CHEMISTRY

PART - I

Standard

X

Government of Kerala
Department of General Education

Prepared by

State Council of Educational Research and Training (SCERT) Kerala

2025

THE NATIONAL ANTHEM

Jana-gana-mana adhinayaka, jaya he
Bharatha-bhagya-vidhata
Punjab-Sindh-Gujarat-Maratha
Dravida-Utkala-Banga
Vindhya-Himachala-Yamuna-Ganga
Uchchala-Jaladhi-taranga
Tava subha name jage,
Tava subha asisa mage,
Gahe tava jaya gatha
Jana-gana-mangala-dayaka jaya he
Bharatha-bhagya-vidhata
Jaya he, jaya he, jaya he,
Jaya jaya jaya, jaya he!

PLEDGE

India is my country. All Indians are my brothers and sisters.

I love my country, and I am proud of its rich and varied heritage. I shall always strive to be worthy of it.

I shall give my parents, teachers and all elders, respect and treat everyone with courtesy.

To my country and my people, I pledge my devotion. In their well-being and prosperity alone, lies my happiness.

Chemistry

X

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Foreword

Dear students,

The researches and discoveries in various fields of science have helped in the progress and modernization of every sectors world wide. Science has become authoritative to be inevitable in everyday life. The method of science is a systematic approach of constructing knowledge, fostering the values based on humanity, understanding the nature around us and identifying and finding means to solve environmental problems.

This textbook has been organized by adopting the scientific method of problem solving which involves the stages such as designing experiments, observation, collection of data, analyzing data, drawing inferences, generalization, prediction and communication. Nomenclature of organic compounds and isomerism, chemical reactions of organic compounds, periodic table and electron configuration, gas laws and mole concept are the units included in this textbook.

The classroom activities, assessment and extended activities are organized in such a way that they are activity oriented, process based and encouraging investigative learning. We hope this textbook will help to develop the innate abilities, to think differently, to carry out innovative discoveries and make learning an enjoyable experience by effectively participating in learning activities with the help of the concepts in the textbook.

With love and best wishes.

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Certain icons are used in this textbook for convenience

For further reading (Not considered for evaluation)

Continuous assessment questions

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Let us assess

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THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [1]**[SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC]** and to secure to all its citizens :

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

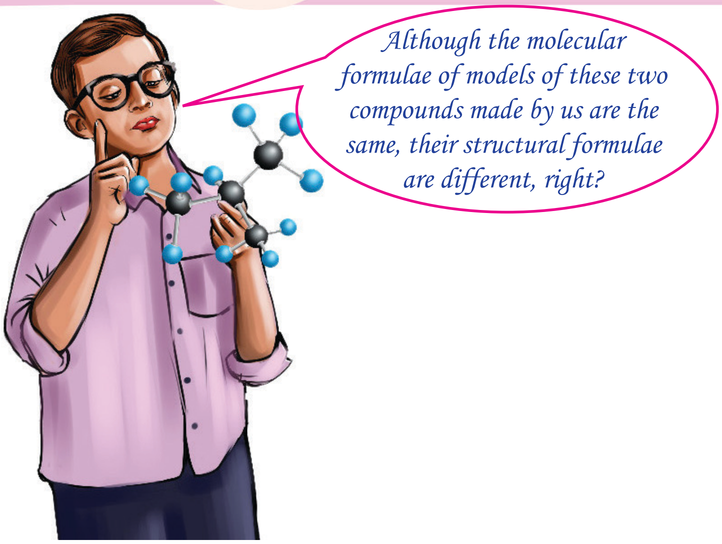
FRATERNITY assuring the dignity of the individual and the [2][unity and integrity of the Nation];

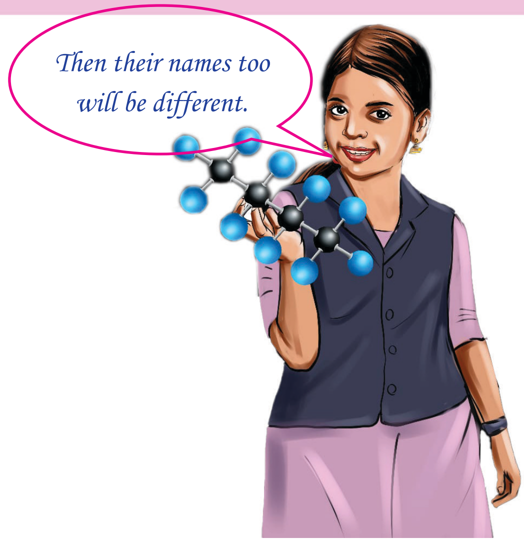
IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do **HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.**

---

1. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Sovereign Democratic Republic" (w.e.f. 3.1.1977)
2. Subs. by the Constitution (Forty-second Amendment) Act, 1976, Sec.2, for "Unity of the Nation" (w.e.f. 3.1.1977)

1 NOMENCLATURE OF ORGANIC COMPOUNDS AND ISOMERISM





Several substances, used in various fields of daily life, are the contributions of organic chemistry. Billions of carbon compounds have already been discovered. We know that, the astonishing count of compounds, their peculiarities and possibilities have led to the formation of the specific branch of chemistry called "organic chemistry". You have already learnt about an important class of organic compounds, the hydrocarbons and their varieties, their structure, IUPAC rules of nomenclature etc. The world of substances formed when carbon combines with elements like hydrogen, oxygen, nitrogen and few other elements has become indispensable to the modern life. The study of the structure, nomenclature and characteristics of numerous such compounds is fascinating. Let us get acquainted with some of these.

The structural formulae of two hydrocarbons are given below.

$$CH_3 - CH_2 - CH_2 - CH_2 - CH_3$$

Hydrocarbon I

$$\begin{array}{l} CH_3 - \underset{\displaystyle CH_3}{\underset{|}{CH}} - CH_2 - CH_3 \end{array}$$

Hydrocarbon II

You are familiar with the formula of hydrocarbon I.

- How many carbon atoms are there in this chain? ....
- What is the word root of this carbon chain? ....
- Write the IUPAC name of this compound. ....

Analyse the structural formula of hydrocarbon I and hydrocarbon II.

- What is the molecular formula of these two hydrocarbons?
- How do they differ in the structure of the carbon chain? ....

Have a look at the structural formula of another hydrocarbon with the same molecular formula.

$$\begin{array}{ccccc} & & CH_3 & & \\ & & | & & \\ H_3C & — & C & — & CH_3 \\ & & | & & \\ & & CH_3 & & \end{array}$$

It is clear that carbon atoms can form branched compounds.

Nomenclature of alkanes with one branch

The structural formula of a hydrocarbon with one branch is given below.

$$\begin{array}{l} CH_3 - CH - CH_2 - CH_3 \\ \qquad\;\;\; | \\ \qquad\; CH_3 \end{array}$$

Certain IUPAC rules are to be followed while naming such branched hydrocarbons.

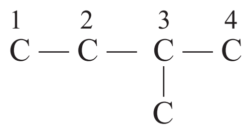
- ❑ The longest chain containing maximum number of carbon atoms should be considered as the main chain and the remaining as branches.

i) $$\begin{array}{l} \boxed{CH_3 - CH - CH_2 - CH_3} \text{ —— Main chain} \\ \qquad\;\;\; | \\ \qquad\; CH_3 \text{ —— Branch} \end{array}$$

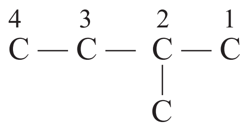
ii) $$\begin{array}{l} CH_3 - CH_2 - CH - CH_3 \text{ —— Branch} \\ \qquad\qquad\quad\;\; | \\ \qquad\qquad\; CH_2 - CH_3 \text{ —— Main chain} \end{array}$$

- Numbering should be done in such a way that the carbon atom carrying branch gets the lowest number. For this you can start by numbering either from the right or from the left of the chain.

A carbon chain containing one branch is given below. Note that it is numbered in two ways.



(I)



(II)

Which of the above chains has the lowest position number for the carbon atom carrying the branch?

Put a ✓ mark against the appropriate one.

I ☐ II ☐

- The small branches attached to carbon atoms are called alkyl groups. An alkyl group is obtained when a hydrogen atom is removed from a carbon atom in a saturated hydrocarbon. That is, when a hydrogen atom is removed from a CH_4 molecule, $-CH_3$ is obtained .This is called a methyl group. An alkyl group is named by adding ‘yl’ to the word root of the corresponding alkane.

Name of alkyl group = Word root corresponding to the number of carbon atom / atoms in the branch + ‘yl’

Name of alkyl group	Structural formula
Methyl	$-CH_3$
Ethyl	$-CH_2-CH_3$
Propyl	$-CH_2-CH_2-CH_3$

Table 1.1

- While writing the IUPAC name, a hyphen (–) is used to separate numerals and alphabets.

Position number of branch+ hyphen + name of alkyl group + word root + suffix (ane)

Let us examine how to write the IUPAC name of the compound given below, based on these rules.

$$\begin{array}{ccccccccc} CH_3 & - & CH_2 & - & CH_2 & - & CH & - & CH_3 \\ &&&&&& | && \\ &&&&&& CH_3 && \end{array}$$

- Number of carbon atoms in the main chain :
- Word root :
- Suffix :
- Name of the branching alkyl group :
- Position of the branch :
- IUPAC name : 2–Methylpentane

Complete the table.

Compound	Number of carbon atoms in the longest chain	Name of branch	Position of branch	IUPAC name
$\begin{array}{ccccccccccc} CH_3 & - & CH & - & CH_2 & - & CH_2 & - & CH_2 & - & CH_3 \\ && \vert &&&&&&&& \\ && CH_3 &&&&&&&& \end{array}$	....	....	....	....
$\begin{array}{ccccccc} CH_3 & - & CH_2 & - & CH & - & CH_3 \\ &&&& \vert && \\ &&&& CH_3 && \end{array}$	....	....	....	....
$\begin{array}{ccccccccc} CH_3 & - & CH & - & CH_2 & - & CH_2 & - & CH_3 \\ && \vert &&&&&& \\ && CH_2 & - & CH_3 &&&& \end{array}$	....	....	....	....
$\begin{array}{ccccccccc} CH_3 & - & CH_2 & - & CH & - & CH_2 & - & CH_3 \\ &&&& \vert &&&& \\ &&&& CH_2 &&&& \\ &&&& \vert &&&& \\ &&&& CH_3 &&&& \end{array}$	....	....	....	....

Nomenclature of alkanes with more than one branch

- If more than one branch is present, select the longest carbon chain. Number the carbon atoms from left to right or right to left in such a way that the carbon atoms with branches get the lowest position numbers.

Eg.
$$\begin{array}{ccccccccccc} 1 & & 2 & & 3 & & 4 & & 5 & & 6 \\ CH_3 & - & CH & - & CH_2 & - & CH & - & CH_2 & - & CH_3 \\ 6 & & 5| & & 4 & & 3| & & 2 & & 1 \\ & & CH_3 & & & & CH_3 & & & & \end{array}$$

Correct way of numbering	:	Left to right
Position number of the first branch	:	2
Correct position number of the branches	:	2, 4

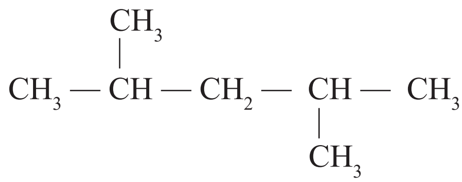
- If the same branch appears more than once in a carbon chain, the number of branches is to be indicated using prefixes like di (two), tri (three), tetra (four) etc. Position numbers should be separated by commas.

Let us examine how to assign the IUPAC name to the compound given below.

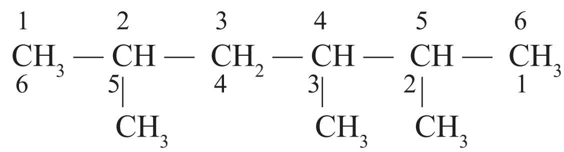
$$\begin{array}{ccccccccccccc} & & & & CH_3 & & & & & & CH_3 & & \\ & & & & 3| & & & & & & 6| & & \\ 1 & & 2 & & & & 4 & & 5 & & & & 7 \\ CH_3 & - & CH_2 & - & CH & - & CH_2 & - & CH_2 & - & CH & - & CH_3 \\ 7 & & 6 & & 5 & & 4 & & 3 & & 2 & & 1 \end{array}$$

- Number of carbon atoms in the main chain : 7
- Number of branches : 2
- Name of branches : Methyl
- Position of the first branch while numbering from left to right : 3
- Position of the first branch while numbering from right to left : 2
- Correct way of numbering : Right to left
- Correct position number of the branches : 2, 5
- IUPAC name : 2,5–Dimethylheptane

Structural formula of a hydrocarbon is given below. Write the IUPAC name of this compound.

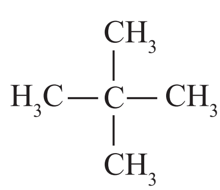


- The longest carbon chain is numbered from left to right or right to left. If the carbon atom containing the first branch gets the same position number when numbered from either side, then the numbering should be done in such a way that the carbon atom containing the second branch gets a lower position number.



- Number of carbon atoms in the main chain :
- Number of branches :
- Name of branches :
- Position number of the first branch while numbering from left to right :
- Position number of the first branch while numbering from right to left :
- When does the second branch get a lower position number? Put a ✓ mark against the correct option. :
  While numbering from left to right : ☐
  While numbering from right to left : ☐
- Correct position number of the branches : 2,3,5
- IUPAC name : 2,3,5–Trimethylhexane

- If a carbon atom has two identical branches, their position numbers should be repeated.



- Number of carbon atoms in the main chain :
- Number of branches :
- Name of branches :
- Position of the branches :
- IUPAC name : 2,2–Dimethylpropane

Now let us see how to write the structural formula of a compound if its IUPAC name is given.

Example : Write the structural formula of 2,3-Dimethylpentane.

- How many carbon atoms are present in its main chain?

  ....

- Let us write the main chain.

  C — C — C — C — C

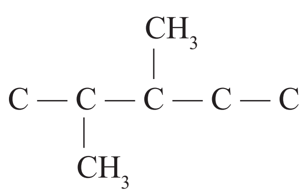
- What are the branches?

  ....

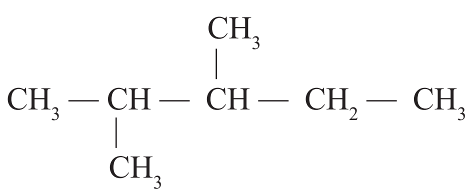
- What are their position numbers?

  ....

- Write the structural formula by attaching the branches to the main chain.



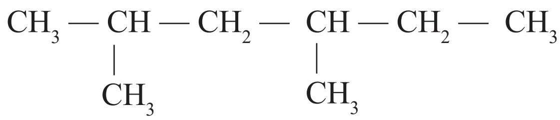
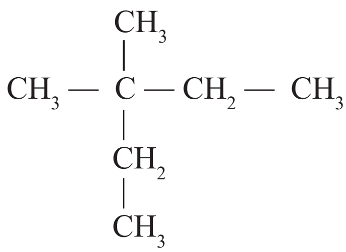
Complete the structure by filling up all valencies of carbon atoms with hydrogen.



- Write the structural formula of the compound 2,4-Dimethylheptane.

  ....

Complete the table given below.

Compound	IUPAC name
	....
....	2,2,3–Trimethylpentane
....	3,3–Diethylhexane
	....

Nomenclature of unsaturated hydrocarbons

You got familiar with the structure and IUPAC names of some alkenes and alkynes in standard IX. Now, let us learn how to name them on the basis of the position of the double or triple bonds in the carbon chain.

- In the nomenclature of hydrocarbons with double bonds, the numbering should be done in such a way that the carbon atoms linked by the double bond gets the lowest position number.

> Word root + hyphen + position of double bond + hyphen + suffix (ene).

The structural formula of an alkene with molecular formula C_4H_8 is given below.

$$CH_2 = CH - CH_2 - CH_3$$

Note that the carbon atoms are numbered in two ways.

$$\overset{1}{C}H_2 = \overset{2}{C}H - \overset{3}{C}H_2 - \overset{4}{C}H_3 \qquad (I)$$

$$\overset{4}{C}H_2 = \overset{3}{C}H - \overset{2}{C}H_2 - \overset{1}{C}H_3 \qquad (II)$$

- In which of these, carbon atoms having double bond gets the lowest position number? Tick ✓ the correct option.

I ☐ II ☐

If so, what will be the IUPAC name of this compound?

- Total number of carbon atoms in this chain : 4
- Word root : But
- The correct position number of carbon atom having double bond. : 1
- Suffix : ene
- IUPAC name : But–1–ene

The structural formula of another alkene with molecular formula C_4H_8 is given below. Let us try to write its IUPAC name.

$$\begin{array}{ccccccc} 1 & & 2 & & 3 & & 4 \\ CH_3 & - & CH & = & CH & - & CH_3 \\ 4 & & 3 & & 2 & & 1 \end{array}$$

- Total number of carbon atoms in this chain :
- Word root :
- The correct position number of carbon atom having double bond. :
- Suffix :
- IUPAC name :

Now you are familiar with the structural formulae of two compounds with the molecular formula C_4H_8.

- How do they differ in their structures?

....

