to determine the name of the hydrocarbon. You have been provided with the molecular formula C_6H_{12}. Name the hydrocarbon and provide a systematic explanation of how you arrived at the name.



Chapter 3

Formulae, Stoichiometry and Mole concept.

By the end of this chapter, you should be able to;

- Explain the concept of relative atomic mass and relative molecular mass
- Examine the relationship between the number of moles and number of particles
- State the relationship between the number of moles of a substance and its mass
- Examine the relationship between the number of moles of a gas and its volume.
- Synthesize chemical formulae
- Interpret chemical equations
- Demonstrate scientific attitudes and values in investigating matter.

Formulae, Stoichiometry and Mole concept.

Introduction

Any chemical reaction requires specific amounts of chemicals to reach its completion. The quantities of these chemicals are estimated in different units which include the mole. The mole relates the mass of a substance with its specific molar mass. The mole concept helps to determine the concentration of the substance when dissolved in solvent or solution. In this chapter, you will learn about the mole concept, molar quantities of substances, and the applications of the mole concept in chemical reactions and different settings. The competencies developed will enable you to determine quantities in different reactions and processes occurring in daily life.

3.1 Relative Atomic mass and Relative Molecular mass

Key question: How can you calculate the Relative Molecular Mass of substances?

Have you ever tried counting the number of rice grains in a sack of rice? Rice grains cannot be counted because their size is extremely small. Chemists face a similar problem too. As atoms are too small, it is difficult to determine their number and the mass of each atom. How do chemists

Relative Atomic mass (Ar)

Chemists use the concept of 'relative atomic mass' by comparing the mass of atom of an element to the mass of atom of another element that is chosen as the standard. Therefore, we do not need to know the actual mass of an atom. Initially, the hydrogen atom was used as the standard atom because it is the lightest atom. Masses of atoms of all other elements were compared with the hydrogen atom. For example, one carbon atom is as heavy as 12 hydrogen atoms. Hence, the relative atomic mass of carbon is 12. However, in 1961, chemists across the world agreed to use carbon-12 atom as the standard atom after finding that the usage of hydrogen atom as the standard atom encountered various problems. The **relative atomic mass, RAM** of an element is defined as the average mass of an atom of the element compared to $\frac{1}{12}$ of the mass of one carbon-12 atom.

Deriving the formula of relative atomic mass

An atom is very small and it would be difficult to measure its actual mass. To overcome this difficulty, chemists developed a simpler way to express the mass of an atom. This involved expressing the mass of an atom in relation to a chosen standard atomic mass. The carbon atom was chosen as the standard atom (reference atom) and its mass was arbitrarily chosen as 12 units (not actual value). Then, using an instrument called a mass spectrometer, all the other atoms were compared to this standard atom. This reference is called the *carbon-12 scale*. For example, it was found that:

(i) the magnesium atom was twice as heavy as the reference atom; so its mass was put at 24.
(ii) the hydrogen atom was $\frac{1}{12}$ as heavy as the reference atom; so its mass was put at 1.
(iii) the helium atom was $\frac{1}{3}$ as heavy as the reference atom; so its mass was put at 4.

The mass of an atom obtained by comparing it with the arbitrary mass of a carbon-12 atom is called its *relative atomic mass* (R.A.M. or Ar). The relative atomic mass of an element is the average mass of one atom of the element relative to $\frac{1}{12}$ the mass of one atom of carbon-12. Therefore, R.A.M. may not necessarily be a whole number.

$$\text{R.A.M.} = \frac{\text{Average mass of atom of an element}}{\frac{1}{12}\ \text{the mass of carbon} - 12\ \text{atom}}$$

CHALLENGER

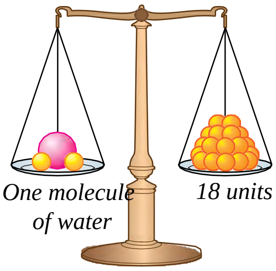
a) Determining the relative atomic mass of hydrogen atom as the standard atom has encountered various problems. Try to investigate what the problems are.
b) Discuss why carbon-12 is used as the standard to determine RAM

