UNIT

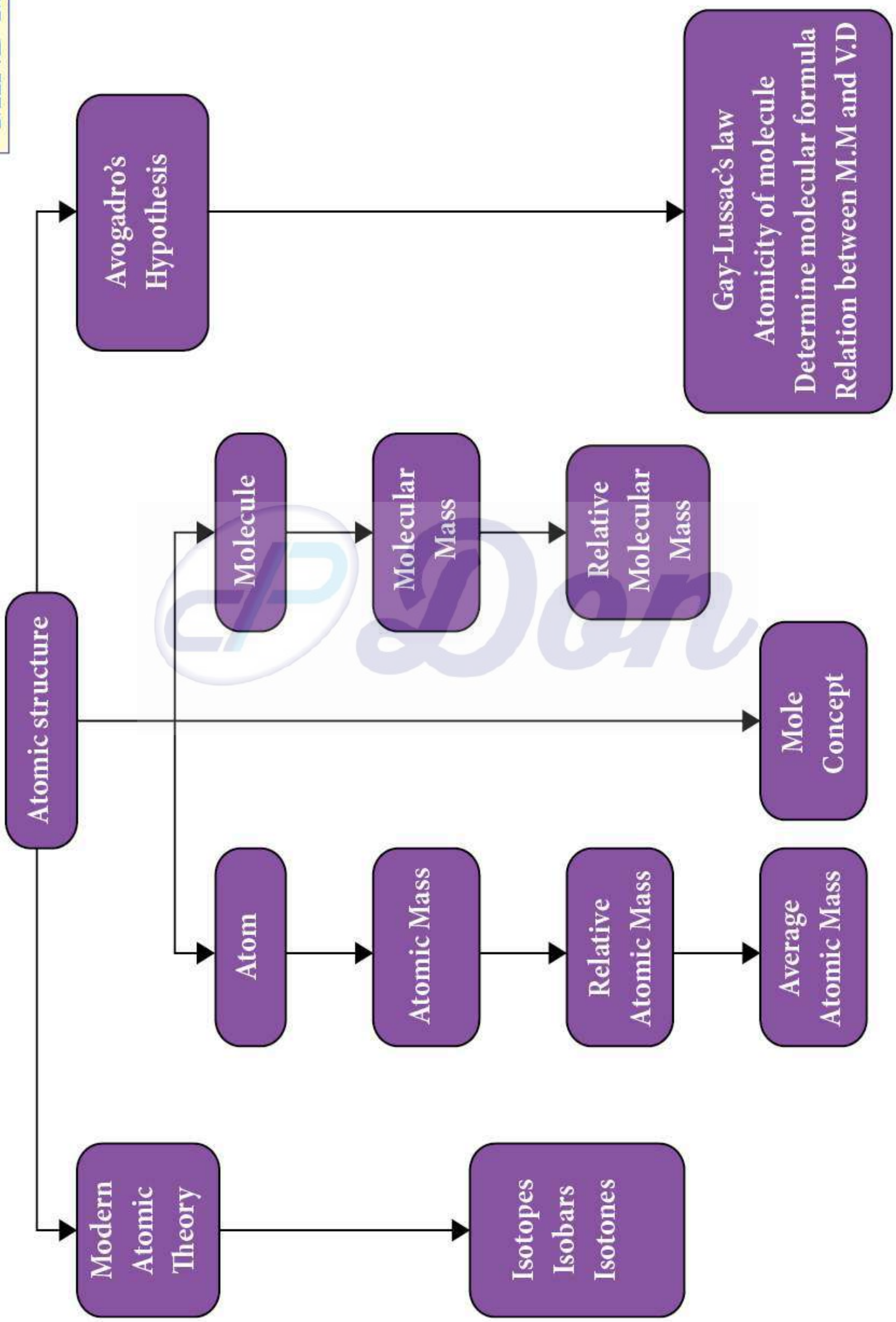
7

Atoms and Molecules

POINTS TO REMEMBER

- Atoms of the same element having different atomic mass are called isotopes. $[_{17}Cl^{35}, _{17}Cl^{37}]$
- Atoms of different elements having same atomic masses are called isobars $[_{18}Ar^{40}, _{20}Ca^{40}]$
- Atoms of different elements have same number of neutrons are called isotone $[_{6}C^{13}, _{7}N^{14}]$
- Atom is the smallest particle that takes part in a chemical reaction.
- Average Atomic Mass of an element is the weighted average of masses of its naturally occurring isotopes.
- Composition of an atom consists of a nucleus composed of protons, neutrons and electrons which encircle the nucleus.
- The sum of the number of protons and neutrons of an atom is called its mass number.
- A molecule is a combination of two or more atoms held together by strong chemical forces of attraction i.e., chemical bonds.
- Homoatomic molecules are classified as monoatomic molecules (Eg. He, Ne), Di-atomic molecules (Eg. O_2, H_2), triatomic molecules (Eg. O_3) and polyatomic molecules (Eg. P_4, S_8)
- Heteroatomic molecules are classified as Diatomic molecules (Eg. HCl, CaO), triatomic molecules (Na_2O, H_2O) and polyatomic molecules (CH_4, $C_6H_{12}O_6$)
- Mole is the amount of a substance that contains as many elementary entities as there are atoms in exactly 12g of the carbon-12 isotope.
- The percentage composition of a compound represents the mass of each element present in 100 g of the compound.
- Avogadro hypothesis explains equal volumes of all gases under similar conditions of temperature and pressure contain equal number of molecules.
- Gay Lussac's law states that for a given mass and constant volume of an ideal gas, the pressure exerted on the sides of its container is directly proportional to its absolute temperature.

MIND MAP


Atomic structure
Modern Atomic Theory
Isotopes
Isobars
Isotones
Atom
Atomic Mass
Relative Atomic Mass
Average Atomic Mass
Molecule
Molecular Mass
Relative Molecular Mass
Mole Concept
Avogadro's Hypothesis
Gay-Lussac's law
Atomicity of molecule
Determine molecular formula
Relation between M.M and V.D

Formulae