Note that the position of the double bond in the carbon chain is different.

$$CH_3 - CH_2 - CH = CH - CH_3$$

Which of the following is the IUPAC name of this compound? Tick ✓ the correct one.

Pent-3-ene ☐ Pent-2-ene ☐

Structural formula of a compound is given below.

$$CH \equiv C - CH_2 - CH_3$$

- What is the molecular formula of this compound? ....
- To which category does this compound belong?

  ....

Is it possible to name alkynes just like we named alkenes?

> Word root + hyphen + position of triple bond + hyphen + suffix (yne)

Let us write the IUPAC name of the alkyne given above.

$$\overset{1}{C}H \equiv \overset{2}{C} - \overset{3}{C}H_2 - \overset{4}{C}H_3$$
$$\underset{4}{C}H \equiv \underset{3}{C} - \underset{2}{C}H_2 - \underset{1}{C}H_3$$

- Total number of carbon atoms in this chain :
- Word root :
- The correct position number of carbon atom having triple bond. :
- Suffix :
- IUPAC name : But–1–yne

Write the structural formula of another alkyne with molecular formula C_4H_6.

....

Write the IUPAC name of this compound.

....

IUPAC name of this compound is But-2-yne.

Now you are familiar with the structural formulae of two compounds with molecular formula C_4H_6?

How do they differ in their structures?

....

Note that the position of the triple bond in the carbon chain is different.

Complete the table.

Compound	IUPAC name
$CH_3 - CH = CH_2$	............................(a).........................
............................(b).......................	Hex-2-ene
$CH_3 - C \equiv C - CH_2 - CH_3$	............................(c).......................
............................(d).......................	Hept-3-yne

Functional groups

What are the constituent elements of the organic compounds discussed so far?

....

There are compounds in which carbon atoms are bonded to atoms or group of atoms, other than hydrogen.

Examine the structure and name of the organic compounds given in Figure 1.1.

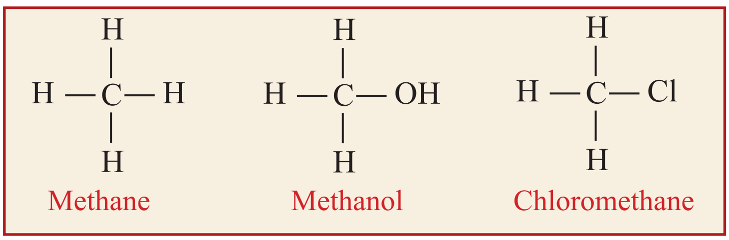


Figure 1.1

Methanol is a compound in which a hydrogen atom in methane is replaced by an –OH group. Similarly, chloromethane is a compound where a –Cl atom is present. The chemical and physical properties of methanol and chloromethane are entirely different from those of methane.

An atom or a group of atoms, bonded to carbon in an organic compound, determines the distinctive chemical and physical properties of that compound. This atom or group of atoms is called a functional group.

Now, let us get familiarised with some functional groups.

1. Hydroxyl group (–OH)

It is understood from Figure 1.1 that methanol is formed as a result of replacing a hydrogen atom of methane with an –OH group.

The presence of –OH group in the carbon chain is responsible for the characteristic properties of methanol. The aliphatic hydrocarbons in which –OH group is attached as a functional group are called alcohols.

According to IUPAC method, the alcohols are named by replacing 'e' in the name of the corresponding alkane with 'ol'.

Alkane - e + ol → Alkanol

Eg. Methane - e + ol → Methanol

Have a look at a few examples.

- $CH_3 - OH$ IUPAC name - Methanol
- $CH_3 - CH_2 - OH$ IUPAC name - Ethanol

Analyse the following structures given below.

(i) $CH_3 — CH_2 — CH_2 — OH$

(ii)
$$\begin{array}{c} CH_3 — \underset{\displaystyle OH}{\underset{|}{CH}} — CH_3 \end{array}$$

- What is the functional group in the two compounds? ....
- What is the molecular formula of the two compounds? ....
- What is the structural difference between them?

The position of the functional group in both compounds is different.

When there are more than two carbon atoms, the position of the –OH group needs to be specified.

For naming such compounds according to IUPAC rules, the following points need to be considered.

- The carbon chain containing the –OH group should be considered as the main chain.
- The carbon atoms should be numbered in such a way that the carbon to which the functional group is attached gets the lowest position number.
- Replace 'e' of the corresponding alkane with 'ol' and indicate the position number of the –OH group before 'ol'.

Alkane – e + hyphen + position number of –OH group + hyphen + ol

Let us examine how to write the IUPAC name of the compound (i).

$$\overset{1}{\underset{3}{CH_3}} - \overset{2}{\underset{2}{CH_2}} - \overset{3}{\underset{1}{CH_2}} - OH$$

- The total number of carbon atoms in this chain :
- The name of the alkane with 3 carbon atoms :
- The correct position number of the carbon containing the – OH group :
- IUPAC name : Propan–1–ol

Now, write the IUPAC name of the second compound (ii).

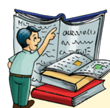
$$CH_3 - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_3$$

IUPAC name : ....

Which of the following is the IUPAC name of the compound given below? Tick ✓ the correct one.

$$CH_3 - CH_2 - CH_2 - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_3$$

Pentan–4–ol ☐ Pentan–2–ol ☐



Monosodium glutamate (MSG)

Monosodium glutamate is often added to food items as a taste enhancer. This compound is the sodium salt of glutamic acid. It is odourless and appears in white crystalline form. This compound is known by the trade name, aginomoto.

2. Carboxyl group $\left[-\overset{\displaystyle O}{\overset{\|}{C}}-OH \quad \text{or} \; -COOH \right]$

Compounds containing the – COOH functional group are known as carboxylic acids.

To assign IUPAC name to these compounds, we must consider the total number of carbon atoms in the main chain, including the one in the carboxyl group. The last letter 'e' of the corresponding alkane is replaced with 'oic acid' to get the name of the acid.

Alkane – e + oic acid → Alkanoic acid

Eg. Methane – e + oic acid → Methanoic acid

Write the IUPAC name of the carboxylic acid given below.

$$CH_3 - \underset{\displaystyle O}{\underset{\|}{C}} - OH$$

Number of carbon atoms in this chain : 2

IUPAC name : Ethanoic acid

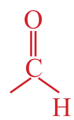
That is,

Ethane – e + oic acid → Ethanoic acid

Complete the Table 1.2.

Compound	IUPAC name
H — COOH	....
CH_3 — COOH	Ethanoic acid
....	Propanoic acid
CH_3 — CH_2 — CH_2 — COOH	....

Table 1.2

3. Aldehyde group ( or –CHO)

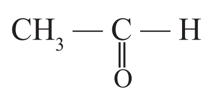
Compounds with — CHO functional group are called aldehydes.

To assign IUPAC names to these compounds, the number of carbon atoms in the main chain, including that in the aldehyde group, must be considered. The last letter 'e' in the name of the corresponding alkane is replaced with '–al' to get the name of the aldehyde.

Alkane – e + al → Alkanal

Eg. Methane – e + al → Methanal

Write the IUPAC name of the aldehyde given below.



- Number of carbon atoms in this chain : 2
- Name of the alkane having 2 carbon atoms : Ethane
- IUPAC name : Ethanal

That is,

Ethane – e + al → Ethanal

Fatty acids

Fatty acids are saturated or unsaturated carboxylic acids with long aliphatic chains. Palmitic acid and stearic acid are examples of fatty acids. These acids contain 16 and 18 carbon atoms respectively. Fatty acids have large scale industrial application. They are used in the manufacturing of soaps, detergents and cosmetics. Soaps are metallic salts of fatty acids. You might have heard of omega fatty acids which play a major role in human diet.

Complete the table given below.

Compound	IUPAC name
....	Butanal
$CH_3 — CH_2 — CHO$	....
....	Pentanal

Table 1.3

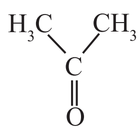
4. Keto group ($>C=O$)

Ketones are compounds with $>C=O$ as the functional group.

To assign IUPAC names to these compounds, the number of carbon atoms in the main chain, including that in the keto group, must be considered. The letter 'e' of the corresponding alkane is replaced with 'one'.

$$\text{Alkane} \; - e + \text{one} \rightarrow \text{Alkanone}$$

Write the IUPAC name of the ketone given below.



- Number of carbon atom in this chain : 3
- Name of alkane having 3 carbon atoms : Propane
- IUPAC name : Propanone

That is, Propane – e + one → Propanone

This compound is known by the name acetone.

The position of the functional group must be considered while naming ketones with more than 3 carbon atoms.

Write the IUPAC name of the compound given below.

$$\overset{1}{\underset{5}{CH_3}} — \overset{2}{\underset{4}{CH_2}} — \overset{3}{\underset{3}{CH_2}} — \overset{4}{\underset{2}{CO}} — \overset{5}{\underset{1}{CH_3}}$$

- Number of carbon atoms in the main chain :
- Name of alkane with the same number of carbon atoms :
- Correct position number of the functional group :
- IUPAC name : Pentan–2–one

$CH_3 — CH_2 — CO — CH_2 — CH_3$ Write the IUPAC name of this compound.

....

5. Halo group (−F, −Cl, −Br, −I)

The compounds formed when one or more hydrogen atoms in a hydrocarbon is replaced with an equal number of halogen atoms are called halo compounds. There are organic compounds with functional groups such as fluoro (–F), chloro (–Cl), bromo (–Br), and iodo (–I).

The IUPAC nomenclature of halo compounds with more than two carbon atoms in the main chain is given below.

> Position of the halo group +hyphen + name of the halo group + name of the alkane

Write the IUPAC name of the compound given below.

$$\begin{array}{ccccccc} 1 & & 2 & & 3 & & \\ CH_3 & — & CH_2 & — & CH_2 & — & Cl \\ 3 & & 2 & & 1 & & \end{array}$$

- Number of carbon atoms in the main chain :
- Name of alkane with the same number of carbon atoms :
- Name of halo group :
- Correct position number of the carbon to which the halo group is attached :
- IUPAC name : 1–Chloropropane

- $$\begin{array}{ccccccc} & & & & Br & & \\ & & & & | & & \\ CH_3 & — & CH_2 & — & C & — & CH_3 \\ & & & & | & & \\ & & & & Br & & \end{array}$$ Write the IUPAC name of this compound.

Complete the table given below.

Compound	IUPAC name
....	2,3–Dichlorobutane
$\begin{array}{ccccc} CH_3 & — & CH & — & CH_3 \\ & & \vert & & \\ & & F & & \end{array}$	....
$CH_3 — CH_2 — CH_2 — CH_2 — CH_2 — I$	....

Table 1.4

6. Alkoxy group (−O−R)

Ethers are compounds containing alkoxy group.

'R' denotes an alkyl group. Let us see how they are named according to IUPAC rules.

$CH_3 - O - CH_2 - CH_3$: IUPAC name Methoxyethane

Ethers are named as alkoxyalkane.

–O– group is called ether linkage. Of the alkyl groups on either side of ether linkage (–O–), the longer alkyl group is considered as alkane and the shorter as alkoxy group.

Complete the table given below.

Compound	IUPAC name
$CH_3 - O - CH_3$	Methoxymethane
$CH_3 - CH_2 - CH_2 - O - CH_3$	....
....	Ethoxypropane

Table 1.5

Complete the table.

Functional group	Name of functional group	Common name
– OH	Hydroxyl	Alcohol
– COOH	....	Carboxylic acid
– CHO	Aldehydic	....
$>C=O$	Keto	....
– O – R	....	Ether
– F, – Cl, – Br, – I	....	Halo compounds

Aromatic compounds

You have learnt some basic concepts about aromatic hydrocarbons in the previous class. Analyse the structure of the compound given below.

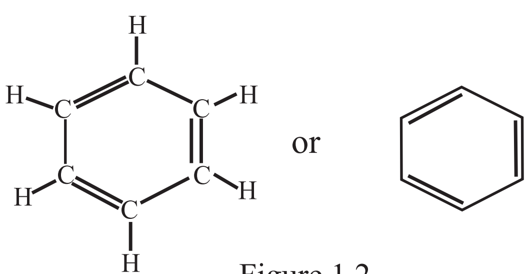
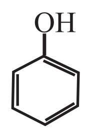


Figure 1.2

- Which category does this compound belong to? (Aliphatic / Alicyclic/ Aromatic)
- What is the name of this compound?
- Write the molecular formula of this compound.

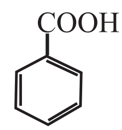
Phenol is the compound obtained when a hydrogen atom in benzene is replaced with an –OH group. Similarly, when a hydrogen atom is replaced with a –COOH group, the resulting compound is benzoic acid.

The structures of these compounds are given below.



Phenol

(C_6H_5 – OH)



Benzoic acid

(C_6H_5 – COOH)

Figure 1.3

Isomerism

The presence of different functional groups contributes to the vast number and diversity of organic compounds.
The structural formulae of certain compounds are given below. Analyse them.

i) $CH_3 — \underset{\substack{| \\ Cl}}{CH} — CH_3$ ii) $CH_3 — CH_2 — CH_2 — OH$

iii) $CH_3 — CH_2 — OH$ iv) $CH_3 — CH_2 — CH_2 — Cl$

- Which of these compounds have the same molecular formula?

  ....

- What is the functional group in each of these? ....
- Write the IUPAC name of these compounds. ....

You can see that the position number of carbon atoms to which the halo (–Cl) group is attached differ in these compounds. Although the compounds have same molecular formulae, they differ in their structural formulae. Therefore, these compounds exhibit differences in their chemical and physical properties. They are known as isomers.

> Compounds having same molecular formula and different chemical and physical properties are called isomers. This phenomenon is called isomerism. The structural formulae of these compounds are different.

Organic compounds show different types of isomerism based on the difference in structures. Let us get familiarised with some of them.

Chain isomerism

The structural formulae of two compounds are given below.

i) $CH_3 - CH_2 - CH_2 - CH_3$

ii)
$$\begin{array}{c} CH_3 - CH - CH_3 \\ \quad | \\ \quad CH_3 \end{array}$$

- Write the molecular formulae of these two compounds....................
- What is the peculiarity in the molecular formulae? ....
- Write their IUPAC names.

i) ....

ii) ....

It is clear that these are isomers. How do these compounds differ in their structures? Draw the structures of these compounds with the carbon atoms alone.

i) ....

$C - C - C - C$

ii) ....

$$\begin{array}{c} C - C - C \\ | \\ C \end{array}$$

Although the molecular formulae of these compounds are the same, the structures of the carbon chain are different. Such isomers are called chain isomers.

> Compounds that have the same molecular formula but differ in the structures of carbon chain are called chain isomers. This phenomenon is known as chain isomerism.

- The structural formulae of two chain isomers of pentane (C_5H_{12}) are given.

Write the structural formula of the third isomer.

i) $CH_3 — CH_2 — CH_2 — CH_2 — CH_3$

ii) $CH_3 — \underset{\underset{CH_3}{|}}{CH} — CH_2 — CH_3$

iii) ....

- How many chain isomers are possible for the compound $CH_3 — CH_2 — CH_2 — CH_2 — CH_2 — CH_3$? Write it down.

Position isomerism

The structural formulae of two familiar compounds are provided below. Analyse them.

i) $CH_3 — CH_2 — CH_2 — OH$ ii) $CH_3 — \underset{\underset{OH}{|}}{CH} — CH_3$

- What is the functional group present in them? ....
- What is their molecular formula? ....
- Write their IUPAC name.

  Compound (i) ....

  Compound (ii) ....

By analysing the structural formulae of these two compounds, it is clear that their molecular formulae are the same but the position numbers of their functional groups are different. Such isomers are known as position isomers.

When two compounds have same molecular formula and same functional group, but differ in the position of the functional group, they are called position isomers, and this phenomenon is known as position isomerism.

Analyse the structural formulae of the two pairs of compounds given below.

Pair I

i) $CH_3 — CH_2 — CH = CH_2$ ii) $CH_3 — CH = CH — CH_3$

- What is the molecular formula of these compounds? ....
- Write their IUPAC names.

  Compound (i) .... Compound (ii) ....

- What type of isomerism do they exhibit? ....

Although their molecular formulae are the same, the position of the double bond in them differs. Hence, they exhibit position isomerism.

Pair II

i) $CH_3 - CH_2 - C \equiv CH$ ii) $CH_3 - C \equiv C - CH_3$

- What is the molecular formulae of these compounds? ....
- Write their IUPAC names.

  Compound (i) .... Compound (ii) ....

- What type of isomerism do they exhibit? ....

Although their molecular formulae are the same, the position of the triple bond in them are different. Hence, they exhibit position isomerism.

After analysing the previous examples, it is clear that double bond and triple bond are also considered as functional groups.

- Write down the structural formulae of all the possible position isomers of the compound $CH_3 - CH_2 - CH_2 - CH_2 - CH_2 - Cl$.
- Write the structural formula and IUPAC name of the position isomers of the compound pentan-2-one.

Functional isomerism

The structural formulae and IUPAC names of two compounds are given.

i) $CH_3 - CH_2 - OH$ IUPAC name - Ethanol

ii) $CH_3 - O - CH_3$ IUPAC name - Methoxymethane

- What is the functional group present in each compound?

  Compound (i) ...., Compound (ii) ....

- Write their molecular formula. ....

After analysing the structural formulae of these two compounds, it is clear that they have the same molecular formula but different functional groups. Such isomers are called functional isomers.