Complete the table by filling in the relative atomic mass of the first 20 elements

Element	Atomic number	Relative atomic mass
Hydrogen	1	1
Helium	2	4
Lithium	3	
Beryllium	4	
Boron	5	10
Carbon	6	12
Nitrogen	7	
Oxygen	8	
Fluorine	9	
Neon	10	
Sodium	11	
Magnesium	12	
Aluminium	13	27
Silicon	14	
Phosphorus	15	
Sulphur	16	
Chlorine	17	
Argon	18	
Potassium	19	
Calcium	20	

Relative Molecular Mass, RMM (Mr)

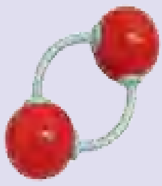
Similarly, we can compare the molecular mass of a substance with the standard carbon-12 atom. The **relative molecular mass, RMM** of a molecule is the average mass of the molecule compared to $\frac{1}{12}$ of the mass of one carbon-12 atom.



$$\text{zR.M.M.} = \frac{\text{Average mass of one molecule}}{\frac{1}{12}\,\text{Mass of one carbon}-12\text{ atom}}$$

The figure shows water molecule that has a relative molecular mass of 18. This means the mass of a water molecule is 18 times the mass of $\frac{1}{12}$ of carbon-12 atom.

*The relative molecular mass of a molecule can be calculated by **adding up the relative atomic masses of all the atoms** that form the molecule, as shown in examples below*

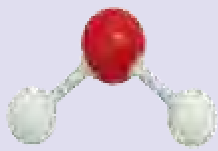


RMM of oxygen gas, O_2

$= 2(\text{RAM of O})$

$= 2(16)$

$= 32$



RMM of water, H_2O

$= 2(\text{RAM of H}) + \text{RAM of O}$

$= 2(1) + 16$

$= 18$

Example 1

Calculate the relative molecular mass of glucose, $C_6H_{12}O_6$.
[Relative atomic mass: H = 1, C = 12, O = 16]

Solution

RMM of glucose, $C_6H_{12}O_6$ = 6(RAM of C) + 12(RAM of H) + 6(RAM of O)
= 6(12) + 12(1) + 6(16)
= 72 + 12 + 96
= 180

Relative Formula Mass,

The concept of relative mass is also used for ionic substances. The relative mass of an ionic substance is called the **relative formula mass**, **RFM**. The relative formula mass is calculated by summing up the relative atomic masses of all the atoms shown in the formula of the ionic substance. This is because the mass of an ion does not differ much from the mass of its atom that forms the ion

Example 2

Calculate the relative formula mass of aluminium sulphate, $Al_2(SO_4)_3$.

[Relative atomic mass: O = 16, Al = 27, S = 32, Cl = 35.5, Zn = 65]

RFM of aluminium sulphate, $Al_2(SO_4)_3$ = 2(RAM of Al) + 3[RAM of S + 4(RAM of O)]
= 2(27) + 3[32 + 4(16)]
= 54 + 3[96]
= 342

Test Yourself

1 a) How many atoms of lithium are required to equalize the mass of one atom of calcium?

b) How many atoms of helium are required to equalize the mass of an oxygen atom?

2 Calculate the relative molecular mass or the relative formula mass of each of the following substances:

a) Methane, CH_4 (c) Sulphuric acid, H_2SO_4

b) Magnesium nitrate, $Mg(NO_3)_2$ (d) Formic acid, HCOOH

Group activity:

3. Determine the relative molecular mass or the relative formula mass of each of the following substances.

a) H_2 **b)** O_3 **c)** CO **d).** NH_3 **e).** N_2O_4
f) C_4H_{10} **g).** $CuCl_2$ **h.** $Zn(OH)_2$ **i)** $K_2Cr_2O_7$ **j)** $Fe(NO_3)_3$

4. Can you explain the significance of using the concept of RAM in calculating the RMM of compounds in various scientific fields

Use your brain power!