Relative Atomic Mass (RAM)	$(A_r) = \dfrac{\text{Average mass of the isotopes of the element}}{\frac{1}{12^{th}} \text{ mass of one Carbon-12 atom}}$
Relative Molecular Mass (RMM)	$\dfrac{\text{Mass of one molecules of the substance}}{\frac{1}{12^{th}} \text{ mass of one C-12 atom}}$
Number of moles	Mass / Atomic Mass Mass / Molecular mass Number of Atoms / 6.023×10^{23} Number of Molecules / 6.023×10^{23} $\dfrac{\text{Volume}}{\text{Molar Volume}}$
Mass % of an element	$\dfrac{\text{mass of that element in the compound}}{\text{molar mass of compound}} \times 100$
Atomicity	$\dfrac{\text{Molecular mass}}{\text{Atomic mass}}$
Vapour Density (V.D)	$\dfrac{\text{Mass of given volume of gas or vapour at S.T.P}}{\text{Mass of same volume of hydrogen}}$
2 × vapour density	Relative molecular mass of a gas
Atomic Number Z	Number of protons = number of electrons
Atomic Mass A	Number of protons + Number of neutrons.

Discoveries and Inventions

Neutrons	Discovered by James Chadwick in the year 1932
First scientific theory of Atom	John Dalton in the year 1808
Plum pudding model of an atom	J.J. Thomson in 1898
Planetary model of an atom	Rutherford in 1909

Textbook Evaluation

I. Choose the most suitable answer from the given four alternatives and write the option code and corresponding answer:

1. Which of the following has the smallest mass? ✶✶
a) 6.023×10^{23} atoms of He
b) 1 atom of He
c) 2 g of He
d) 1 mole atoms of He

2. Which of the following is a triatomic molecule?
a) Glucose   b) Helium
c) Carbon dioxide   d) Hydrogen

3. The volume occupied by 4.4 g of CO_2 at S.T.P ✶✶
a) 22.4 litre   b) 2.24 litre
c) 0.24 litre   d) 0.1 litre

4. Mass of 1 mole of Nitrogen atom is
a) 28 amu   b) 14 amu
c) 28 g   d) 14 g

5. Which of the following represents 1 amu?
a) Mass of a C – 12 atom
b) Mass of a hydrogen atom
c) $1/12^{th}$ of the mass of a C – 12 atom
d) Mass of O – 16 atom

6. Which of the following statement is incorrect?
a) One gram of C – 12 contains Avogadro's number of atoms.
b) One mole of oxygen gas contains Avogadro's number of molecules.
c) One mole of hydrogen gas contains Avogadro's number of atoms.
d) One mole of electrons stands for 6.023×10^{23} electrons.