When compounds have the same molecular formula but different functional groups, they are known as functional isomers, and this phenomenon is called functional isomerism.

The structural formulae of two compounds are given below.

i) $CH_3 — CH_2 — CHO$ ii) $CH_3 — CO — CH_3$

- What are the functional groups in them?

  Compound (i) .... , Compound (ii) ....
- Write their molecular formula. ....
- What type of isomerism do they exhibit? ....
- Write the structural formula and IUPAC name of the functional isomer of the compound $CH_3 — CH_2 — CH_2 — CHO$.

Metamerism

The structural formulae of two ethers are given below.

i) $CH_3 — CH_2 — O — CH_2 — CH_3$

ii) $CH_3 — O — CH_2 — CH_2 — CH_3$

- Write the molecular formulae of these compounds. ....

Now, examine the alkyl groups on either side of the ether linkage (— O —).

- What is peculiar about the alkyl groups on either side of the ether linkage (— O —) in compound (i)? ....
- What is peculiar about the alkyl groups on either side of the ether linkage (— O —) in compound (ii)? ....

In compound (i), the ether linkage (— O —) has same alkyl groups on either side, whereas in compound (ii), the ether linkage (— O —) has different alkyl groups on either side. These types of isomers are called metamers.

Compounds having same molecular formula but different alkyl groups attached to either side of the functional group are called metamers.

Look at another example.

i) $CH_3 — CH_2 — CO — CH_2 — CH_3$

ii) $CH_3 — CO — CH_2 — CH_2 — CH_3$

- Write their molecular formula. ....

These are also metamers.

The isomerism exhibited by compounds with the same molecular formula but different alkyl groups on either side of the bivalent functional group (group having valency 2, eg. (— O — , $>C = O$) is known as metamerism.

It is understood that the above metamers are also examples of position isomers.

- Write the structural formulae and IUPAC names of any two metamers of the compound
  $CH_3 — CH_2 — CH_2 — O — CH_2 — CH_2 — CH_3$.

Examine the compounds given below and identify the isomeric pairs. Specify the type of isomerism exhibited by each pair.

i) $CH_3 — CH_2 — CH_2 — CH_2 — OH$

ii) $CH_3 — CH_2 — CH_2 — CH_2 — CH_3$

iii) $CH_3 — CH_2 — CH_2 — O — CH_3$

iv) $\begin{array}{l} CH_3 — CH_2 — \underset{\displaystyle CH_3}{\underset{|}{CH}} — CH_3 \end{array}$

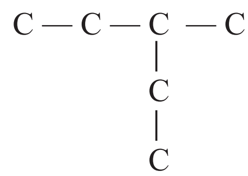
v) $CH_3 — CH_2 — O — CH_2 — CH_3$

vi) $\begin{array}{l} CH_3 — CH_2 — \underset{\displaystyle OH}{\underset{|}{CH}} — CH_3 \end{array}$

Chain isomerism	
Position isomerism	
Functional isomerism	
Metamerism	

Let us assess

1. A chain having 6 carbon atoms is given below.



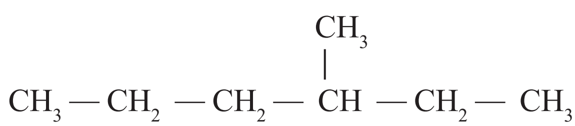
   a) Complete the structure by adding hydrogen atoms to each carbon atom.

   b) Write the molecular formula of this compound.

   c) How many carbon atoms are there in the main chain of this compound?

   d) Write its IUPAC name.

2. Write down the IUPAC names of the given compounds.

a) 

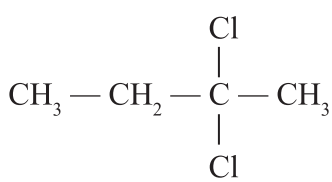
b) $CH_3 - CH_2 - CH_2 - CH = CH - CH_3$

c) $CH_3 - CH_2 - CH_2 - C \equiv C - CH_3$

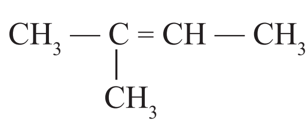
d) $CH_3 - CH_2 - CH_2 - CH_2 - COOH$

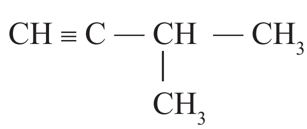
e) $CH_3 - CH_2 - CH_2 - CHO$

f) $CH_3 - CH_2 - CH_2 - CO - CH_3$

g) 

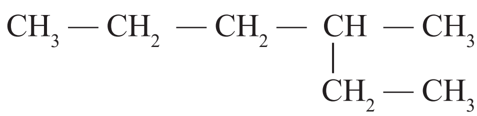
h) $CH_3 - CH_2 - O - CH_2 - CH_3$

i) 

j) 

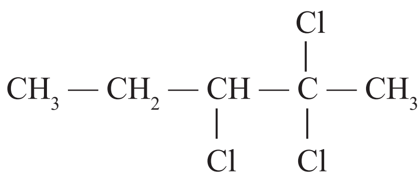
3. Write the structural formulae of the compounds given below.
   a) 2,3,3–Trimethylhexane
   b) Ethoxybutane
   c) Butan-2-one
   d) Pent–1–yne
   e) Hexan–2–ol
   f) 3–Bromoheptane
   g) Pentanal

4. The structural formulae and IUPAC names of certain compounds are given. Identify the wrong ones and correct them.

   i)  2–Ethylpentane

   ii) $CH_3 - CH_2 - CH_2 - CO - CH_3$ Pentan–2–one

   iii) $CH_3 - CH_2 - CH_2 - C \equiv C - CH_3$ Hex–3–yne

   iv)  2,3–Dichloropentane

5. i) $CH_3 - CH_2 - O - CH_2 - CH_3$ ii) $CH_3 - CH_2 - CH_2 - CH_2 - OH$
   a) What type of isomerism do these compounds exhibit?
   b) Write the structural formula of the metamer of compound (i).

6. The structural formulae of two compounds are given.
   i) $CH_3 - CH_2 - CH_2 - CH_2 - CHO$ ii) $CH_3 - CH_2 - CH_2 - CO - CH_3$
   a) What is the IUPAC name of the first compound?
   b) These two compounds are isomers. Why?
   c) What type of isomerism do these compounds exhibit?
   d) Write the structural formula of the position isomer of the second compound.

7. Examine the compounds given below and identify the isomeric pairs. What type of isomerism is shown by each pair?
   a) Methoxypropane
   b) 2,3–Dimethylbutane
   c) Propan–1–ol
   d) Ethoxyethane
   e) Propan–2–ol
   f) Hexane

Extended activities

1. Make and display the ball and stick models of the following compounds.
   a) 2, 2–Dimethylbutane
   b) But–2–ene
   c) Pent–1–yne
2. The molecular formulae of two compounds are given below. Draw their structures.
   a) C_6H_5–OH b) C_6H_5–COOH
3. Prepare and present a brief note on isomerism.
4. A student assigned the name 2–Ethyl–3–methylpentane to an organic compound.
   a) Write the structural formula of the compound and verify if the name given is correct.
   b) If incorrect, write the correct name of the compound.
   c) Write the molecular formula of the compound.
   d) Record the structural formulae of all the possible isomers of the compound in your science diary, along with their IUPAC names. Mention the type of isomerism they exhibit.

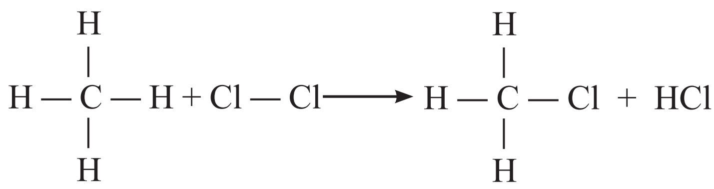
2 CHEMICAL REACTIONS OF ORGANIC COMPOUNDS

We use many substances like drugs, polymers, fuels, plastics, paints, clothing etc., which are the contribution of organic chemistry. Various organic compounds of these types are formed by organic reactions. Organic reactions are chemical reactions involving carbon compounds. Major organic reactions are substitution reactions, addition reactions, combustion, thermal cracking, polymerisation etc. Let us examine these types of chemical reactions.

Substitution reactions

Examine the given chemical equation of the reaction of methane with chlorine in the presence of sunlight.

Step (1)



$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$$

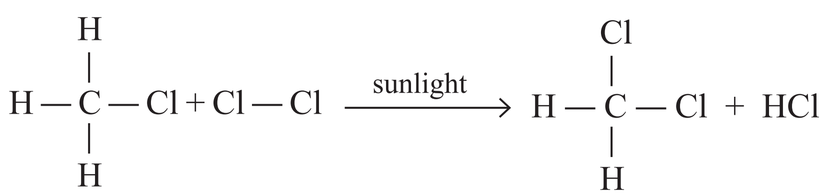
- Which hydrocarbon is given here?
- Which atom replaces hydrogen in the hydrocarbon?
- Write the IUPAC name of the product.

Such chemical reactions are called substitution reactions.

> Substitution reactions are chemical reactions in which an atom or group of atoms is replaced with another atom or group of atoms in a compound.

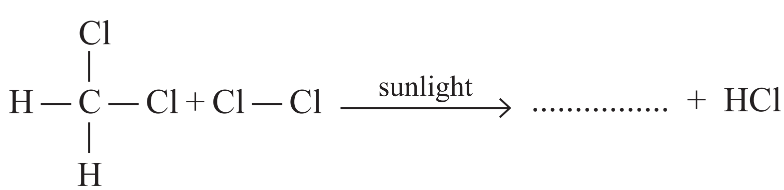
The products formed when CH_3Cl reacts further with chlorine in the presence of sunlight are given.

Step (2)

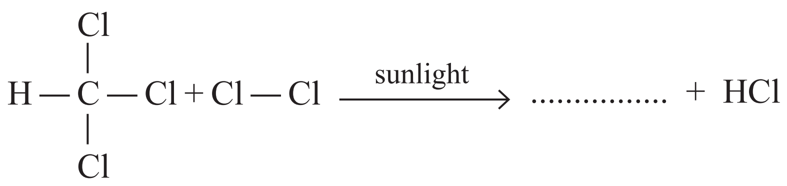


Complete the steps (3) and (4) and write the IUPAC name of the products.

Step (3)



Step (4)



- What are the products formed when ethane ($CH_3 - CH_3$ or C_2H_6) reacts with chlorine? Write the equations.

Addition reactions

CH_4 , $CH_2 = CH_2$, $CH \equiv CH$

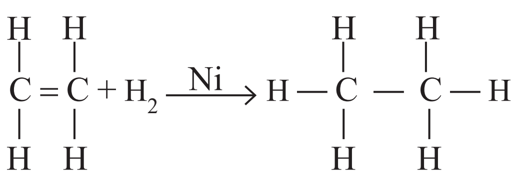
- Which among these are unsaturated hydrocarbons?

Write their IUPAC names.

....

....

The chemical equation of the reaction between ethene (C_2H_4) and hydrogen, in the presence of nickel (Ni) as catalyst at high temperature, is given.



$$CH_2 = CH_2 + H_2 \xrightarrow{Ni} CH_3 - CH_3$$

- What change takes place to the carbon-carbon double bond in ethene?
- What is the product formed?
- Is this product saturated or unsaturated?

Such chemical reactions are called addition reactions.

Addition reactions are reactions in which unsaturated organic compounds with double or triple bonds combine with certain molecules to form saturated compounds. The reactions in which triple bonded organic compounds partially combine with small molecules to form double bonded compounds are also addition reactions.

Complete the chemical equations of the addition reactions of ethyne and ethene.

$$H-C \equiv C-H + H_2 \rightarrow \text{..........................}$$

$$CH_2 = CH_2 + Cl_2 \rightarrow \text{..........................}$$

Complete the Table 2.1 given below.

Chemical reaction	Product	IUPAC name
$CH_3-CH=CH_2+H_2$		
$CH_2=CH_2+HCl$		
$CH_3-CH=CH-CH_3+HBr$		

Table 2.1

Polymerisation

Polymerisation is the process by which simple molecules join together to form large complex molecules.

The simple molecules are called monomers and the large complex molecules formed as a result of polymerisation are called polymers.

(Polymers: poly - many, mer - unit/part)

Based on the method of polymerisation, polymers are classified into addition polymers and condensation polymers.

Addition polymers

Addition polymers are obtained by the repeated addition reaction of monomers.

Have a look at the addition polymerisation between ethene molecules under high pressure and temperature in the presence of a catalyst.

$$nCH_2 = CH_2 \rightarrow \left[CH_2 - CH_2\right]_n$$

ethene polyethene (polythene)

In this chemical reaction,

What is the monomer? ....

What is the polymer? ....

Polyvinyl chloride (PVC) is a polymer used for the manufacture of plastic pipes. Its monomer is vinyl chloride.

Complete the equation given below.

$$nCH_2 = \underset{\displaystyle Cl}{\underset{|}{CH}} \longrightarrow \ldots\ldots\ldots\ldots\ldots\ldots$$

Vinyl chloride

Polytetrafluoroethene (Teflon), a polymer manufactured from tetrafluoroethene, is used to coat the inner surface of non stick cookware. Teflon is a polymer that can withstand high temperature.

$$nCF_2 = CF_2 \rightarrow \left[CF_2 - CF_2\right]_n$$

Tetrafluoroethene Polytetrafluoroethene (Teflon)

Polythene, polyvinyl chloride, teflon, etc. are addition polymers.

Monomer	Polymer	Uses
Vinyl chloride	PVC	Manufacture of pipes, plastic furniture, coating of electric conductors etc.
Ethene	Polythene	Manufacture of tarpaulin sheets, carry bags etc.
Isoprene	Natural rubber	Manufacture of tyres.
Tetrafluoroethene	Teflon	Coating of the inner surface of non stick cookware.
Acrylonitrile (Vinyl cyanide)	Orlon	Manufacture of synthetic fibres.

Table 2.2

Condensation polymers

Nylon 66 is a condensation polymer. Let us examine how it is manufactured.

Nylon 66 is obtained by the condensation polymerisation of adipic acid and hexamethylenediamine at high temperature and pressure. Here a small molecule, H_2O is removed.

$$\underset{\text{Adipic acid}}{nHOOC-(CH_2)_4-COOH} + \underset{\text{Hexamethylenediamine}}{nNH_2-(CH_2)_6-NH_2} \rightarrow$$

$$\underset{\text{Nylon 66}}{\left[CO-(CH_2)_4-CO-NH-(CH_2)_6-NH \right]_n} + nH_2O$$

Condensation polymerisation is the process in which different monomers combine together to form larger compounds accompanied by the removal of simple molecules.

Examine the Table 2.3 and answer the following questions.

Monomer	Polymer	Use
• Adipic acid • Hexamethylenediamine	Nylon 66	Manufacture of fabrics, combs, bristles of brushes etc.
• Phenol • Formaldehyde	Phenol formaldehyde resin (bakelite)	Manufacture of switches, plugs, handles of pressure cookers etc.
• Ethylene glycol • Terephthalic acid	Polyethylene terephthalate (polyester)	Manufacture of tarpaulin, bottles, fabrics etc.

Table 2.3

- What are the monomers of nylon 66?
- What polymer is obtained when phenol and formaldehyde undergo condensation polymerisation?
- What are the monomers of polyester?

Thermal cracking

The chemical equation involved in the heating of propane in the absence of air is given.

$$CH_3-CH_2-CH_3 \xrightarrow{\text{heat}} CH_4 + CH_2=CH_2$$

- What are the products obtained?
- Which is the unsaturated compound formed?

When heated in the absence of air, some hydrocarbons with high molecular weight decompose into hydrocarbons with lower molecular weight. This process is called thermal cracking.

Let us look at more examples.

Complete the chemical equations.

$$CH_3 - CH_2 - CH_2 - CH_3 \rightarrow CH_3 - CH = CH_2 + \text{..............}$$

$$CH_3 - CH_2 - CH_2 - CH_2 - CH_3 \rightarrow \text{..............} + CH_2 = CH_2$$

When hydrocarbons containing more carbon atoms are subjected to thermal cracking, the carbon chain is likely to break up in several ways. The products obtained as a result of thermal cracking depend on the temperature, pressure and nature of the hydrocarbons undergoing cracking. When saturated hydrocarbons undergo thermal cracking, the products include saturated and unsaturated hydrocarbons.

Certain plastic wastes can be broken down into lighter molecules by thermal cracking. This helps to control pollution to some extent.

Combustion of hydrocarbon

The chemical equation of burning of methane in air is given.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Heat}$$

What are the products obtained in this process?

....

Heat and light are also produced along with this process.

What are the products obtained when butane burns in air?

$$2C_4H_{10} + 13O_2 \rightarrow \text{..........} + \text{..........} + \text{Heat}$$

On burning, all hydrocarbons give the same products.

When hydrocarbons burn, they combine with oxygen in air to form CO_2 and H_2O along with heat and light. This process is called combustion.

Complete Table 2.4 related to the chemical reactions of hydrocarbons. Write the name of the type of each chemical reaction.