5. You are given the RAM values for all the elements present in a mixture of compounds. However, the mixture contains different compounds in varying amounts. How would you calculate the RMM of the mixture, taking into account the different compounds and their respective ratios?

6. You are analyzing a sample of an unknown compound and need to determine its RMM. Unfortunately, the sample has impurities, leading to multiple elements being present. How would you accurately calculate the RMM of the unknown compound despite the presence of impurities?

7. You are investigating the ratio of carbon to oxygen atoms in a specific chemical reaction. In this reaction, one atom of oxygen combines with carbon atoms to form a product. If the mass of the oxygen atom is 16 atomic mass units, how many carbon atoms are necessary to achieve a balanced reaction?

My notes Answer template

3.2 Number of moles and number of Particles

Key question: **What is the relationship between number of moles and number of Particles?**

The mole is conceptually similar to other measurements such as; a pair, which is a set of two items, a dozen, which is a set of twelve items, and a gross, which is a set of twelve dozens with 144 items. A pair, a dozen, and a gross are units of measurements with fixed numbers of items. These measurements put the items into groups to simplify the counting. Examples of items that employ these measurements include a pair of shoes, a dozen of pencils, and a gross of scones

A pair of shoes

A dozen of pencils

A gross of scones

In the field of chemistry, we use the unit **mole** to measure the amount of substance.

What is a mole?

A mole is the amount of the substance which contains as many particulate entities (atoms, molecules, or ions) as there are atoms in 12g of carbon–12. Therefore, the mole is the basic unit of the amount of a substance, usually abbreviated as ***mol.*** The term mole is derived from the Latin word *moles*, which means a large mass or bulk, which is consistent with its use as the SI unit of the amount of a substance. To obtain the exact number of particles in any substance, the amount of that substance is multiplied by a constant factor which is called ***Avogadro's constant*** **(*Avogadro's number*).**

Avogadro's constant

In order to establish a quantitative relationship between one mole of a substance and the respective number of particulate entities, the number of atoms contained in 12g of carbon–12 will be calculated. The measured mass of one atom of carbon–12 is 1.9927×10^{-23} g. The number of atoms in 12g of carbon–12 is obtained by dividing the 12g by the measured mass.

That is:

$$\frac{12\ g}{1.9927 \text{ x } 10} = 6.02198 \times 10^{23} \approx 6.022 \times 10^{23} \text{ atoms}$$

This number 6.022×10^{23} is known as the Avogadro's constant or Avogadro's number expressed by the symbol, N_A. The constant was named after Amedeo Avogadro, an Italian physicist (1776–1856) who was honoured for his work on gases. One mole of any substance therefore contains 6.022×10^{23} particulate entities, that is, atoms, molecules or ions, just like there are two items in every pair or 12 items in every dozen. Since 6.022×10^{23} is the number of particulate entities composing a mole, the constant is properly reported with an explicit unit of **per mole** that is, 6.022×10^{23} (atoms, molecules or ions)/mol. The Avogadro's number makes it easy to convert the number of particulate entities present in a sample to the amount of substance in moles by using the following relation:

$$\text{Number of moles (n)} = \frac{\text{number of particulate entities (N)}}{\text{number of particulates per mole } (N_A)}$$

Number of particulate entities (N), can be expressed as:

$$N = n \times N_A$$

where; n = the amount of substance in moles (number of moles of a substance),
N = number of particulate entities per mole.

Diagrammatically, the relationship between the number of mole and the number of particles by using Avogadro constant as the conversion factor is shown below:

$$\text{Number of moles} \underset{\div N_A}{\overset{\times N_A}{\rightleftarrows}} \text{Number of particles}$$

Example 1

How many moles of nitrogen gas are there in 2.2×10^{12} molecules of the gas?