7. The volume occupied by 1 mole of a diatomic gas at S.T.P is
a) 11.2 litre   b) 5.6 litre
c) 22.4 litre   d) 44.8 litre

8. In the nucleus of $_{20}Ca^{40}$, there are
a) 20 protons and 40 neutrons
b) 20 protons and 20 neutrons
c) 20 protons and 40 electrons
d) 40 protons and 20 electrons

9. The gram molecular mass of oxygen molecule is
a) 16 g   b) 18 g
c) 32 g   d) 17 g

10. 1 mole of any substance contains ____ molecules.
a) 6.023×10^{23} b) 6.023×10^{-23}
c) 3.0115×10^{23} d) 12.046×10^{23}

Ans:

1.	b) 1 atom of He	6.	c) One mole of hydrogen gas contains Avogadro's number of atoms..
2.	c) Carbon dioxide	7.	c) 22.4 litre
3.	b) 2.24 litre	8.	b) 20 protons and 20 neutrons
4.	d) 14 g	9.	c) 32 g
5.	c) 1/12th of the mass of a C – 12 atom	10.	a) 6.023×10^{23}

II. Fill in the blanks

1. **Atoms of different elements having _______ mass number, but ________ atomic numbers are called isobars.** ✶ ✶ ✶
2. **Atoms of different elements having same number of ___________ are called isotones.**
3. **Atoms of one element can be transmuted into atoms of other element by ________**
4. **The sum of the numbers of protons and neutrons of an atom is called its ________**
5. **Relative atomic mass is otherwise known as __________**
6. **The average atomic mass of hydrogen is ___________ amu.** ✶ ✶ ✶
7. **If a molecule is made of similar kind of atoms, then it is called ____________ atomic molecule.**
8. **The number of atoms present in a molecule is called its ____________**
9. **One mole of any gas occupies ________ ml at S.T.P** ✶
10. **Atomicity of phosphorous is ___________**

Ans:

1.	Same, different	2.	Neutrons
3.	Artificial trSol:mutation	4.	Mass number
5.	Standard atomic weight	6.	1.008
7.	Homo	8.	Atomicity
9.	22400	10.	Four

III. Match the following

1. **Column I** — **Column II**

Column I		Column II	
1) 8 g of O_2	-	a) 4 moles	(b)
2) 4 g of H_2	-	b) 0.25 moles	(c)
3) 52 g of He	-	c) 2 moles	(e)
4) 112 g of N_2	-	d) 0.5 moles	(a)
5) 35.5 g of Cl_2	-	e) 13 moles	(d)

IV. True or False: (If false give the correct statement)

1. **Two elements sometimes can form more than one compound.** **True**
2. **Noble gases are Diatomic** **False**
   Noble gases are monoatomic
3. **The gram atomic mass of an element has no unit.** **False**
   The relative atomic mass of an element has no unit.
4. **1 mole of Gold and Silver contain same number of atoms.** **True**
5. **Molar mass of CO_2 is 42g.** **False**
   Molar mass of CO_2 is 44g.

V. Assertion and Reason

Answer the following questions using the data given below.

i) A and R are correct, R explains the A.
ii) A is correct, R is wrong.
iii) A is wrong, R is correct.
iv) A and R are correct, R doesn't explains A.

1. **Assertion:** Atomic mass of aluminium is 27.
   Reason: An atom of aluminium is 27 times heavier than $1/12^{th}$ of the mass of the C-12 atom.

Ans : ii) A is correct, R is wrong.

2. **Assertion:** The Relative Molecular Mass of Chlorine is 35.5 a.m.u.
   Reason: The natural abundance of Chlorine isotopes are not equal.

Ans : iii) A is wrong, R is correct.

VI. Short answer questions.

1. Define: Relative atomic mass. ★★★

- Relative atomic mass of an element is the ratio between the average mass of its isotopes to $\frac{1}{12^{th}}$ part of the mass of a carbon-12 atom.
- It is denoted as **Ar.**
- It is otherwise called **"Standard atomic weight".**

2. Write the different types of isotopes of oxygen and its percentage abundance.

Isotopes of oxygen and its percentage abundance

$_8O^{16}$ - 99.757 %
$_8O^{17}$ - 0.038 %
$_8O^{18}$ - 0.205 %

3. Define: Atomicity. ★★★

The **number of atoms** present in the homo atomic molecule is called its atomicity.

$$\boxed{\text{Atomicity} = \frac{\text{Molecular mass}}{\text{Atomic mass}}}$$

4. Give any two examples for heterodiatomic molecules.

Heteroatomic molecules are classified as

- Diatomic molecule - HCl, CaO
- Triatomic molecule - H_2O, CO_2
- Polyatomic molecule - H_2SO_4, CH_3COOH

5. What is the molar volume of gas?

- One mole (6.023×10^{23} of entities) of any gas occupies **22.4 litre** or 22400 ml at **STP**.
- This volume is called as molar volume of gas.