No.	Chemical equation	Name of the chemical reaction
1.	$CH \equiv CH + 2H_2 \xrightarrow{Ni}$	....
2.	$CH_2Cl_2 + Cl_2 \xrightarrow{sunlight}$ .... $+ HCl$	....
3.	$nCH_2 = CH_2 \longrightarrow$	....
4.	$CH_4 +$ .... $\longrightarrow CO_2 +$	....
5.	.... $+ H_2 \longrightarrow CH_3 - CH_3$	....

Table 2.4

Some important organic compounds

Methanol ($CH_3 - OH$)

Methanol or methyl alcohol is the first member of the alcohol family.

The structural formulae of some alcohols are given below.

(i) $CH_3 - OH$ (ii) $CH_3 - CH_2 - OH$ (iii) $CH_3 - CH_2 - CH_2 - OH$

- Write the name of the functional group.
- Write the IUPAC names of these alcohols.

Methanol is a compound with great industrial significance. It is also called wood spirit.

Methanol is industrially produced by treating carbon monoxide with hydrogen in the presence of catalysts.

The chemical equation of this reaction is given.

$$CO + 2H_2 \xrightarrow[573\ K]{catalyst} CH_3 - OH$$

Methanol is a poisonous substance.

Uses of methanol

- For manufacturing varnish, paint etc.
- For the manufacture of formic acid, formaldehyde etc. 40% solution of formaldehyde is formalin.

Ethanol ($CH_3 - CH_2 - OH$)

Ethanol or ethyl alcohol is another industrially important alcohol.

Industrial preparation of ethanol

Ethanol is manufactured by the fermentation of molasses. During the production of sugar from sugarcane, a viscous concentrated sugar solution is left behind after the separation of sugar crystals. This solution is called molasses.

The fermentation is carried out by adding yeast to the dilute molasses. The enzyme invertase present in yeast converts sugar solution to glucose and fructose. Then another enzyme zymase, converts glucose and fructose into ethanol.

Analyse the chemical equation of this reaction given below.

$$\underset{\text{(Sugar solution)}}{C_{12}H_{22}O_{11} + H_2O} \xrightarrow{\text{Invertase}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{Glucose / Fructose}}{C_6H_{12}O_6} \xrightarrow{\text{Zymase}} \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2$$

- 8-10% ethanol thus obtained is known as 'wash'.

- When wash is subjected to fractional distillation, 95.6% of ethanol is obtained. This is known as rectified spirit.
- 100% of ethanol is known as absolute alcohol.
- Power alcohol is a mixture of 20% absolute alcohol and 80% of petrol. It is used as fuel in vehicles.

Ethanol is an organic compound used in the manufacture of various other organic compounds. In such situations, toxic substances like methanol/pyridine/rubber distillate etc. are added to ethanol in order to prevent its misuse as a beverage. Ethanol thus obtained is called denatured spirit.

When denaturing is done with methanol, the resulting ethanol is called methylated spirit.

Uses of ethanol

- Production of power alcohol.
- As a solvent for medicines.
- Manufacture of paints.
- As preservatives.
- Production of organic compounds.

Ethanoic acid ($CH_3 - COOH$)

Ethanoic acid (acetic acid) is a carboxylic acid having great industrial importance.

The structural formulae and the IUPAC names of few other important carboxylic acids are given in Table 2.5. Complete it.

Sanitizers

Sanitizers are chemicals used to eliminate micro organisms like bacteria from the surface of objects making them safe. The word 'sanitizer' is derived from the Latin word 'sanitus' which means 'health'. They are available in the form of liquid, gel or foam. A solution prepared by mixing 833.3 mL of ethanol (96%), 41.7 mL of hydrogen peroxide (3%) and 14.5 mL of glycerol (98%) and made upto 1 litre using water can be used as a sanitizer. A few drops of perfume can also be added to give it a distinct fragrance.

Structural formulae	IUPAC names
$H - COOH$	Methanoic acid
$CH_3 - COOH$	Ethanoic acid
$CH_3 - CH_2 - COOH$	....
$CH_3 - CH_2 - CH_2 - COOH$	....

Table 2.5

Industrial preparation of ethanoic acid

Ethanoic acid can be prepared industrially by treating methanol with carbon monoxide in the presence of a catalyst.

$$CH_3 - OH + CO \xrightarrow{\text{catalyst}} CH_3 - COOH$$

Fermentation of ethanol with acetobacter bacteria in the presence of air yields less concentrated (5-8%) ethanoic acid. This is called vinegar.

Uses of ethanoic acid

- Manufacture of vinegar.
- Production of acetic anhydride, acetate ester, synthetic fibres etc.
- Solvent of polymers and resins.
- Manufacture of disinfectants.
- Manufacture of medicines.

Esters

Esters are formed when alcohols react with carboxylic acids. This reaction is called esterification.

The general formula of esters is $R - \overset{\overset{\displaystyle O}{\|}}{C} - O - R^1$. Here R, R^1 etc, are alkyl groups.

The chemical equation for the formation of the ester, ethyl ethanoate is given.

Methyl salicylate

Methyl salicylate is a methyl ester of the aromatic carboxylic acid, salicylic acid. It relieves the pain of joints and muscles. It is also known as the oil of wintergreen. It is extracted from certain species of evergreen plants which grow in winter and hence the name. This compound used as a flavouring agent, can also be prepared synthetically.

$$CH_3 - COOH + HO - CH_2 - CH_3 \xrightarrow{con.H_2SO_4}$$

$$CH_3 - COO - CH_2 - CH_3 + H_2O$$

Ethyl ethanoate

- What are the reactants?
- Write the names of their functional groups.

The ester, ethyl ethanoate is formed when ethanoic acid reacts with ethanol in the presence of concentrated sulphuric acid.

As esters have the fragrance of flowers and fruits, they are used to make artificial perfumes and juices.

Examine Table 2.6 which shows the names of the carboxylic acids and the alcohols required to prepare certain esters and the fragrance provided by them.

Name of carboxylic acid	Name of alcohol	Name of ester	Fragrance
Ethanoic acid	Isoamyl alcohol	Isoamyl acetate	Banana
Ethanoic acid	Benzyl alcohol	Benzyl ethanoate	Jasmine
Ethanoic acid	Octyl alcohol	Octyl ethanoate	Orange
Butanoic acid	Ethyl alcohol	Ethyl butanoate	Pineapple

Table 2.6

Find the esters from the compounds given below. Complete Table 2.7 by identifying the carboxylic acids and alcohols required to prepare them.

- $CH_3 - COO - CH_2 - CH_2 - CH_3$
- $CH_3 - CH_2 - COOH$
- $CH_3 - CH_2 - CH_2 - OH$

- $CH_3 - CH_2 - COO - CH_3$
- $CH_3 - CH_2 - COO - CH_2 - CH_3$
- $CH_3 - CH_2 - OH$
- $CH_3 - OH$
- $CH_3 - COOH$
- $CH_3 - CH_2 - COO - CH_2 - CH_2 - CH_3$

Ester	Carboxylic acid	Alcohol
$CH_3 - COO - CH_2 - CH_2 - CH_3$	$CH_3 - COOH$	$CH_3 - CH_2 - CH_2 - OH$
....	....	....
....	....	....
....	....	....

Table 2.7

Medicines

Medical science and medicines play a pivotal role in enhancing health and life span. Chemistry has contributed immensely to the advancement of various fields of medical science and pharmaceutical research.

The category and functions of certain medicines used in modern methods of medical therapy are given in Table 2.8.

Category	Function	Examples
Analgesics	Relieve pain	Aspirin
Antipyretics	Reduce body temperature	Paracetamol
Antiseptics	Control microorganism	Dettol
Antibiotics	Destroy infectious microorganisms and prevent their growth.	Penicillin

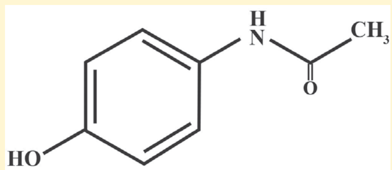
Table 2.8

Paracetamol and aspirin are commonly used medicines in the allopathic treatment system. Paracetamol is used both as an antipyretic and as an analgesic.

As aspirin has anti-blood coagulant property, it is used to prevent heart attack. Aspirin is used as an analgesic too.

Paracetamol

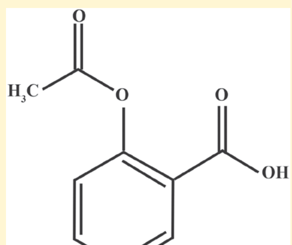
Paracetamol (N-acetyl-p-amino phenol) is a much familiar medicine to all of us. Although it is a medicine with comparatively less side effects, higher levels of its consumption affect the liver adversely. Paracetamol is included in the list of essential medicines of World Health Organisation.



Paracetamol

Aspirin

The chemical name of aspirin is acetyl salicylic acid.



Aspirin

Let us assess

1. a) In which of the following situation is methane converted to chloromethane?
   - (i) Chlorine + sunlight
   - (ii) Hydrochloric acid + sunlight
   - (iii) Oxygen + temperature
   - (iv) Heating in the absence of oxygen

   b) Write the name of such types of reactions.

2. a) How many hydrogen molecules are required to convert $CH \equiv CH$ (ethyne) into C_2H_6 (ethane)?

   b) Write the chemical equation of the reaction.

   c) To which category does this chemical reaction belong?

3. a) Complete the chemical equation.

   i) $CH \equiv CH + HCl \rightarrow A$

   ii) $n\,A \rightarrow B$

   b) Write the IUPAC names of the molecules A and B.

   c) To which category does each of these chemical reactions belong?

4. a) Which of the given polymers is used to coat the inner surface of cookware? (Polythene, polyvinyl chloride, teflon)

   b) What is the monomer of this polymer?

5. a) Which among the following is a condensation polymer? (Polyvinyl chloride, nylon 66, teflon)

   b) What are the monomers of nylon 66?

6. $$C_{12}H_{22}O_{11} + H_2O \xrightarrow{\quad A \quad} C_6H_{12}O_6 + B$$

   $$C_6H_{12}O_6 \xrightarrow{\quad C \quad} 2C_2H_5OH + D$$

   a) Identify A, B, C and D in the given chemical reactions.

   b) What is wash?

   c) How is rectified spirit obtained from wash?

   d) What is the purpose of denaturing rectified spirit?

7. a) How is ethanoic acid prepared industrially?

   b) 5 - 8% ethanoic acid is called ....

8. $CH_3 - COOH + CH_3 - OH \xrightarrow{\text{conc. } H_2SO_4} CH_3 - COO - CH_3 + H_2O$

   Analyse the equation and answer the following questions.

   a) What is the name of this chemical reaction?

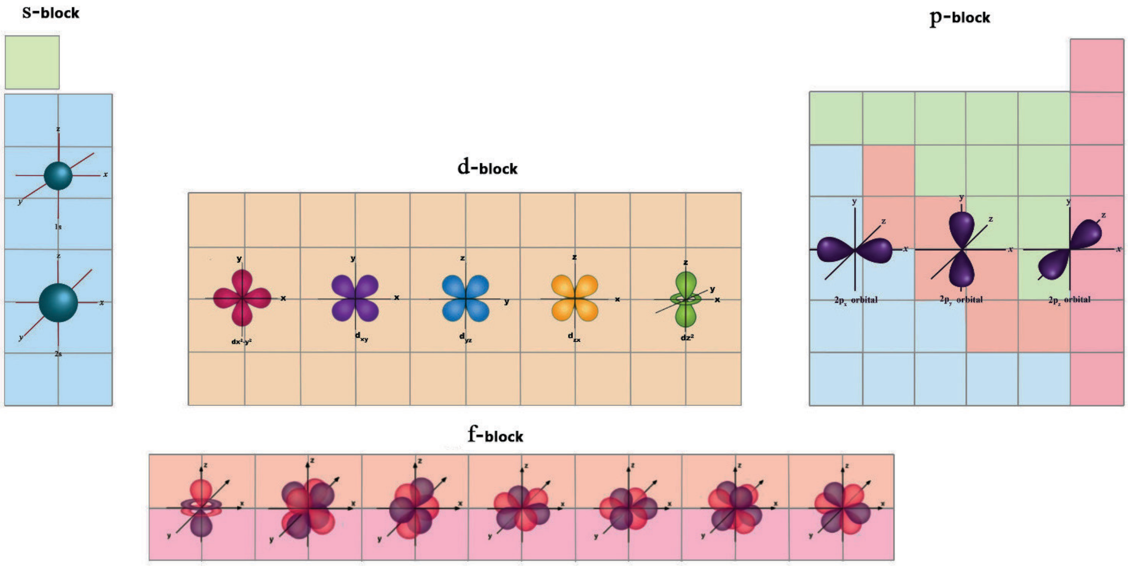
   b) What is the name of the ester formed?

   c) Write any two uses of esters.

Extended activities

1. Write an essay on the harmful effects on the human body and the social issues caused by the use of ethanol as a beverage.
2. Prepare and present a seminar on the topic ‘Polymers in daily life.’
3. Make a presentation on the topic ‘Organic compounds and their importance in daily life.’

3 PERIODIC TABLE AND ELECTRON CONFIGURATION



All substances in the universe are composed of atoms of different elements. You have already learnt that the table in which elements are arranged on the basis of their chemical properties is known as the periodic table. You know how to write and illustrate the electron configuration of the atoms of various elements. The orbit electron configuration of magnesium atom is given (Fig. 3.1).

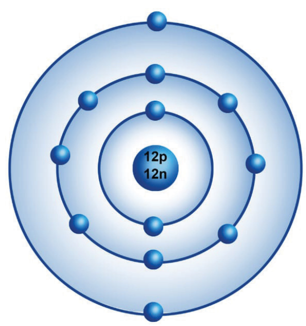


Figure 3.1

- Write down the electron configuration of magnesium.

  ....

- Electrons are arranged in three orbits (shells) in this element, aren't they? Which of these orbits has the least energy?

  ....

- Which orbit is the farthest from the nucleus?

  ....

- Which orbit has the maximum energy?

  ....

You have learnt that according to Bohr model of atom, orbits have definite energy and hence they are known as stationary energy levels.

But, later studies showed that Bohr model of atom has certain limitations. Louis de Broglie discovered the wave nature of matter. This wave nature is highly significant for microscopic particles. In other words, the scientific community has recognised the particle nature as well as the wave nature of electrons. According to Heisenberg's Uncertainty Principle, it is impossible to determine simultaneously the exact position and the exact velocity of a fast moving subatomic particle like electron. That is, on the basis of wave - particle dual nature and uncertainty principle an electron cannot be considered merely as a particle moving along an orbit. This is considered as one of the limitations of Bohr atom model.

An atom model that is in line with the dual nature of matter and the uncertainty principle was developed on the basis of quantum mechanics. According to quantum mechanical model of atom, there are regions around the nucleus where there is maximum probability of finding the electrons.

The regions around the nucleus where there is maximum probability of finding the electrons are called orbitals. The numbers which are used to describe the characteristics of orbitals and electrons based on quantum mechanical model of atom are called quantum numbers.

1. Principal quantum number (n)

Principal quantum number (n) is used to represent the shells or principal energy levels. The possible values for this quantum number are n = 1, 2, 3, 4, ...

n = 1 denotes K shell whereas n = 2 denotes L shell.

Have a look at the table given below.

Principal quantum number (n)	1	2	3	4
Shell	K	L	M	N

Table 3.1

2. Azimuthal quantum number (*l*)

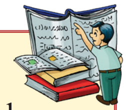
Azimuthal quantum number (*l*) defines the three dimensional shape of the orbital. The orbitals having definite three dimensional shape and oriented towards different directions are clubbed together and considered as subshells. Azimuthal quantum number is also used to represent the subshells of each shell. The subshells are denoted using the symbols s, p, d and f. The number of subshells in a particular shell is equal to the values of n. The value of *l* ranges from zero to (n-1). In other words, the value of *l* can be determined from the value of n.

When n = 1, $l = 0$

When n = 2, $l = 0,1$

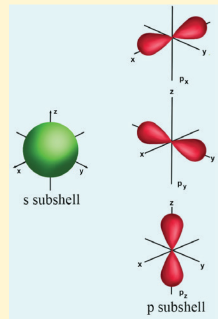
$l = 0$ denotes s subshell, and $l = 1$ denotes p subshell.

Look at Table 3.2.



Subshells

The subshells are represented using the symbols s, p, d, f etc. which are derived from the words describing certain properties of atomic structures of elements. s-sharp, p-principal, d-diffuse, f-fundamental. The s subshell has only one orbital, which is spherical in shape. The p subshell has three orbitals, each having dumbbell shape. The d subshell has five orbitals and the f subshell has seven orbitals with more complex shapes.



Principal quantum number (n)	1	2		3			4			
Shell	K	L		M			N			
l	0	0	1	0	1	2	0	1	2	3
Sub shell	s	s	p	s	p	d	s	p	d	f

Table 3.2

3. Magnetic quantum number (m)

Magnetic quantum number is denoted using the symbol 'm'. The quantum number that represents the difference in the orientation of orbitals is called magnetic quantum number. For a particular value of *l*, there are $(2l + 1)$ values for m. When the value of *l* is zero ($l = 0$), m can have only one value, that is (2 x 0 + 1 = 1). This shows that s orbital ($l = 0$) has only one orientation.

Which subshell is denoted by $l = 1$?

Here, m can have 3 values , that is $(2 \times 1 + 1) = 3$. It means that there are three different orientations for p orbitals.

How many values will be there for m when $l = 2$?