Solution

1 mole of nitrogen gas contains 6.022×10^{23} molecules. Therefore, the number of moles of N_2 in 2.2×10^{12} molecules will be:

$$n = \frac{\textit{number of particular entities } N}{\textit{number of particulates permole } N_A}$$

$$= \frac{2.2 \times 10^{12} \text{ molecules}}{6.022 \times 10^{23} \text{ molecules mol}^{-1}}$$

$$= 3.65 \times 10^{-12} \text{ mol}$$

The amount of nitrogen gas present in 2.2×10^{12} molecules of the gas = 3.65×10^{-12} mol.

Examples

2. How many atoms are there in 0.2 mol of magnesium, Mg?

Solution

Number of particles = $n \times N_A$
= $0.2 \text{ mol} \times 6.02 \times 10^{23} \text{ mol}^{-1}$
= 1.204×10^{23} atoms

3. A sample of zinc chloride, $ZnCl_2$ contains 3.01×10^{24} $ZnCl_2$ units. Calculate the number of moles of zinc chloride, $ZnCl_2$ found in the sample.

Solution

$$n = \frac{N}{N_A} = \frac{3.01 \times 10^{24}}{6.02 \times 10^{23} \text{ mol}^{-1}}$$
$$= 5 \text{ mol}$$

4. A gas jar is filled with 2 mol of oxygen gas, O_2.
(a) How many molecules of oxygen are there in the gas jar?
(b) How many atoms of oxygen are there in the gas jar?

Solution

(a) Number of oxygen molecules, O_2 = Number of moles × N_A
= 2 mol × 6.02 × 1023 mol-1
= 1.204 × 1024 molecules

(b) Each oxygen molecule, O_2 has 2 oxygen atoms, O.
Hence, the number of oxygen atoms, O = Number of O_2 molecules × 2
= 1.204 × 1024 × 2
= 2.408 × 1024 atoms

Group activity:

1. Calculate the number of atoms found in
   (a) 0.1 mol of carbon, C (b) 3.5 mol of neon gas, Ne
2. Calculate the number of molecules found in
   (a) 1.2 mol of hydrogen gas, H_2 (b) 0.8 mol of ammonia, NH_3
3. Calculate the number of formula units found in
   (a) 3 mol of sodium chloride, NaCl (b) 0.25 mol of potassium nitrate, KNO_3
4. Calculate the number of moles of each of the following substances:
   (a) 6.02×10^{24} lead atoms, Pb (c) 9.03×10^{22} bromine molecules, Br_2
   (b) 3.02×10^{23} magnesium oxide units, MgO (d) 3.612×10^{24} carbon dioxide molecules, CO_2
5. A reagent bottle contains 1.806×10^{25} units of copper(II) oxide, CuO.
   (a) How many moles of copper(II) oxide, CuO are found in the bottle?
   (b) Calculate the number of ions found in that bottle.
6. A sample contains 0.2 mol of ethene gas, C_2H_4.
   (a) How many ethene molecules, C_2H_4 are found in the sample?
   (b) How many hydrogen atoms, H are found in the sample?

Use your brain power!

Scenario: You are a student preparing for a chemistry exam, and one of the topics covered is the mole concept. Choose a real-life scenario (e.g., cooking, baking, or making a solution) and explain how understanding moles and stoichiometry can be applied to solve problems and make accurate measurements. Discuss the significance of using mole ratios in chemical calculations.

Chapter five

Fossil-fuels

By the end of this chapter, you should be able to;

- Define fossil fuels
- Describe the different types of fossil fuels
- Describe how fossil fuels were formed
- Explain chemical reactions on fossil fuels
- Explain how fossil fuels are mined and extracted
- Explain the contribution of fossil fuels to the economy of Uganda
- Describe the environmental impact of fossil fuels
- Explain other alternatives to fossil fuels

5.1 introduction to fossil fuels

Key question: Describe the advantages and disadvantages of using the different types of fossil fuels.

Fossil fuels

Fossil fuels are natural resources formed over millions of years from the remains of ancient plants and organisms. They are considered non-renewable energy sources, as they take a significant amount of time to form and are being used up faster than they can be replenished. Fossil fuels play a vital role in powering various sectors such as transportation, electricity generation, and industrial processes.