6. Find the percentage of nitrogen in ammonia. ✶ ✶

Formula used:
Mass percentage of an elements
$= \frac{\text{Mass of that element in the compound}}{\text{Molar mass of the compound}}\times 100$

Molar mass of ammonia (NH_3) = 14 + 3

= **17**

Mass percentage of Nitrogen = $\frac{\textbf{mass of nitrogen in ammonia}}{\textbf{molar mass of the ammonia}}$ ⊠ **100**

$$= \frac{14}{17}\times 100 = \frac{1400}{17} = \mathbf{82.35\ \%}$$

The mass percentage of nitrogen in ammonia is **82.35%**

VII. Long answer questions:

1. Calculate the number of water molecules present in one drop of water which weight 0.18 g ✶ ✶

Molecular mass of water (H_2O) = $H_2O = H\times 2 + O\times 1$

$= 1\times 2 + 16\times 1$

$= 2 + 16$

$= 18$

Formula used:
No. of moles = $\frac{\text{Mass}}{\text{Atomic mass}}$

Number of moles = $\frac{\text{Given mass}}{\text{Molecular mass}}$

Number of moles = $\frac{0.18}{18} = \frac{0.18\times 100}{18\times 100} = 0.01$

Number of moles = $\frac{\text{Number of molecules}}{\text{Avogadro's number}}$

Formula used:
No. of moles = $\frac{\text{Number of molecules}}{\text{Avogadro's number}}$

Number of molecules

= Number of moles × Avogadro's number

$= 0.01\times 6.023\times 10^{21}$

Number of molecules in 0.18 g of water = $\mathbf{6.023\times 10^{21}}$

Alternative method

Gram molecular mass of water = H_2O

$= 1\times 2 + 16\times 1 = 2 + 16$

$= 18$ g

Formula used:
No. of molecules
$= \frac{\text{Avogadro's number}\times\text{given mass}}{\text{Gram molecular mass}}$

$$\text{Number of molecules} = \frac{\text{Avogadro's number} \times \text{given mass}}{\text{Gram molecular mass}}$$

$$\text{Number of molecules} = \frac{6.023 \times 10^{23} \times 0.18}{18}$$

$$= 6.023 \times 10^{23} \times 0.01$$

Number of molecules of 0.18 g of water = $\mathbf{6.023 \times 10^{21}}$

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

(The atomic mass of nitrogen is 14, and that of hydrogen is 1)

1 mole of nitrogen (__g) + 3 moles of hydrogen (__g) → 2 moles of ammonia (__g)

Mass of 1 mole of nitrogen (N_2) $= 2 \times N = 2 \times 14 = 28$ g

Mass of 3 moles of hydrogen (H_2) $= 3[2 \times H]$

$= 3[2 \times 1] = 3[2]$

$= 6$ g

Mass of 2 moles of ammonia (NH_3) $= 2[NH_3]$

$= 2[1 \times N + 3 \times H]$

$= 2[1 \times 14 + 3 \times 1]$

$= 2[14 + 3]$

$= 2[17] = \mathbf{34\ g}$

$$\left.\begin{array}{l}\text{1 mole of nitrogen } \mathbf{(28g)} \\ \quad + \\ \text{3 mole of hydrogen } \mathbf{(6g)}\end{array}\right\} = \text{2 moles of ammonia } (\mathbf{34\,g})$$

3. Calculate the number of moles in

i) 27 g of Al

ii) 1.51×10^{23} molecules of NH_4Cl

i) 27 g of Al

$$\text{Number of moles} = \frac{\text{given mass}}{\text{Atomic mass}} = \frac{27}{27} = 1$$