There will be 5 values for m, $(2 \times 2 + 1) = 5$

If so, how many d orbitals are there? ....

You can find the number of f orbitals in the same manner.

The total number of orbitals with respect to each shell is given in Table 3.3.

Principal quantum number (n)	1 K shell	2 L shell		3 M shell			4 N shell			
Subshell	s	s	p	s	p	d	s	p	d	f
Number of orbitals	1	1	3	1	3	5	1	3	5	7
Total number of orbitals	1	4		9			16			

Table 3.3

It is clear that the total number of orbitals in each shell is n^2.

You have already learnt that the maximum number of electrons that can be accommodated in each shell is $2n^2$.

If so, let us find out the maximum number of electrons that can be accommodated in each orbital.

The maximum number of electrons that can be accommodated in

$$\text{K shell} = \frac{\text{Total number of electrons}}{\text{Total number of orbitals in K shell}} = \frac{2}{1} = 2$$

Find out the maximum number of electrons that can be accommodated in L, M and N shells in the same way and record the values in your science diary.

Now it is clear that the maximum number of electrons that can be accommodated in each orbital $= 2n^2/n^2 = 2$

Complete the Table 3.4 based on this.

Principal quantum number (n)	1 K shell	2 L shell		3 M shell			4 N shell			
Maximum number of electrons that can be accommodated in each shell ($2n^2$)	2	8		18			32			
l	0	0	1	0	1	2	0	1	2	3
Subshell	s	s	p	s	p	d	s	p	d	f
Number of orbitals	1	1	3	1	3	5	1	3	5	7
Maximum number of electrons that can be accommodated in each subshell	1×2 = 2	.....	3×2 = 6	.....	.....	5 × 2 = 10	.....	....	....	7 × 2 = 14

Table 3.4

The maximum number of orbitals that can be accommodated in each shell = n^2
The maximum number of electrons can be accommodated in each shell = $2n^2$
The maximum number of electrons that can be accommodated in each orbital = 2
The maximum number of electrons that can be accommodated in each subshell = $2(2l+1)$

The maximum number of electrons that can be accommodated in each subshell = s – 2, p – 6 , d – 10, f – 14

Filling of electrons in subshells

You know that each shell has subshells.

Which subshell is common to all shells ? ....

How can the s subshell in each shell be represented?

Let us represent the subshells along with the serial number (value of n) of the corresponding shell.

The s subshell of K shell (n=1) can be represented as 1s.

If so, how can the subshells of the shells L, M , and N be represented?

Similarly, it is possible to represent the other subshells such as p, d, and f.

Complete the Table 3.5.

Principal quantum number (n)	1 K shell	2 L shell		3 M shell			4 N shell			
Subshell	s	s	p	s	p	d	s	p	d	f
The method of representing the subshell	1s	.....	2p	.....	.....	3d	.....	....	....	4f

Table 3.5

Now, you know the maximum number of electrons that can be accommodated in each subshell.

Complete the Table 3.6 based on this.

Principal quantum number (n)	1 K shell	2 L shell		3 M shell			4 N shell			
Subshell	1s	....	2p	....	3p	....	4s	....	....	....
The maximum number of electrons that can be accommodated in each subshell	2	....	6	....	....	10	....	....	....	14
The maximum number of electrons that can be accommodated in each shell	2	8		18			32			

Table 3.6

You have learnt that the shells do not have the same energy.

How does the energy of shells vary with the increase in distance from the nucleus? ....

The energy of shells increases in the order K< L< M< N.

The energy of subshells increases in the following order.

$$s < p < d < f$$

In each shell, there is a gradual increase in the energy of a particular subshell.

Example: 1s < 2s < 3s < 4s < 5s ....

The energies of other subshells also vary in this manner.

When electrons are added to a shell in an atom, they will be distributed in various subshells. Electrons are being filled gradually in the subshells in the increasing order of energy. This type of arrangement is known as subshell electron configuration.

When the electrons in an atom are distributed in subshells, they are being filled gradually in the increasing order of energies of the subshells. This is called subshell electron configuration.

Now it is evident that the ascending order of energy of subshells should be known, in order to write the subshell electron configuration. The order of energy can be found from the principal quantum number (n) and azimuthal quantum number (l) values representing each subshell.

The energy of subshells increases in the ascending order of (n+l) values.

On the basis of (n+l) values , let us examine which subshell has greater energy, 1s or 2s.

$1s \rightarrow n = 1, l = 0 \qquad (n+l) = 1 + 0 = 1$

$2s \rightarrow n = 2, l = 0 \qquad (n+l) = 2 + 0 = 2$

2s subshell has more energy than 1s subshell.

In this manner, we can find out that 2p subshell has more energy than 2s subshell.

Write down the (n+l) values of 2p and 3s subshells. ....

Now, it is clear that the (n+l) values of both 2p and 3s subshells are the same. In such cases, it is considered as the subshell with higher n value has more energy. This means that 3s subshell has more energy than 2p subshell. 3s represents the s subshell of the third shell (M) and 2p represents the p subshell of the second shell (L). It can be seen that on the basis of the distance from the nucleus, the 3s subshell has more energy than 2p subshell.

Examine which subshell has more energy, 3d or 4s.

3d $\qquad n = 3, l = 2, \quad n + l = 5$

4s $\qquad n = 4, l = 0, \quad n + l = 4$

That is, 4s subshell has lesser energy than 3d subshell. Hence filling of electrons takes place in 3d subshell only after 4s subshell gets filled.

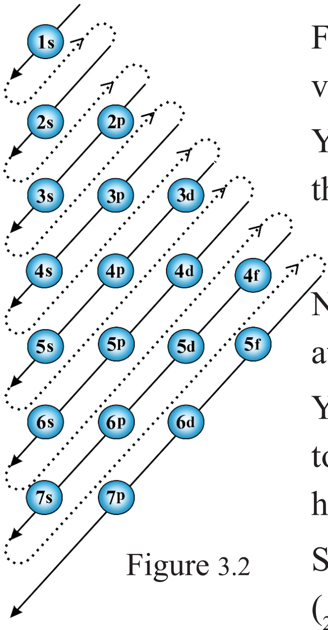


Figure 3.2

Figure 3.2 will help you to find the ascending order of energy of various subshells as mentioned above.

You can write the subshells in the ascending order of energy with the help of this figure.

$$1s < 2s < 2p < 3s < ..... < ..... < ..... < ....$$

Now, let us see how to write the subshell electron configuration of atoms of various elements.

You know that the only electron of the hydrogen atom gets added to its 1s subshell. Thus, the subshell electron configuration of hydrogen atom can be written as $1s^1$.

Similarly, what will be the electron configuration of Helium atom ($_2He$)? ....

It is clear that, in Helium atom the 1s subshell gets occupied by the maximum number of electrons that can be accommodated in it.

In the case of the subshell electron configuration of Lithium ($_3Li$), the electrons get filled in 1s and 2s subshells in the ascending order of energy. $_3Li$ ....

How to read the subshell electron configuration.

$1s^1$ 'One s one'

$1s^2 2s^1$ 'One s two' ' Two s one'

Complete Table 3.7 by writing the subshell electron configuration of the elements given below.

Complete Table 3.7 and verify it using Kalzium software.

Element	Number of electrons	Subshell electron configuration
$_4Be$	4	$1s^2 2s^2$
$_5B$	5	$1s^2\ 2s^2\ 2p^1$
$_6C$	6	....
$_7N$	7	....
$_8O$	8	....
$_9F$	9	....
$_{10}Ne$	10	$1s^2\ 2s^2\ 2p^6$

Table 3.7

It is evident that the p subshell of neon atom is occupied by the maximum number of electrons that it can accomodate.

Therefore in sodium the last electron is added to the 3s subshell. The subshell electron configuration of sodium is ....

Write down the subshell electron configuration of elements from $_{12}Mg$ upto $_{18}Ar$ in your science diary.

With the help of Figure 3.2, write down the electron configuration of potassium ($_{19}K$).

In which subshell does the last electron gets filled in potassium?

When 3p subshell is completely filled, the next electron is added to the 4s subshell.

Which subshell has more energy, 3d or 4s?

Write the shell wise electron configuration of potassium. ....

M shell of potassium can accomodate more than eight electrons. However, after the first 8 electrons get added to M shell, the next electron goes to the N shell. The reason is now clear to you.

Write down the electron configuration of calcium ($_{20}Ca$) in the same manner.

Shell wise electron configuration ....

Subshell wise electron configuration ....

?

- Compare the energies of 1s and 2s subshells.
- Which subshell has more energy, 3d or 4s?

You have learnt that scandium ($_{21}Sc$) is a transition element. To which shell does the last electron get added in the case of transition elements?

....

Now, write the shell wise electron configuration of scandium.

....

The subshell electron configuration of scandium is in the order $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$.

This is written as $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$ in the order of the shell.

That means, as per the order of energy, in transition elements, the 4s subshell is completely filled first followed by the gradual filling up of 3d subshell.

Write the electron configuration of the elements that follow, namely $_{22}Ti$ and $_{23}V$.

$_{22}Ti$ ...., $_{23}V$ ....

Record the subshell electron configuration of more transition elements in your science diary.

Let us get familiarised with another method of representing subshell electron configuration.

While writing the electron configuration of an element, the symbol of the noble gas preceding that element is shown within square bracket followed by the electron configuration of the remaining subshell.

For example, let us see how the electron configuration of sodium is written in this manner.

The electron configuration of sodium is $1s^2\ 2s^2\ 2p^6\ 3s^1$.

Which noble gas precedes this element? What is its atomic number?

....

Hence the electron configuration of sodium can be written including the symbol of neon as $[Ne]\ 3s^1$.

So, how will you write the electron configuration of potassium in the same manner? ....

Similarly write the subshell electron configuration of other elements also.

This method is commonly used for writing the subshell electron configuration of elements with higher atomic numbers.

The peculiarity of the subshell electron configuration of chromium (Cr) and copper (Cu)

Write the subshell electron configuration of chromium $_{24}Cr$. ....

But the stable subshell electron configuration of chromium is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$.

Let us examine the reason for this anomalous electron configuration.

What is the maximum number of electrons that can be accommodated in a d subshell?

It can be represented as d^{10}.

How can we represent a half filled d orbital?

....

The completely filled configuration (d^{10}) and the half filled configuration (d^5) are more stable than other configurations.

In other words, among the electron configuration from d^1 to d^{10}, d^5 and d^{10} are more stable. Hence for atoms where the configuration should be $d^4\ s^2$ and $d^9\ s^2$, the filling of electrons takes place such that the configuration becomes $d^5\ s^1$ and $d^{10}\ s^1$ respectively to attain stability.

Isn't it clear why there is a change in the electron configuration of chromium?

Write down the subshell electron configuration of $_{29}Cu$.

What change is to be made in the electron configuration of copper in order to attain stability as mentioned above? Note it down.

....

In the subshell electron configuration of chromium and copper, the configuration with half filled d subshell or completely filled d subshell show greater stability.

How to find the block from subshell electron configuration

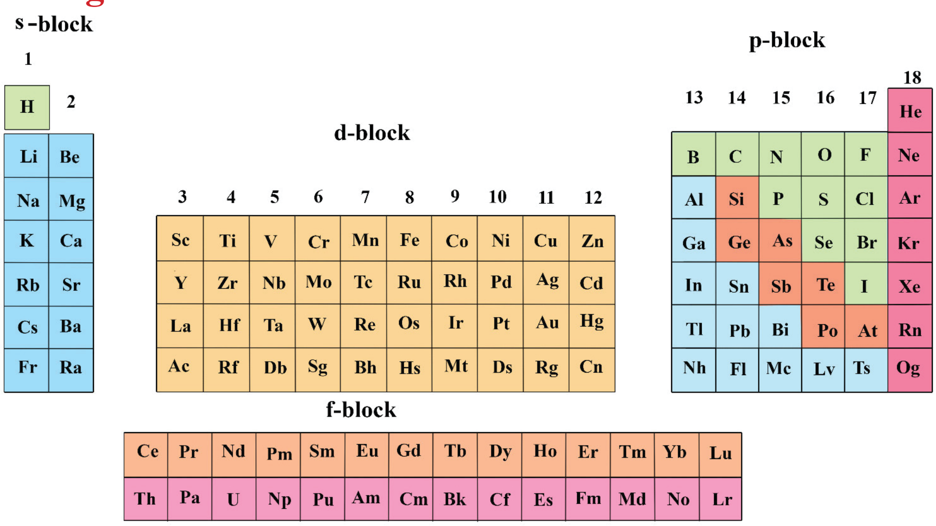


Figure 3.3

With the help of periodic table, complete Table 3.8 by finding the blocks to which the given elements belong.

Element	Subshell electron configuration	The subshell to which the last electron was added	Block
$_{4}Be$	....	....	s
$_{11}Na$	....	....	....
$_{8}O$	....	....	p
$_{17}Cl$	....	....	....
$_{21}Sc$	....	....	d
$_{26}Fe$	....	....	....

Table 3.8

By analysing the table, can you find the relation between the subshell to which the last electron was added and the block to which the element belongs?

The subshell to which the last electron is added will be the same as the block to which the electron belongs.

The groups which are included in s block - 1, 2
The groups which are included in p block - 13 to 18
The groups which are included in d block - 3 to 12
f block elements are placed at the bottom of the periodic table in two separate rows.

How to find the period number from subshell electron configuration

You know how to find the period number from shell wise electron configuration.

Write down the shell wise electron configuration of magnesium ($_{12}Mg$). ....

To which period does magnesium belong?...................................

It is possible to find the period number from subshell electron configuration. Complete the Table 3.9 with the help of periodic table.

Element	Subshell electron configuration	The highest shell number	Period number
$_{6}C$	....	2	....
$_{11}Na$	....	3	....
$_{21}Sc$	....	4	....

Table 3.9

The period number of an element is the highest shell number in its subshell electron configuration

How to find the group number from subshell electron configuration

Complete Table 3.10 and verify it using Kalzium software.

The group number of s block elements

It is possible to find the group number of elements on the basis of subshell electron configuration. Complete Table 3.10 with the help of periodic table.

Element	Subshell electron configuration	Block	Number of electrons in the outermost subshell	Group number
$_{3}Li$	....	....	....	1
$_{11}Na$	....	....	....	....
$_{12}Mg$	....	....	....	2
$_{20}Ca$	....	....	....	....

Table 3.10

Group number of s block elements is the number of electrons in the outermost s subshell.

The group number of p block elements

Which are the groups included in p block? ....

The group number of p block elements is the number obtained by adding the digit 10 (which represents 10 groups of transition elements) to the number of outermost electrons.

Element	Subshell electron configuration	The total number of electrons in the outermost s and p subshells	Group number
$_{5}B$	$1s^2\ 2s^2\ 2p^1$	3	13
$_{14}Si$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$	4	14
$_{7}N$	$1s^2\ 2s^2\ 2p^3$	5	15
$_{8}O$	$1s^2\ 2s^2\ 2p^4$	6	16
$_{17}Cl$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$	7	17
$_{18}Ar$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	8	18

Table 3.11

The group number of p block elements is the number obtained by adding the digit 10 (which represents 10 groups of transition elements) to the number of outermost electrons.

Complete Table 3.12 and verify it using Kalzium software.

Group number of d block elements

Where are the d block elements placed in periodic table? From which period does d block elements begin?

A few d block elements are given in table 3.12. Find the group number of these elements with the help of the periodic table and complete the table.

Element	Subshell electron configuration	Group number	Total number of electrons in 3d and 4s subshells
$_{21}Sc$	....	3	1+2 = 3
$_{24}Cr$	....	....	5 + 1 = 6
$_{26}Fe$	....	....	6 + 2 = 8
$_{29}Cu$	....	....	10 + 1 = 11
$_{30}Zn$	....	....	10 + 2 = 12

Table 3.12

The group number of d block elements will be same as the sum of the number of electrons in the outermost s subshell and the number of electrons in the d subshell preceding it.

Periodic trend in periodic table

Ionisation enthalpy

You have learnt about ionisation enthalpy (ionisation energy) in Standard IX.

Ionisation enthalpy of an element is the minimum amount of energy required to remove the most loosely bound electron from the outermost shell of an isolated gaseous atom of the element.

Using periodic table, let us examine how ionisation enthalpy varies on moving down a group.

What happens to the number of shells on moving down a group? (Increases / decreases)

What happens to the attractive force of nucleus on the outermost electrons as the number of shells increases? (Increases / decreases)

How does the nuclear charge vary on moving down a group? (Increases / decreases)

What happens to the attractive force of nucleus on the outermost electrons with an increase in the nuclear charge? (Increases / decreases)

Though the nuclear charge increases down a group, its influence is overcome by the increase in the number of shells.

If so, on moving down a group, does the possibility of donating the outermost electrons increase or decrease? ....

Ionisation enthalpy decreases on moving down a group.

Let us have a look at how ionisation enthalpy varies along a period.

Is there any change in the number of shells on moving from left to right in a period? ....

Does the nuclear charge increase? ....

Though nuclear charge increases on moving from left to right in a period, there is no change in the number of shells.

How does the attractive force of nucleus on the outermost electrons vary? (Increases / decreases)

If so, how does the ionisation enthalpy change?

....

On moving from left to right in a period, there is no change in the number of shells. But, nuclear charge increases gradually. The attractive force of the nucleus on the outermost electrons increases. Hence, ionisation enthalpy increases.