Types of fossil fuels

The 3 main types of fossil fuels are coal, nature gas and crude oil.
Coal: coal is a black combustive sedimentary rock primarily composed of carbon, along with various other elements like hydrogen, sulphur, oxygen and nitrogen
Crude oil or petroleum: it's a thick, dark liquid consisting of mainly of hydrocarbons. It is formed from the remains of marine plants and animals that lived in large bodies of water millions of years ago. Crude oil is made of carbon, hydrogen, nitrogen, sulphur, & oxygen
Natural gas: Nature gas is a gaseous fossil fuel composed of mainly methane but can also contain other hydrocarbons and impurities. It is typically found alongside petroleum deposits or in coal beds. Natural gas is made up of carbon, hydrogen, nitrogen, sulphur & oxygen

Characteristics of a good fuel

Fuels can be classified according to their effectiveness (usefulness) or productivity and convenience for use. The following are the characteristics that are considered when choosing a good fuel:

Energy value - A good fuel should have high energy value (calorific value). The energy value of a fuel is determined by the amount of energy produced per unit mass of the fuel. This is called the *heat value* or *calorific value* of the fuel.

Velocity of combustion - This refers to the rate at which a fuel burns. A good fuel should burn with moderate velocity for continuous supply of heat. It should not burn too fast or too slowly.

Ignition point - This is the temperature to which the fuel must be heated before it starts burning. A good fuel should have a proper (average) ignition point. A low ignition point is risky due to fire hazards, while high ignition point makes it difficult to start a fire with the fuel. Fuels with high ignition points are safe for transportation and storage.

Non-combustible material content - A good fuel should have no or low content of non-combustible materials. The non-combustible material is left in form of ash once the fuel burns. A high content of non-combustible materials lowers the heat value of the fuel. The figure below shows ashes from burnt substances. High contents of ashes per fuel burned indicate that the burnt substances are not good fuels.

ashes from burnt from fuels

Non-hazardous products of combustion-

A good fuel should give clean gases during combustion. The fuel should also give off very little or no smoke. In general, the combustion of a good fuel should not produce harmful substances like soot, and toxic substances. The figure on the right shows smoke from a chimney. This indicates that the burning fuel is not good or incomplete combustion takes place.

Smoke of a burning fuel emitted from a chimney

Burning gaseous fuel

Pyrometric burning effect - This is the highest temperature that can be reached by the burning fuel. A good fuel should have high pyrometric effect. Burning gaseous fuels produce the highest pyrometric effect. The figure on the left shows a burning gaseous fuel.

Availability - A good fuel should be readily available in large quantities.

Affordability - A good fuel should be cheap and affordable.

Ease of transportation and storage - A good fuel should be easy and safe to transport, handle, and store. Figure 4.4 shows transportation of a gaseous fuel using a truck.

Effects in the environment - A good fuel should not pollute the environment during its production, storage, and use. Fossil fuels, which produce carbon dioxide on burning, are major contributors to environmental pollution. Solid fuels like wood and coal are not good due to the following reasons:

(i) They produce harmful gases when burnt.
(ii) They leave solid residues.
(iii) The resulting ashes can cause health problems.

Liquid fuels, like petrol, kerosene and diesel, burn more smoothly than solid ones. However, upon incomplete burning, they also produce poisonous gases and soot.


Smoke emitted from burning fossil fuels

Group activity

1. John is considering using coal to generate electricity for his new manufacturing plant. What are the advantages and disadvantages of using coal as a fossil fuel?

2. Sarah is considering using natural gas for heating and cooking in her newly built house. What are the advantages and disadvantages of using natural gas as a fossil fuel?

3. Mark wants to power his car using petroleum (crude oil). What are the advantages and disadvantages of using petroleum as a fossil fuel?

Use your brain power!

1. Imagine you are a community leader in a rural village that currently relies on firewood for cooking and heating. Given the environmental impact of deforestation and indoor air pollution, what initiatives would you propose to transition the village to a more sustainable and clean energy source? How would you engage with the community to raise awareness and encourage adoption of alternative fuels, such as biogas or solar power?