Number of moles of 27 g of Al is **1**

Formula used:

$$\text{No. of moles} = \frac{\text{Mass}}{\text{Atomic mass}}$$

ii) 1.51×10^{23} molecules of NH_4Cl

$$\text{Number of moles} = \frac{\text{Number of molecules}}{6.023 \times 10^{23}}$$

$$= \frac{1.51 \times 10^{23}}{6.023 \times 10^{23}}$$

$$= \frac{1.51}{6.023}$$

Number of moles of 1.51×10^{23} molecules of NH_4Cl = **0.25**

4. **Give the salient features of "Modern atomic theory.** ✶ ✶ ✶

- An atom is no longer **indivisible**.
- Atoms of the same element may have **different atomic mass** [isotopes $_{17}Cl^{35}$, $_{17}Cl^{37}$)
- Atoms of the different elements may have **same atomic masses** (isobars $_{18}Ar^{40}$, $_{20}Ca^{40}$)
- Atoms of one element can be transmitted into atoms of other elements. So atom is no longer indestructible. It is called **artificial transmutation.**
- Atoms may not always combine in a simple **whole number ratio** [eg. Glucose $C_6H_{12}O_6$, sucrose $C_{12}H_{22}O_{11}$)
- Atom is the smallest particle that takes part in a **chemical reaction.**
- The **mass** of an atom can be converted into **energy** ($E = mc^2$).

5. **Derive the relationship between relative molecular mass and vapour density.** ✶ ✶ ✶

Relative molecular mass:

Relative molecular mass of a gas or vapour is the ratio between the mass of one molecule of gas or vapour to mass of one atom of hydrogen.

$$\text{Relative molecular mass} = \frac{\text{Mass of 1 molecule of a gas (or) vapour at STP}}{\text{Mass of 1 atom of hydrogen}} \quad \text{--- (1)}$$

Vapour density:

It is the ratio of the mass of a certain volume of a gas or vapour to the mass of an equal volume of hydrogen measured under the same conditions of temperature and pressure.

$$\text{Vapour density} = \frac{\text{Mass of a given volume of gas (or) vapour at STP}}{\text{Mass of the same volume of the hydrogen}}$$

According to Avogadro's law [Let the number of molecules 'n']

$$\text{Vapour density} = \frac{\text{Mass of 'n' molecules of a gas (or) vapour at STP}}{\text{Mass of 'n' molecules of a hydrogen}}$$

$$\text{cancelling n vapour density} = \frac{\text{Mass of 1 molecule of a gas or vapour at STP}}{\text{Mass of 1 molecule of a hydrogen}}$$

Hydrogen is diatomic molecule, so

$$\text{Vapour density} = \frac{\text{Mass of 1 molecule of a gas or vapour at STP}}{\text{Mass of 2 atoms of hydrogen}}$$

$$\text{Vapour density} = \frac{\text{mass of 1 molecule of a gas or vapour at STP}}{2 \times \text{mass of 1 atom of hydrogen}}$$

$$2 \times \text{Vapour density} = \frac{\text{mass of 1 molecule of a gas (or) vapour at STP}}{\text{mass of 1 atom of hydrogen}}$$

From eqn (1)

$$2 \times \text{Vapour density} = \text{Relative molecular mass}$$

VIII. Solve the following problems

1. How many grams are there in the following? ✶✶

i) 2 moles of hydrogen molecule, H_2
ii) 3 moles of chlorine molecule, Cl_2
iii) 5 moles of sulphur molecule, S_8
iv) 4 moles of phosphorous molecule, P_4

i) 2 moles of hydrogen molecule, H_2

mass = number of moles × molecular mass

= 2 × 2

Mass of 2 moles of H_2 = **4g**

Molecular mass of H_2
$H_2 = H \times 2$
$= 1 \times 2 = 2$

ii) 3 moles of chlorine molecule, Cl_2

mass = number of moles × molecular mass

= 3 × 71

Mass of 3 moles of Cl_2 = **213 g**

Molecular mass of Cl_2
$Cl_2 = Cl \times 2$
$= 35.5 \times 2 = 71$

iii) 5 moles of sulphur molecules, S_8

mass = number of moles × molecular mass

= 5 × 256

Mass of 5 moles of S_8 = **1280 g**

Molecular mass of S_8
$S_8 = S \times 2$
$= 32 \times 8 = 256$

iv) 4 moles of phosphorous molecule, P_4

mass = number of moles × molecular mass

= 4 × 120

Mass of 4 moles of P_4 = **480 g**

Molecular mass of P_4
$P_4 = P \times 4$
$= 30 \times 4$
$= 120$

2. Calculate the percentage of each element in calcium carbonate [atomic mass: C-12, O-16, Ca-40]

Formula used:

$$\text{Mass \% of an element} = \frac{\text{mass of that element in the compound}}{\text{molar mass of the compound}} \times 100$$