Where can you locate the elements with comparatively low ionisation enthalpy in the periodic table? ....

Caesium and Francium are the elements having the least ionisation enthalpy.

The elements having ns^1 and ns^2 as the valence shell electron configurations are considered to be s block elements. The elements of group 1 and that of group 2 have configuration ns^1 and ns^2 respectively. Hydrogen ($1s^1$) and helium ($1s^2$) are s block elements.

Where are the elements having generally higher ionisation enthalpy placed in the periodic table? ....

Now it is clear that ionisation enthalpy of s block elements is relatively lower than that of the elements of other blocks.

Which family of elements has the highest ionisation enthalpy? ....

Characteristics of s block elements

You know that alkali metals and alkaline earth metals belong to s block.

In these elements, electrons of which subshell take part in chemical reactions?

When s block elements take part in chemical reactions, the electrons of outermost s subshell are .... (donated / accepted / shared)

Find out the oxidation states of s block elements in the compounds given below.

- NaCl ....
- MgO ....

Determine the oxidation states of more s block elements from their compounds and record it in your science diary.

The elements of group 1 and group 2 exhibit +1 and +2 oxidation states respectively.

Radium (Ra)

Radium is the alkaline earth metal having the highest atomic mass. This radioactive element was discovered by Marie curie and her husband Pierre Curie in 1898. Radium does not exist free in nature This is mostly found in the minerals of uranium.

The most stable isotope of radium is Ra-226. As the alpha radiations emitted by radium produce scintillations on zinc sulphide, it was used as luminescent paint in watch, clock etc. In early days isotopes of radium were used for the treatment of cancer. Since contact with radium may cause cancer, genetic changes and other serious health issues, its industrial use is restricted . However the mixture of radium and beryllium is used as a source of neutrons in the fields of scientific research and petroleum exploration.

s block elements generally exist in solid state. But Caesium ($_{55}Cs$) is a metal having very low melting point (28.40°C). Hence it exists in liquid state on warm days. The elements Francium ($_{87}Fr$) and Radium ($_{88}Ra$) are radioactive in nature.

Characteristics of p block elements

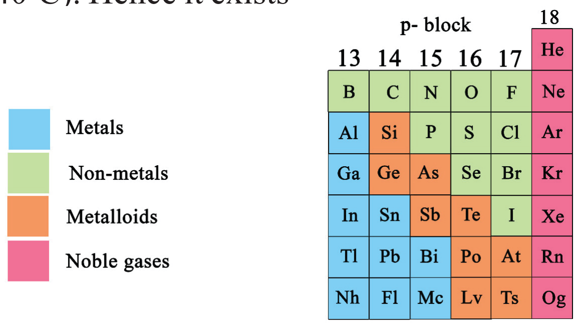


Figure 3.4

Notice the given portion of the periodic table.

- Which are the groups that include p block elements?
- p block elements include metals, non metals and metalloids. These elements exist in solid, liquid and gaseous states. Find examples and note them down in your science diary.

Let us see what is the peculiarity in the oxidation state of p block elements as compared to s block elements.

Find the oxidation state of p block elements in the following compounds.

HF $\quad\quad$ Al_2O_3 $\quad\quad$ SO_2

p block elements exhibit both positive (+) and negative (–) oxidation states.

Gallium is an element having a very low melting point (29.77°C). On warm days, it exist in the liquid state.

s block and p block elements are main group elements.

Is the ionisation enthalpy lower for s block elements or p block elements? Explain.

Characteristics of d block elements

d block elements are known as transition elements.

Using periodic table, analyse the peculiarities of d block elements given in the box.

- They are placed in groups 3 to 12.
- The electrons are being gradually filled up in the penultimate shell.
- All the d block elements are metals.

Let us examine some other characteristics of d block elements.

You have learnt that elements of the same group show similarities in properties. d block elements also show similarities in properties in their corresponding groups. Have a look at the Table 3.13 in which subshell electron configuration of d block elements of 4^{th} period is given.

Group number	3	4	5	6	7	8	9	10	11	12
Electron configuration	Sc $3d^1\ 4s^2$	Ti $3d^2\ 4s^2$	V $3d^3\ 4s^2$	Cr $3d^5\ 4s^1$	Mn $3d^5 4s^2$	Fe $3d^6 4s^2$	Co $3d^7 4s^2$	Ni $3d^8 4s^2$	Cu $3d^{10}$ $4s^1$	Zn $3d^{10}$ $4s^2$

Table 3.13

What is the outermost subshell electron configuration of these elements (excluding Cr , Cu)? ....

Similarly the outermost subshell electron configuration of the elements of 5th period will be generally $5s^2$.

The electron configuration of the outermost subshell of d block elements (transition elements) along a period is generally the same (ns^{1-2}). Therefore, they show similarities in properties not only within the groups but also along the periods. You have already learnt about this similarity along a period in shell wise electron configuration.

General outermost electron configuration

s block - ns^{1-2}

p block - $ns^2\ np^{1-6}$

d block - $(n - 1)d^{1-10}\ ns^{1-2}$

Oxidation states of d block elements

Ferrous chloride and ferric chloride are two chlorides of iron.

Ferrous chloride $FeCl_2$

Ferric chloride $FeCl_3$

The oxidation state of Fe in $FeCl_2$ is ....

The oxidation state of Fe in $FeCl_3$ is ....

(Hint: The oxidation state of Cl = -1)

It is clear that Fe shows variable oxidation states.

What is the reason for this?

The subshell electron configuration of $_{26}Fe$ is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$.

How does it change into Fe^{2+}? ....

Can you write the subshell electron configuration of Fe^{2+} ? ....

How does Fe get + 3 oxidation state in $FeCl_3$?

....

The elements Zinc, Cadmium and Mercury which belong to the 12th group do not show all the general characteristics of transition elements. Hence, they are known as pseudo transition elements.

From which subshells are the electrons lost?

There is only a slight difference between the energies of the outermost s (4s) subshell and the penultimate d (3d) subshell. Hence, from which subshell is the third electron lost along with the two 4s electrons? ....

You can write the subshell electron configuration of Fe^{3+} on the basis of this, can't you ? ....

The atomic number of manganese (Mn) is 25. Different compounds of manganese are given in Table 3.14. Determine the oxidation state of Mn and complete the table.

Compound	Oxidation state of **Mn**	Subshell electron configuration of **Mn** ion
$MnCl_2$	+2	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$
MnO_2	....	....
Mn_2O_3	....	....
Mn_2O_7	....	....

Table 3.14

Now it is clear that d block elements show variable oxidation states. What is the reason for it?

In transition elements there is only a slight energy difference between the outermost s subshell and the penultimate d subshell. As a result, under favourable conditions, electrons from the d subshell also take part in chemical reactions. That is why transition elements show variable oxidation states.

Coloured compounds

Among the compounds in your science lab, identify the coloured ones and list them. Aren't they generally compounds of transition elements?

For example: Copper sulphate ($CuSO_4 . 5H_2O$), potassium permanganate ($KMnO_4$), potassium dichromate ($K_2Cr_2O_7$).

The presence of ions of transition elements (eg:- Cu^{2+} , Co^{2+}) or the ions which contain transition elements (eg:- MnO_4^- , $Cr_2O_7^{2-}$) are generally responsible for the colour of the compounds.

But the compounds of zinc ($_{30}Zn$) are colourless.

The compounds of transition elements are generally coloured.

Record the characteristics of d block elements in your science diary.

Characteristics of f block elements

Where are the f block elements located in the periodic table?..

In which subshell does the filling up of electrons take place in them?

In these elements, filling up of electrons takes place in the anti penultimate shell. They are known as inner transition elements.

The metal of the 21st century- Titanium (Ti)

Titanium gets its name from the name of the Greek God Titan. It was discovered by the scientist William Gregor in 1791. Although it is strong, it has light weight, low density and high melting point (1668°C). This metal can be easily alloyed. It shows superconductivity at very low temperatures. This metal does not undergo corrosion when it comes into contact with sea water, acids , chlorine etc. Since it is non-toxic and non-allergic, it is used in medical field to make various implants. Titanium plays a significant role in the manufacture of aircraft, spacecraft, missiles, ships, sports equipments, and energy storage cells. Titanium dioxide is a key component in the manufacture of paint. It is also used in MRI scanning machine and water purification.

How are the f block elements of the 6th period known?

....

What about the elements of the 7th period?

....

Let us have a look at the characteristics and uses of f block elements.

They show variable oxidations states.

Actinoids are radioactive elements. These include man-made elements as well.

Certain isotopes of elements like Uranium (U), Thorium (Th) and Plutonium (Pu) are used as fuel in nuclear reactors.

Neodymium (Nd) is used for making strong magnets.

Some elements are used as catalyst in the petroleum industry. For example:- Cerium (Ce), Lanthanum (La).

Rare earth elements

Rare earth elements consist of 17 elements including 15 elements of Lanthanoids along with scandium and yttrium. In reality, they are not so rare in nature as the name indicates. Since they lie scattered on the earth's surface, it is difficult to find them in large quantities in a particular region. Hence, the process of extracting the metal from its ore is often a challenging task. Rare earth elements have diverse applications in the field of technology. They are used in computers, LCD screens, mobile phones, renewable energy sources, batteries, etc. Monazite, one of the main ores of rare earth metals, is commonly found in the coastal regions of southern Kerala.

Let us assess

1. The element X having 3 shells belongs to group 17.
   a) Write the subshell electron configuration of this element.
   b) To which block does this element belong?
   c) What is its period number?
   d) Write the molecular formula of the compound formed when X reacts with an atom of element Y which belongs to the third period and has one electron in its p subshell.

2. A few subshells are given.

   3p, 4d, 3f, 2d, 2p

   a) Among these, which subshells are not possible?
   b) Explain the reason.

3. The position of two elements A and B in the periodic table are given. (Symbols are not real)

   A - 4^{th} period and 2^{nd} group
   B - 2^{nd} period and 16^{th} group

   a) Write the subshell electron configuration of A and B.
   b) Write the values of n and l of electrons in the outermost subshell of A.
   c) How many orbitals are there in the subshell of B having the outermost electron? Find it on the basis of magnetic quantum number 'm'.
   d) Write the molecular formula of the compound formed by the combination of A and B.
   e) What type of chemical bond is present in this compound?

4. The subshell electron configuration of a few elements are written on the basis of noble gas.

   (i) [Ne] $3s^2\ 3p^6$ (ii) [He] $2s^1$
   (iii) [Ar] $3d^2\ 4s^2$ (iv) [Kr] $5s^2$

   a) Write the complete subshell electron configuration.
   b) Find the symbols of these elements with the help of periodic table.

5. The last electron of an atom is added to the 3d subshell. There are 7 electrons in this subshell. Answer the following questions regarding this atom.

   a) What is its atomic number?
   b) Write its complete electron configuration.
   c) To which block does it belong?
   d) Find its period number.
   e) What is its group number?

6. Find the oxidation state of s block elements in the following compounds..

   a) Na_2O b) KBr c) CaO d) $MgCl_2$

7. Which subshell is represented by each pair of the quantum number values given below?

   a) n = 1, $l = 0$ b) n = 2, $l = 1$

8. A few subshells are given. Find the values of n and l.

   a) 2s b) 4p c) 3d d) 5f

9. The subshell electron configuration of certain elements are given. Write the short form of each using the symbol of corresponding inert gas.

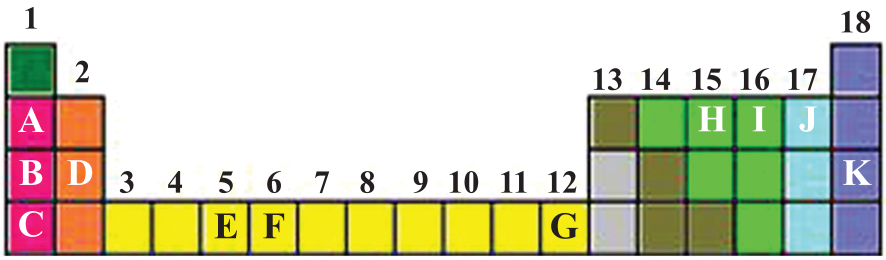
   a) $1s^2 2s^2 2p^4$ b) $1s^2 2s^2 2p^6 3s^2 3p^5$

   c) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ d) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$

10. Iron (Fe) takes part in chemical reactions and becomes Fe^{3+} ion. (Atomic number of Fe = 26).

    a) Write the electron configuration of this ion.
    b) Write the chemical formula of the compound formed when this ion combines with sulphate ion (SO_4^{2-}) .
    c) Which is the other oxidation state of this element? Write the electron configuration of the ion thus formed.
    d) Iron shows variable oxidation states. Why?

11. A portion of the periodic table is given. Answer the following questions (Symbols are not real).



a) Which element has the lowest ionisation enthalpy?

b) Identify the alkaline earth metal.

c) Which are the d block elements?

d) Which element has the completely filled d subshell?

e) Identify the element having the electron configuration $3d^3\,4s^2$?

f) Identify the noble gas.

g) Which element has only 3 electrons in the outermost p subshell?

Extended activities

1. Write down the subshell electron configuration of elements having atomic number 1 to 30.
2. Prepare a a slide show on the shapes of various orbitals with the help of presentation software.
3. Prepare a short note on various fields in which f block elements are used.

4 GAS LAWS AND MOLE CONCEPT

As in this picture, we can see huge balloons flying in the air in some tourist centres. Do you feel like rising up and flying in such balloons?

Have you ever thought about the reasons why these balloons rise up in the air, float and come down? Helium gas is filled in such balloons. Why do balloons filled with helium gas rise up in the air?

Is the density of helium gas filled in these balloons greater or lesser than that of the atmospheric air?

....

Tabulate the substances around us on the basis of their physical states.

Solid	Liquid	Gas

Table 4.1

Do you know, which of these states has the least density?

....

Find out the elements which exist in gaseous state at ordinary temperature (20°C-25°C) and write them down in the science diary.

....

From the following, tabulate the compounds which exist in gaseous state at ordinary temperature.

- Carbon dioxide, sodium chloride, ammonia, glucose, ammonium chloride, methane, sulphur dioxide, carbon monoxide, nitric acid, nitrogen dioxide.

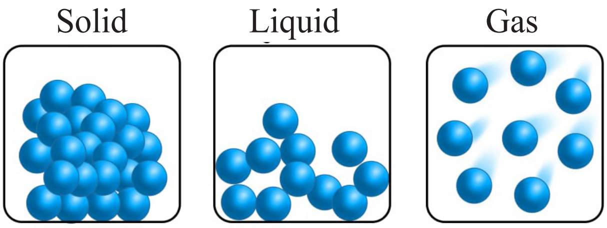


Figure 4.1

You have learnt about the arrangement of particles in different physical states.

Compare the distance between the molecules, force of attraction between them, freedom of movement of the molecules and their energy in gaseous state, with those in the other states of matter and write down.

Distance between the molecules	Very high
Force of attraction between the molecules	
Freedom of movement of the molecules	
Energy of the molecules	

Table 4.2

Scientists have conducted numerous studies on the general properties of gases. The postulates of kinetic molecular theory proposed by James Clerk Maxwell and Ludwig Boltzmann to explain these properties are given below.

- Gases are made up of minute particles (atoms/molecules).
- The attractive force between gaseous molecules is very low.
- As the molecules are so far apart, the volume of gaseous molecules is negligible in comparison with the total volume of the gas.

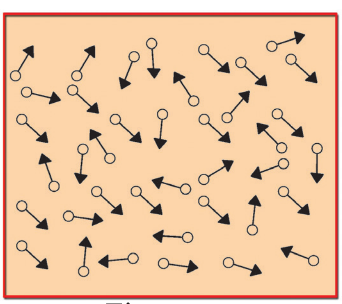


Figure 4.2

- The volume can be reduced by reducing the distance between the gaseous molecules.
- Gaseous molecules are in constant motion in all directions. As a result, the molecules collide with one another and with the walls of the container. The force produced due to the collision of molecules with the walls of the container results in gaseous pressure.

- Collisions of gaseous molecules are elastic in nature. That means, the kinetic energy of the molecules before and after the collision will be same.
- The average kinetic energy of the gaseous molecules is directly proportional to its temperature.

General properties of gases

The measurable properties of gases such as volume, pressure and temperature are explained below.

Volume

The space occupied by a substance is taken as its volume.

If a liquid filled in a bottle of volume 1L is transferred to a bottle of volume 2 L, what will be its volume?

....

If oxygen gas filled in a bottle of volume 1L is transferred to a bottle of volume 2 L, what will be its volume?

....

Figure 4.3

What if a gas of volume 2 L is transferred to a bottle of 10 L volume?

....

> The volume of a gas is the volume of the container in which it is occupied.

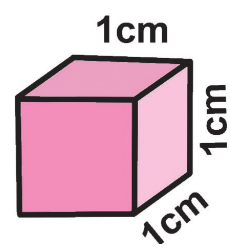
Let us examine the units used to state the volume of a gas.

Generally, the unit used is litre (L).

1 cm^3 is the volume of a container having length 1cm, breadth 1 cm and height 1 cm.

This is equal to 1mL.

$$1000\ cm^3 = 1000\ mL = 1\ L$$



1 cm^3 = 1 cc
(cc=cubic centimeter)

Figure 4.4

The SI unit of volume is m^3.

1m^3 is the volume of a container having length 1m, breadth 1m and height 1m.

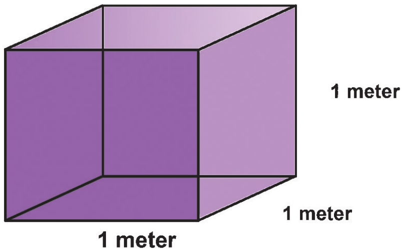


Figure 4.5

$$
\begin{aligned}
1\ m^3 &= 1\ m \times 1\ m \times 1\ m \\
&= 100\ cm \times 100\ cm \times 100\ cm = 1000000\ cm^3 \\
&= 1000000\ mL \\
&= \frac{1000000}{1000}\ L\ [1000\ mL = 1L] \\
&= 1000\ L
\end{aligned}
$$

Now it is clear that $1\ m^3 = 1000\ L$.

Pressure

We have seen that gaseous molecules are in constant random motion. As a result, they collide with one another and with the walls of the container. Due to these collisions, a force is experienced on the surface. Gaseous pressure is the force experienced per unit surface area.

$$\text{Pressure} = \frac{\text{Force}}{\text{Surface area}}$$

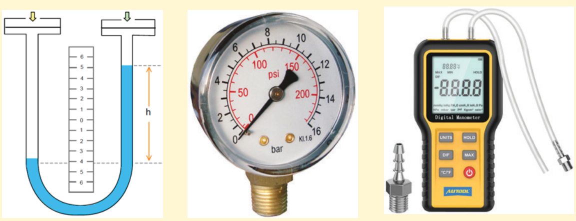
$$P = \frac{F}{A}$$

Generally, pressure is expressed in terms of atmospheric pressure (atm). You have learnt about atmospheric pressure in lower classes. The SI unit of pressure is Pascal (Pa).

(Pa = N/m^2 or Newton per square meter).

$$1\ atm = 1.01325 \times 10^5\ Pa.$$

The pressure of gases is measured using manometer.



Different types of manometers.

Temperature

Temperature is another measurable property of a gas.

Which is the energy acquired by molecules due to its movement? (Kinetic energy / potential energy)

What happens to the kinetic energy of the molecules if a gas is heated? (Increases / decreases)

When gases are heated, the energy of molecules increases and hence temperature also increases.

The SI unit of temperature is Kelvin(K). To convert the common unit °C to Kelvin, add 273 to it.

If temperature is t°C,

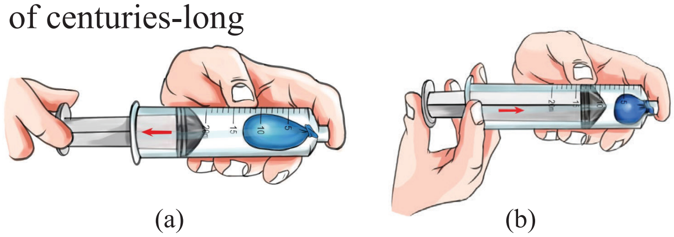
$$t°C = (t + 273)\ K$$

We can learn more about Kelvin scale in the following parts of this unit.

Gas Laws

The gas laws were established as a result of centuries-long experiments and observations on the physical properties of gases.

a) The relation between pressure and volume of a gas - Boyle's law



(a) (b)

Figure 4.6

Take a large syringe and remove its piston. Put into the syringe a small inflated balloon with its open end tied up. Now, refix the piston in its position (Fig. 4.6). Close the other end of the syringe with your finger. Record the changes happening to the balloon when the piston is pushed in and pulled back.

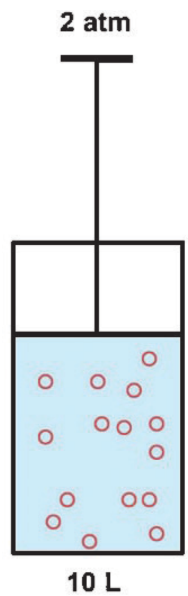


Figure 4.7 (a)

Activity	Observation
Piston is pushed in.	
Piston is pulled back.	

Table 4.3

What happens to the pressure inside the syringe when the piston is pushed in? (Increases / decreases)

What happens when the piston is pulled back?

....

Now, let us look at another situation.

A definite mass of a gas taken in a cylinder with a freely movable piston is illustrated in the figure (Fig. 4.7(a))

Let us increase the pressure applied on this without changing the temperature (Fig. 4.7 b & c).

P (atm)	V (L)
2	10
4	5
10	2

Table 4.4

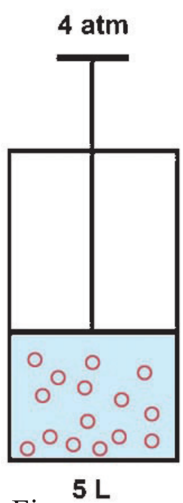


Figure 4.7 (b)

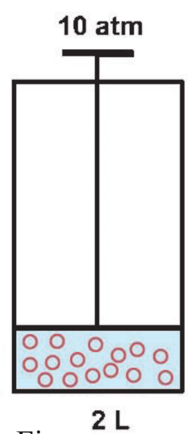


Figure 4.7 (c)

What happens to the volume when pressure is increased in each situation?

....

Robert Boyle
(1627-1691)

As pressure increases, volume decreases.

This relation was proposed by the scientist, Robert Boyle in 1662.

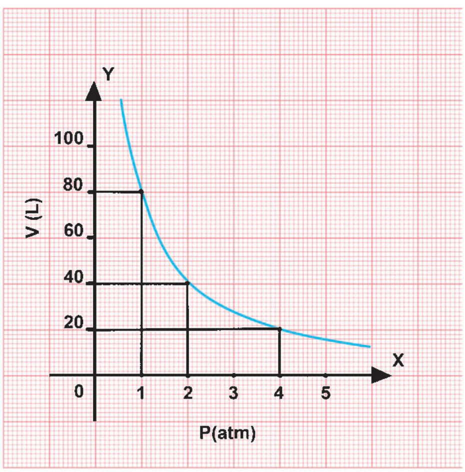
At constant temperature, the volume of a fixed mass of gas is inversely proportional to its pressure.

That is, $V \alpha \frac{1}{P}$ (temperature, mass constant)

$V = \text{a constant} \times \frac{1}{P}$

$PV = k$ (k = a constant)

The value of k depends on the gas and its mass.



Pressure-volume (P - V) graph
Figure 4.8

If the volume of a fixed mass of gas is V_1 at pressure P_1 and V_2 at pressure P_2, Then

$$P_1V_1 = P_2V_2$$

To substantiate Boyle's law, we can illustrate the relation between volume and pressure of a fixed mass of gas, using a graph (Fig 4.8). From this graph, we can see that PV is a constant at constant temperature, for a definite mass of gas.

It can be seen that PV is a constant at all points in the graph.

Explain the following situations on the basis of Boyle's law.

a. The size of weather balloons goes on increasing as they rise above the sea level.

b. The size of the air bubbles rising up from the bottom of an aquarium increases as they reach the surface of the water.

- The volume of a definite mass of gas at a pressure 1 atm is 44 L. If the pressure is increased to 4 atm, what will be its volume?

According to Boyle's law,

$$P_1V_1 = P_2V_2$$
$$1 \times 44 = 4 \times V_2$$
$$V_2 = 44/4 = 11 \text{ L}$$

The volume of a definite mass of gas at 1 atm pressure is 1200 L. How much pressure is to be applied to change its volume to 30 L? (Temperature constant) ?

b) The relation between volume and temperature - Charles's Law

Let us do an experiment (Fig. 4.9). Make a small hole on the lid of a glass bottle and fix an empty refill into it. Add a small drop of ink into the refill, then blow gently to move the ink to the centre of the refill. Cover the bottle with your palms. What do you observe?

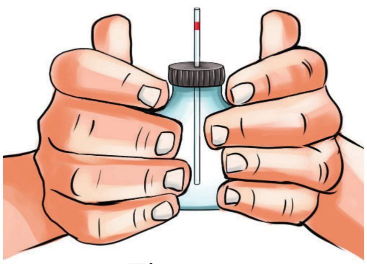


Figure 4.9

....

Upto which point of the arrangement does air occupy?

It is from the bottom of the bottle to that part of the refill that contains the ink.

What change occurs to the temperature of the air inside the bottle when covered the bottle with palms?

....

Does the volume of the gas increase or decrease during this period? ....

It is now clear why the ink rises up in the refill.

Place the bottle in water and cool it. What do you observe?

....

What happens to the volume of the gas when the bottle is cooled?

....

From this, can you find out the relation between the temperature of a gas and its volume?

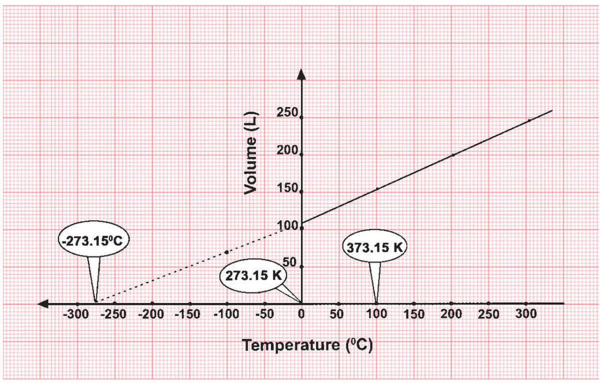
....

Here, you can see that the ink in the refill acts like a freely moving piston. When temperature of the gas increases, ink rises up in the refill and when temperature decreases, it comes down.

Jacques Alexandre Ceasre Charles (1746-1823)

Towards the end of the 18th century, it was Jacques Alexandre Ceasre Charles, a French scientist, who studied and recorded the changes in the volume of gases in accordance with temperature.

Plot the relation between temperature and volume of gases at constant pressure in a graph. If this graph is extrapolated backwards, you can see that it will meet the temperature axis (X axis) at –273.15°C (Fig 4.10).



Volume-temperature (V - T) graph

Figure 4.10

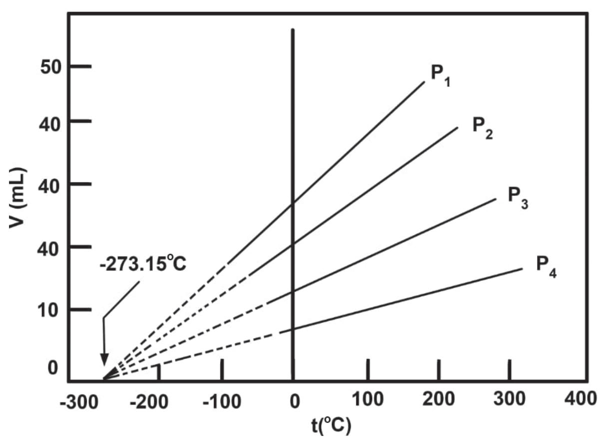
This means that at –273.15°C, the volume of a gas becomes zero.

Even if the pressure is changed, it is found that the temperature-volume graph is a straight line and all the straight lines meet at –273.15°C (Fig. 4.11).

The analysis of the graph (Fig. 4.11) is given in the table below.

	Kelvin scale	Celsius scale	Volume
Absolute zero	0 K	–273°C	0
Freezing point of water	273 K	0°C	115 L
Boiling point of water	373 K	100°C	150 L

Table 4.5



Volume-temperature (V - T) graph at different pressures

Figure 4.11

It was Lord Kelvin who identified that the lowest temperature that can be attained by a gas is –273.15°C and named it Absolute zero. For practical purposes, –273°C is taken as the value of Absolute zero. Using this, he developed the Kelvin scale of temperature.

According to Table 4.5, it is evident that as temperature increases, the volume of gas increases.

That is,

> At constant pressure, the volume of a definite mass of a gas is directly proportional to its temperature in Kelvin Scale. This is Charles's law.
> $V \propto T$ (pressure, mass constant)
> $V = k \times T$ (k - a constant)
> $V/T = k$, a constant

If the volumes of a definite mass of gas are V_1 and V_2 at temperatures T_1 and T_2 respectively, then

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

- If the volume of a gas is 150 L at 27°C, what will be its volume at 0°C?

$$27°C = 27 + 273 = 300\ K$$

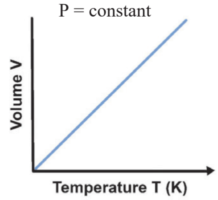
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{150}{300} = \frac{V_2}{273}$$

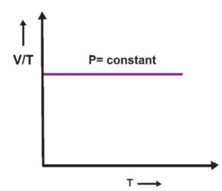
$$V_2 = \frac{150 \times 273}{300} = 136.5\ L$$

- The volume of a definite mass of hydrogen gas at 300 K temperature is 60 mL. At what temperature the volume of this gas becomes 20 mL?
- The relation between volume and temperature of a definite mass of a gas at constant pressure is illustrated in the two graphs given below.

a) What is the relation between temperature and volume?
b) To which gas law do these graphs relate?
c) State the law.
d) What is the peculiarity of the value of V / T ?



V-T ഗ്രാഫ്



V/T-T ഗ്രാഫ്

Practical applications of Charles's law in everyday life.

- During summer, vehicle tyres are filled with air at lower pressure.

- Liquid ammonia is a substance that quickly changes from liquid to gaseous state. The containers of liquid ammonia are submerged in cold water for some time, before opening.

Avogadro's Law

Avogadro's law shows the relation between the number of particles in gases (N) and their volumes (V).

That is,

At constant temperature and pressure, equal volumes of all gases contain an equal number of molecules. In other words, at constant temperature and pressure, equal number of molecules of different gases occupy equal volumes.

At constant temperature and pressure, the volume of a gas is directly proportional to the number of molecules. This is Avogadro's Law.

$$V \propto N \text{ (Temperature, pressure constant)}$$

Applications of Avogadro's law in daily life.

- Inflating balloons.
- Filling air in footballs.

Combined gas equation

Let us consider Boyle's law and Charles's law which we have already discussed.

Boyle's law

$V \propto \frac{1}{P}$ (mass, temperature constant)

Charles's law

$V \propto T$ (pressure, mass constant)

Considering both laws together,

$$V \propto \frac{1}{P} \times T$$

$$V = \text{a constant} \times \frac{1}{P} \times T$$

$$\frac{PV}{T} = k \text{ (a constant)}$$

If the pressure, volume and temperature of a definite mass of a gas are changed from P_1, V_1 and T_1 to P_2, V_2 and T_2 respectively, then

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$. This is combined gas equation.

The volume of a definite mass of gas at 1 atm pressure and 300 K temperature is 30 L. What will be its volume at 273 K temperature and 0.5 atm pressure?

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{1 \times 30}{300} = \frac{0.5 \times V_2}{273}$$

$$V_2 = \frac{30 \times 273}{300 \times 0.5} = 54.6 \text{ L}$$

The volume of a gas at 27°C and 1atm pressure is 100 mL. What will be its volume at 273 K temperature and 2 atm pressure?

Mole concept

In everyday life various units are used to count objects.

Eg.

2 numbers : pair	12 numbers : dozen
20 numbers : score	144 numbers : gross

Are these units sufficient to count extremely small particles like atoms, molecules and ions?

Even the presence of such tiny particles can be detected only with the help of powerful modern microscopes. Counting such minute particles is impossible.

Can you believe that a single drop of water contains approximately 10^{19} water molecules?

Can you imagine how huge this number is?

How many years it will take to finish counting this number?

Mole is the unit used to indicate such large numbers.

A mole is the quantity of a substance containing 6.022×10^{23} particles (atoms /molecules/ ions). This number came to be known as Avogadro number (N_A) named in honour of the Italian scientist Amedeo Avogadro.

Amedeo Avogadro (1776-1856)

Mole is the SI unit of quantity of matter. This represents the number of particles in that substance.

One mole of water contains 6.022×10^{23} water molecules.

The concept of mole is highly significant in Chemistry. It enables accurate measurement of the quantity of reactants and products that are to be used in chemical reactions.

Avogadro number

In 1908, Jean Perrin, a physicist, discovered that the number of particles in one mole is 6.7×10^{23}. This number came to be known as Avogadro number. The value of Avogadro number changes from time to time. A more accurate value of 6.022×10^{23}, which was found by De Bievre in 2001, is being considered now. The value of Avogadro's number continues to change based on advanced methods of accurate quantifications, new findings on atomic structure and the modified scientific definition of the concept of a mole.

Year	Scientist who discovered	Avogadro number
1908	Perrin	6.7×10^{23}
1917	Mullikan	6.064×10^{23}
1929	Birge	6.0644×10^{23}
1931	Bearden	6.019×10^{23}
1945	Birge	6.02338×10^{23}
1951	DuMond	6.02544×10^{23}
1965	Bearden	6.022088×10^{23}
1973	Cohen	6.022045×10^{23}
1987	Deslattes	6.022134×10^{23}
1994	Basile	6.0221379×10^{23}
2001	De Bievre	6.0221339×10^{23}

The changed values of Avogadro's number

Relative atomic mass and mole

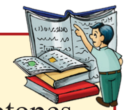
Relative atomic mass expresses the mass of one atom relative to that of the another. It indicates how many times one atom is heavier as compared to another. The atomic mass of an element is expressed as, how many times is the mass of the atom, when compared to the $1/12^{th}$ mass of a carbon-12 atom, which is considered as a single unit. This mass is known as unified mass.