Molar mass of calcium carbonate $CaCO_3$ = Ca × 1 + C × 1 + O × 3

= 40 × 1 + 12 × 1 + 16 × 3

= 40 + 12 + 18 = 100 g

$$\text{Mass \% of an element} = \frac{\text{mass of that element in the compound}}{\text{molar mass of the compound}} \times 100$$

Mass % of calcium = $\frac{40}{100} \times 100 =$ **40 %**

Mass % of carbon = $\frac{12}{100} \times 100 =$ **12 %**

Mass % of oxygen = $\frac{48}{100} \times 100 =$ **48 %**

3. Calculate the % of oxygen in $Al_2(SO_4)_3$ [Atomic mass: Al- 2, O-16, S-32]

Molar mass of $Al_2(SO_4)_3 = Al \times 2 + 3[S \times 1 + O \times 4]$

$27 \times 2 + 3[32 \times 1 + 16 \times 4]$

$= 54 + 3[32 + 64]$

$= 54 + 3[96]$

$= 54 + 288 = \mathbf{342}$

Mass of oxygen: 12 oxygen

$12 \times O$

$12 \times 16 = 192$

$$\text{Mass \% of an element} = \frac{\text{mass of that element in the compound}}{\text{molar mass of the compound}} \times 100$$

$$\text{Mass \% oxygen in } Al_2(SO_4)_3 = \frac{192}{342} \times 100$$

$$= 0.5614 \times 100 = \mathbf{56.14\ \%}$$

Mass % of oxygen in $Al_2(SO_4)_3$ is **56.14 %**

4. Calculate the % relative abundance of B-10 and B-11, if the average atomic mass is 10.804 amu.

We consider B-11 isotope presents x % in nature. So B-10, isotope presents $(1 - x)$ %.

Average atomic mass = mass of B-11 + mass of B-10

$10.804 = x \times 11 + (1 - x) \times 10$

$10.804 = 11x + 10 - 10x$

$10.804 = x + 10$

$x = (10.804 - 10)$

$\mathbf{x = 0.804}$

So, % relative abundance of B-11 is $0.804 \times 10 = 80.4$ %

% relative abundance of B-10 is $(1 - x) \times 100$

$= (1 - 0.804) \times 100$

$= 0.196 \times 100$

$= \mathbf{19.6\ \%}$

% relative abundance of B-10 and B-11 are **19.6%** and **80.4%** respectively.

IX. Higher Order Thinking Skill (HOTS)

1. Calculium carbonate is decomposed on heating in the following reaction.

$CaCO_3 \rightarrow CaO + CO_2$

i) How many moles of calcium carbonate are involved in this reaction?

ii) Calculate the gram molecular mass of calcium carbonate involved in this reacion.

iii) How many moles of CO_2 are there in this equation?

i) **1 mole** of calcium carbonate are involved

ii) Gram molecular mass of $CaCO_3 \rightarrow Ca \times 1 + C \times 1 + O \times 3$

$40 \times 1 + 12 \times 1 + 16 \times 3$

$40 + 12 + 48 = 100$ g

Gram molecular mass of $CaCO_3$ is **100 g / mol.**

iii) **1 mole** of CO_2 are there in above equation.

X. Answer for activities:

1. Activity

Complete the following table by filling the appropriate values /terms

Element	No. of Protons	No. of Neutrons	Mass Number	Stable Isotopes (abundance)	Atomic Mass (amu)
	7			N-14 (99.6 %)	
		8		N-15 (0.4 %)	
Sulphur	14		28	S-28 (92.2 %)	
	14			S-29 (4.7 %)	
		16		S-30 (3.1 %)	
	17			Cl-35 (75 %)	
	17			Cl-37 (25 %)	

Ans:

Element	No. of Protons	No. of Neutrons	Mass Number	Stable Isotopes (abundance)	Atomic Mass (amu)
Nitrogen	7	7	14	N-14 (99.6 %)	13.944
	7	8	15	N-15 (0.4 %)	0.66
Silicon	14	14	28	Si-28 (92.2 %)	25.816
	14	15	29	Si-29 (4.7 %)	1.363
	14	16	30	Si-30 (3.1 %)	0.93
Chlorine	17	18	35	Cl-35 (75 %)	26.25
	17	20	37	Cl-37 (25 %)	9.25

Calculation:

i) The average atomic mass of nitrogen $= \left(\frac{99.6}{100}\times 14\right) + \left(\frac{0.4}{100\times 15}\right)$

$= 14 \times 0.996 + 0.004 \times 15$

$= 13.944 + 0.66$

The average atomic mass of Nitrogen = **14.004 amu**

ii) The average atomic mass of Silicon $= \frac{92.2}{100} \times 28 + \frac{4.7}{100} \times 29 + \frac{3.1}{100} \times 30$

$= 0.922 \times 28 + 0.047 \times 29 + 0.031 \times 30$

$= 25.816 + 1.363 + 0.93$

The average atomic mass of Silicon = **28.109 amu**

iii) The average atomic mass of chlorine $= \frac{75}{100} \times 35 + \frac{25}{100} \times 35$

$= 0.75 \times 35 + 0.25 \times 37$

$= 26.25 + 9.25$

The average atomic mass of chlorine = **35.5 amu**

2. **Activity**

Classify the following molecules based on their atomicity and fill in the tables: Fluorine (F_2), Carbon dioxide (CO_2), Phosphorous (P_4), Sulphur (S_8), Ammonia (NH_3), Hydrogen iodide (HI), Sulphuric Acid (H_2SO_4), Methane (CH_4), Glucose ($C_6H_{12}O_6$), Carbon monoxide (CO)

Molecule	Diatomic	Triatomic	Polyatomic
Homo			
Hetero			

Ans:

Molecule	Diatomic	Triatomic	Polyatomic
Homo	F_2	-	P_4, S_8
Hetero	HI, CO	CO_2	NH_3, H_2SO_4, CH_4, $C_6H_{12}O_6$

3. **Activity**

Under same conditions of temperature and pressure if you collect 3 litre of O_2, 5 litre of Cl_2 and 6 litre of H_2,

i) Which has the highest number of molecules?

ii) Which has the lowest number of molecules?

Ans:

Under same conditions of temperature and pressure all atoms and molecules have same number of molecules in 1 litre. so

i) 6 litres of H_2 has the highest number of molecules

ii) 3 litres of O_2 has the lowest number of molecules.

Additional Questions

I. Choose the most suitable answer from the given four alternatives and write the option code and corresponding answer:

1. **The first scientific theory of the atom was proposed by**
   a) Avogadro b) J-J Thomson
   c) John Dalton d) Niels Bohr

2. **Atoms of different elements have same number of neutrons are called as** ✶
   a) Isotones b) Isotopes
   c) Isobars d) Isothermal

3. **In Einstein mass energy equivalence $E = mc^2$, 'c' is**
   a) Charge of the atom b) Mass of carbon atom
   c) Number of moles d) Velocity of light in vaccum

4. **The sum of the number of protons and neutrons of an atom is called its** ✶
   a) atomic number b) mass number
   c) relative atomic mass d) relative molecular mass

5. **Relative atomic mass of magnesium is**
   a) 6 b) 12 c) 48 d) 24
6. **Which of the following is not an isotope of oxygen?**
   a) ${}_8O^{16}$ b) ${}_8O^{17}$ c) ${}_8O^{18}$ d) ${}_8O^{19}$
7. **Noble gases are**
   a) Monoatomic molecule b) Diatomic molecules
   c) Triatomic molecules d) Polyatomic molecules
8. **Atomicity of Ozone is**
   a) 3 b) 4 c) 6 d) 7
9. **Mass of carbon -12 atom is**
   a) 1 amu b) 12 amu c) 1/12 amu d) none of these
10. **1 mole contains**
    a) 6.023×10^{23} atoms b) 6.023×10^{23} molecules
    c) 6.023×10^{23} ions d) Any of these
11. **Mass percentage of carbon and oxygen in CO is**
    a) 43 % and 57 % b) 57 % and 43 %
    c) 50 % and 50 % d) 25 % and 75 %
12. **Volume of 2 mole of hydrogen gas is**
    a) 22.4 litre b) 44.8 litre
    c) 2 litre d) 11.2 litre
13. **Number of neutrons in ${}_{11}Na^{23}$ is**
    a) 11 b) 23 c) 12 d) 34

Ans:

1.	c) John Dalton	8.	d) 7
2.	a) Isotones	9.	b) 12 amu
3.	d) Velocity of light in vaccum	10.	d) Any of these
4.	b) mass number	11.	a) 43 % and 57 %
5.	d) 24	12.	b) 44.8 litre
6.	d) ${}_8O^{19}$	13.	c) 12
7.	a) Monoatomic molecules		