The atomic masses have decimal values because the average atomic mass is calculated by taking into account the presence of isotopes.

However, for practical purposes, they are often used as whole numbers.

Element	Average atomic mass	Relative atomic mass
Hydrogen	1.0079	1
Oxygen	15.9994	16
Sodium	22.989	23
Carbon	12.011	12
Nitrogen	14.0067	14

Table 4.6



Why atomic mass is a fraction.

The atomic mass of elements is calculated by considering the average mass of their isotopes based on their natural abundance.

For example, the natural abundance of neon is as, $^{20}Ne = 90.48\%$, $^{21}Ne = 0.27\%$, $^{22}Ne = 9.25\%$.

$$\text{Average atomic mass} = \frac{(20 \times 90.48) + (21 \times 0.27) + (22 \times 9.25)}{100}$$
$$= 20.18 \text{ u}$$

The natural abundance of Cl-35 isotope is 75% and that of Cl-37 is 25%.

$$\text{The average atomic mass of this element} = \frac{(35 \times 75) + (37 \times 25)}{100}$$
$$= 3550/100 = 35.5 \text{ u}$$

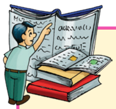
The atomic mass of most elements is a fraction, since average atomic mass is calculated in this way.

Analyse the table given below.

Element	Relative atomic mass	Gram atomic mass	Number of mole atoms	Number of atoms
Copper	63.5	63.5 g	1	6.022×10^{23}
Iron	55.8	55.8 g	1	6.022×10^{23}
Zinc	65.3	65.3 g	1	6.022×10^{23}
Aluminium	27	27 g	1	6.022×10^{23}
Nitrogen	14	14 g	1	6.022×10^{23}

Table 4.7

An element that weighs as much as its relative atomic mass in grams contains 6.022×10^{23} atoms.



Dalton

Dalton is a unit used to express the atomic mass. In 1993, IUPAC put forward a non-SI unit, Dalton which was equivalent to unified mass unit. This is represented by the symbol Da.

Eg. The atomic mass of Hydrogen - 1.008 Da

This mass is known as gram atomic mass. One gram atomic mass contains 1 mole atoms.

Why is the quantity of one mole atom of different substances different, even though they contain the same number of atoms?

The difference in quantity is due to the different sizes of the atoms, even though they are same in number.

Molar Mass

The total mass of atoms in a molecule is known as molecular mass.

Eg. Calculate the molecular mass of carbon dioxide (CO_2, atomic mass O = 16, C = 12).

Molecular mass $= 1 \times C + 2 \times O$

$= 1 \times 12 + 2 \times 16 = 12 + 32 = 44$

Calculate the molecular mass of molecules given in the table. Atomic masses of constituent elements are given in the bracket.

(Atomic mass - H = 1, O = 16, N = 14, C = 12, S = 32)

Element / Compound	Chemical formula	Molecular mass
Oxygen	O_2	$2 \times 16 = 32$
Ammonia	NH_3	$14 + 3 \times 1 = 17$
Water	H_2O	....
Glucose	$C_6H_{12}O_6$	....
Sulphuric acid	H_2SO_4	....
Nitrogen	N_2	....

Table 4.8

If 6.022×10^{23} oxygen molecules are taken, the mass will be 32 g. This is the molecular mass of oxygen expressed in grams. This is known as gram molecular mass.

What will be the mass of 6.022×10^{23} CO_2 molecules?......... g

This is the molar mass of the compound.

One molar mass of a compound contains one mole molecules.

Complete the following table.

(Atomic mass - H = 1, O = 16, N = 14, C = 12, S = 32, Ca = 40)

Compound	Molecular mass	Molar mass	Number of moles	Number of Molecules
NH_3	17	17g	1	6.022×10^{23}
CO_2	....	....	....	6.022×10^{23}
H_2O	....	....	1	....
NO_2	....	....	....	6.022×10^{23}
$CaCO_3$	....	....	....	....

Table 4.9

How many moles are there in 44g of CO_2?

....

Can you find out the number of moles in 88 g CO_2 ?

44 g = 1 mole

88 g = $\frac{88}{44}$ = 2 mole

That is, number of moles = $\frac{\text{Given mass}}{\text{Molar mass}}$

- What is the number of molecules in this sample of CO_2?

Number of molecules in 1 mole of CO_2 = 6.022×10^{23}

Number of molecules in 2 moles of CO_2 = $2 \times 6.022 \times 10^{23}$

Complete the following table.

(Atomic mass - H = 1, O = 16, N = 14, C = 12, S = 32, Ca = 40, Na = 23, Cl = 35.5)

Substance	Molar Mass	Given mass	Number of moles	Number of molecules
NH_3	....	85 g	....	.... $\times 6.022 \times 10^{23}$
CO_2	....	220 g	....	....
H_2O	....	....	10	$10 \times 6.022 \times 10^{23}$
NO_2	....	92 g	....	....
$C_6H_{12}O_6$	....	360 g	....	....
NaCl	58.5 g	1170 g	....	....

Table 4.10

Volume of gases and mole

According to Avogadro's law, at constant temperature and pressure equal volumes of all gases contain equal number of molecules.

What is the peculiarity of the volume occupied by an equal number of molecules of different gases kept at same temperature and pressure?

....

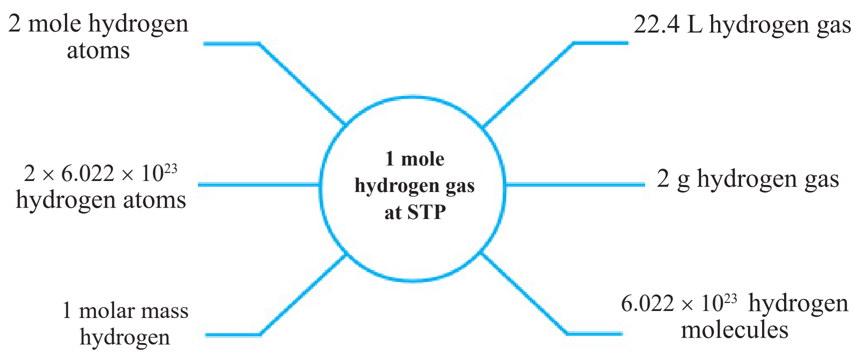
If temperature and pressure are fixed at 273 K and 1 atm respectively, it is known as STP (Standard Temperature and Pressure). At STP, one mole of any gas occupies a volume of 22.4 L. This is known as molar volume at STP.

$$\text{Number of moles of gases at STP} = \frac{\text{Given volume (in litres)}}{\text{Molar volume at STP}}$$

Complete the table given below.

Gas	Molar mass	Given Mass	Number of moles	Volume (L)
O_2	......	32 g	....	22.4
NH_3	....	170 g	....	....
CO_2	....	....	3	....
NO_2	....	....	2	....

Table 4.11



Ideal gas equation

Considering Boyle's law, Charles's law and Avogadro's law,

$V \ \alpha \ \frac{1}{P}$ (T, n constant)

$V \ \alpha \ T$ (P, n constant)

$V \propto n$ (n = number of moles), (P, T constant)

$V \propto \frac{1}{P} \times T \times n$

$PV = \text{a constant} \times nT$

This constant is known as Universal Gas Constant. This is represented by the letter R.

PV = nRT

This is ideal gas equation.

The gases which obey ideal gas equation at all temperature and pressure are known as ideal gases.

?

1. 224 L O_2 (oxygen) gas is taken at STP.
   a) How many moles of oxygen are there in it?
   b) How many molecules are there in it?
   c) Calculate the mass of this oxygen sample. (Hint: atomic mass O = 16)
2. Find the samples with equal volumes from the ones given below at STP.
   a) 64 g O_2
   b) 44 g CO_2
   c) $2 \times 6.022 \times 10^{23}$ NH_3 molecules

Mole concept and chemical equations

You have already learnt to balance equations.

Have a look at the given equation.

$$2H_2 + O_2 \rightarrow 2H_2O$$

Here, it can be seen that two hydrogen molecules combine with one oxygen molecule to form two water molecules.

If we take two moles of hydrogen molecules instead of two hydrogen molecules?

$$2 \text{ mol } H_2 + 1 \text{ mol } O_2 \rightarrow 2 \text{ mol } H_2O$$

How can the equation be written in terms of mass?

What is the mass of 2 mol hydrogen?

$2 \times 2 = 4$ g

What is the mass of 1 mol oxygen? ....

You have already found that the mass of 2 mol H_2O is 36 g.

$$4 \text{ g } H_2 + 32 \text{ g } O_2 \rightarrow 36 \text{ g } H_2O$$

According to this equation, when 4 g hydrogen completely reacts with oxygen, 36 g water is obtained.

How many grams of water will be obtained if 40 g hydrogen reacts completely with oxygen?

Water obtained when 4 g H_2 reacts completely = 36 g

Water obtained when 1 g H_2 reacts completely = 36/4= 9 g

Water obtained when 40 g H_2 reacts completely = 9×40 =360 g

How much oxygen is required for this much hydrogen to react completely and form water?

$$4 \text{ g } H_2 + 32 \text{ g } O_2 \rightarrow 36 \text{ g } H_2O$$

The oxygen required for 4 g hydrogen to react completely = 32 g

The oxygen required for 1 g hydrogen to react completely = 32/4 = 8 g

The oxygen required for 40 g hydrogen to react completely

= 8 x 40 = 320 g

Let us analyse another situation.

The reaction in which nitrogen and hydrogen react to give ammonia is of high significance in the field of agriculture.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

If this equation is analysed on the basis of mole concept,

1 mol N_2 + 3 mol H_2 $\rightarrow$ 2 mol NH_3

On the basis of mass, it is

28 g N_2 + 6 g H_2 $\rightarrow$ 34 g NH_3

If we know how much ammonia is to be produced, we can determine the amount of reactants to be used?

- How many moles of nitrogen and hydrogen are required to produce 6 mol ammonia?

  1 mol N_2 + 3 mol H_2 $\rightarrow$ 2 mol NH_3

What is the ratio of the reactants?

....

The amount of nitrogen required to produce 2 mole ammonia - 1 mol

The amount of nitrogen required to produce 1 mole ammonia - ½ mol

The amount of nitrogen required to produce 6 mole ammonia - ½ × 6 = 3 mol

The amount of hydrogen required to produce 2 mole ammonia - 3 mol

The amount of hydrogen to be reacted for producing 1 mole ammonia - 3/2 mol

The amount of hydrogen to be reacted for producing 6 mole ammonia - 3/2 × 6 = 9 mol.

- 3 moles of nitrogen should react with 9 moles of hydrogen to form 6 moles of ammonia . If the amount of any of these reactants is less, the product will be formed proportionately.
- What is the quantity of ammonia produced when 6 moles of nitrogen react with 6 moles of hydrogen?

Only 2 moles of nitrogen react with 6 moles of hydrogen. (N : H = 1 : 3)

2 moles of nitrogen + 6 moles of hydrogen → 4 moles of ammonia

How many moles of nitrogen will be left after the reaction?

.... mol.

The main component of biogas is methane (CH_4). Note the equation of its combustion.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

On the basis of moles,

.... mol CH_4 + ... mol O_2 → .... mol CO_2 + ... mol H_2O

On the basis of mass,

.... g CH_4 + ... g O_2 → .... g CO_2 + ... g H_2O

What is the mass of oxygen required to react with 16 g of methane?

....

Find the volume of CO_2 produced by the complete combustion of 16 g of methane?

....

Thus, it can be seen that the amount of CO_2 released when each gram of methane is burned is about three times the mass of methane. Butane (C_4H_{10}) present in cooking gas also emits about three times CO_2 when burned.

All of these are fossil fuels. Now, do you understand why it is advised to control the use of fossil fuels?

Compounds such as lime and baking soda are used to neutralise acid wastes from industries. The above examples will help you to find out the amount of compounds to be used for this purpose.

Eg. $H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$

$H_2SO_4 + 2NaHCO_3 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$

The amount of lime and baking soda used by factories can be found out from these equations.

- Calculate the amount of lime in kg required to neutralise 980 kg of sulphuric acid.

Let us assess

1. Convert the units of the given temperatures.

°C	K
0	273
100	373
30	......
....	300
40	....

2. Complete the table. (Atomic Mass - H = 1, C = 12, O = 16, N = 14)

Substance	Molecular Mass	Given mass	Number of moles	Volume at STP
H_2	....	10 g	....	112 L
CO_2	....	440 g	....	....
NH_3	....	340 g	....	....

3. A balanced equation of the reaction to produce ammonia is given.

$$N_2 + 3H_2 \rightarrow 2NH_3$$

a) How many moles of hydrogen is required for 10 moles of nitrogen to react completely?

b) How much ammonia will be produced if 10 moles of nitrogen react completely?

4. 448 L of gas is stored in a cylinder at 0°C and 1 atm pressure.

a) How many moles of molecules does this gas contain?

b) What is the number of molecules in this sample?

5. 400 L of gas is stored in a cylinder at 27 °C and constant pressure.

a) What will be the temperature if the volume of this gas is reduced to 200 L at the same pressure?

b) Which gas law is relevant to this context?

c) The boiling point of a substance is 3°C. Above what temperature in Kelvin does this substance obey the gas laws?

6. a) What is the number of Cl_2 molecules in 710 g chlorine gas?

b) What is the total number of atoms in this sample?

7. How many grams of hydrogen is required to react with 700 g nitrogen in the production of ammonia?
8. Calculate the following.
   a) How many moles of $CaCO_3$ are present in its 1 kg?
   b) Mass of the same number of NH_3 molecules as contained in 88 g of CO_2.
   c) Mass of 22.4 L CO_2 kept at STP.

   (Hint: Atomic mass - H = 1, C = 12, O = 16, N = 14, Ca = 40)
9. The volume of a cylinder containing NH_3 at STP is 4480 mL.
   a) Find the number of moles of NH_3 in the cylinder.
   b) Find the mass of this NH_3 gas.
   c) How many molecules of NH_3 are there in this gas cylinder??
10. Consider the chemical reaction

$$2H_2 + O_2 \rightarrow 2H_2O$$

   a) How many moles of oxygen (O_2) should react to obtain 10 mole H_2O?
   b) Find the mass of Oxygen gas (O_2) required to obtain 10 mole H_2O?

   (Atomic mass - H = 1, O = 16)

Extended activities

1. 448 L HCl gas kept at STP completely reacts with ammonia gas at STP to form NH_4Cl.

$$NH_3 + HCl \rightarrow NH_4Cl$$

   Find the mass of ammonia gas used in this reaction.

2. 48 g C burns in air and carbon monoxide gas is formed. If the mass of CO gas formed is 56 g, what is the volume of oxygen gas at STP used in this reaction?

CONSTITUTION OF INDIA

Part IV A

FUNDAMENTAL DUTIES OF CITIZENS

ARTICLE 51 A

Fundamental Duties- It shall be the duty of every citizen of India:

(a) to abide by the Constitution and respect its ideals and institutions, the National Flag and the National Anthem;

(b) to cherish and follow the noble ideals which inspired our national struggle for freedom;

(c) to uphold and protect the sovereignty, unity and integrity of India;

(d) to defend the country and render national service when called upon to do so;

(e) to promote harmony and the spirit of common brotherhood amongst all the people of India transcending religious, linguistic and regional or sectional diversities; to renounce practices derogatory to the dignity of women;

(f) to value and preserve the rich heritage of our composite culture;

(g) to protect and improve the natural environment including forests, lakes, rivers, wild life and to have compassion for living creatures;

(h) to develop the scientific temper, humanism and the spirit of inquiry and reform;

(i) to safeguard public property and to abjure violence;

(j) to strive towards excellence in all spheres of individual and collective activity so that the nation constantly rises to higher levels of endeavour and achievements;

(k) who is a parent or guardian to provide opportunities for education to his child or, as the case may be, ward between age of six and fourteen years.

CHILDREN'S RIGHTS

Dear Children,

Wouldn't you like to know about your rights? Awareness about your rights will inspire and motivate you to ensure your protection and participation, thereby making social justice a reality. You may know that a commission for child rights is functioning in our state called the ***Kerala State Commission for Protection of Child Rights.***

Let's see what your rights are:

- Right to freedom of speech and expression.
- Right to life and liberty.
- Right to maximum survival and development.
- Right to be respected and accepted regardless of caste, creed and colour.
- Right to protection and care against physical, mental and sexual abuse.
- Right to participation.
- Protection from child labour and hazardous work.
- Protection against child marriage.
- Right to know one's culture and live accordingly.
- Protection against neglect.
- Right to free and compulsory education.
- Right to learn, rest and leisure.
- Right to parental and societal care, and protection.

Major Responsibilities

- Protect school and public facilities.
- Observe punctuality in learning and activities of the school.
- Accept and respect school authorities, teachers, parents and fellow students.
- Readiness to accept and respect others regardless of caste, creed or colour.

Contact Address:

Kerala State Commission for Protection of Child Rights

'Sree Ganesh', T. C. 14/2036, Vanross Junction

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Email: childrights.cpcr@kerala.gov.in, rte.cpcr@kerala.gov.in

Website : www.kescpcr.kerala.gov.in

Child Helpline - 1098, Crime Stopper - 1090, Nirbhaya - 1800 425 1400

Kerala Police Helpline - 0471 - 3243000/44000/45000

Online ***R. T. E Monitoring : www.nireekshana.org.in***