II. Fill in the blanks

1. **The smallest particle that takes part in chemical reaction is called_____ .**
2. **Anything that has mass and occupies space is called _______.**
3. **______ represents the total charged particles present in the nucleus of an atom.**
4. **_______ elements generally have atomicity one.**
5. **In homoatomic molecule, _____ is an example for tetra atomic molecule.**
6. **Gram molecular mass of methane [CH_4] is _______.**
7. **12.046×10^{23} atoms of Carbon occupies ______ volume at STP**
8. **Avogadro's hypothesis law is in agreement with _____ theory.**

9. Number of moles of 64 g oxygen molecule is ______.

10. Standard temperature is _______.

Ans:

1.	Atom	2.	Matter
3.	Atomic number	4.	Noble gases
5.	Phosphorous	6.	16g
7.	44.8 litre	8.	Dalton's atomic
9.	2	10.	273.15 K

III. Match the following

1. **Column I** — **Column II** ✶

Column I		Column II	
1) Avogadro number	-	a) Gay-lussac	(d)
2) Molar volume	-	b) Albert Einstein	(c)
3) 2 × vapour density	-	c) 22.4 litres	(e)
4) $E = mc^2$	-	d) 6.023×10^{23}	(b)
5) Law of combining volume of gases	-	e) Relative molecular mass	(a)

2. **Column I** — **Column II**

Column I		Column II	
1) ${}_1H^1$, ${}_1H^2$	-	a) Isotones	(c)
2) ${}_6C^{13}$, ${}_7N^{14}$	-	b) Hetero atomic molecules	(a)
3) ${}_6C^{14}$, ${}_7N^{14}$	-	c) Isotopes	(e)
4) Water	-	d) Homoatomic molecules	(b)
5) Ozone	-	e) Isobars	(d)

3. **Column I** — **Column II**

Element		Relative atomic masses	
1) Carbon	-	a) 9	(b)
2) Magnesium	-	b) 12	(d)
3) Beryllium	-	c) 32	(a)
4) Oxygen	-	d) 24	(e)
5) Sulphur	-	e) 16	(c)

IV. True or False: (If false give the correct statement)

1. **Atoms of one element cannot be converted into atoms of another element.** **False**
   Atoms of one element can be converted into atoms of another element.

2. **Unit of mass in atomic level is amu.** **True**

3. **Atomicity of Sulphur is 8.** ✶ **True**

4. **Ratio of molecular mass to a given mass of a substance gives number of moles present in that given mass.** **False**
   Ratio of a given mass to molecular mass of a substance gives number of moles presents in that given mass.

5. Sodium chloride is an example for polyatomic molecule. **False**

Sodium chloride is an example for Diatomic molecules.

V. Assertion and Reason

Answer the following questions using the data given below.

i) A and R are correct, R explains the A.
ii) A is correct, R is wrong.
iii) A is wrong, R is correct.
iv) A and R are correct, R doesn't explains A.

1. **Assertion:** 35.5 g of chlorine molecule contains 6.023×10^{23} atoms.
   Reason: 25 % Cl - 35 and 75 % Cl - 37 % isotopes combination occurs naturally.

Ans : ii) A is correct, R is wrong.

2. **Assertion:** The molecule that consist of atoms of different elements is called heteroatomic molecule.
   Reason: H_2O is a triatomic molecule.

Ans: iv) A and R are correct, R doesn't explains A.

3. **Assertion:** Neon is a diatomic molecule.
   Reason: Neon is an inert gas (or) noble gas.

Ans : iii) A is wrong, R is correct.

VI. Short answer questions.

1. Define: Average atomic mass.

The average atomic mass of an element is the **average weight** of the masses of its naturally occuring isotopes.

2. State Avogadro's law.

Equal volumes of all gases **under similar conditions** of temperature and pressure contain equal number of molecules.

3. Electron has mass. But mass number of an atom does not conclude the electron. Why?

- Mass of electron **(9.11×10^{-31} kg)** is very very less than the mass of proton **(1.672×10^{-27} kg)** and mass of neutron **(1.674×10^{-27} kg).**
- So mass number of an atom does not conclude the mass of electron.

4. Define: Mole.

Mole is the amount of a substance that contains as many elementary entities (atoms molecules or other particle) as there are atoms in exactly **12 g** of the **carbon-12** isotope.

5. State: Gay-lussac's law.

For a given mass and constant volume of an ideal gas, the **pressure** exerted on the sides of its container is **directly** proportional to its absolute **temperature**.

6. Write the applications of Avogadro's law.

- It explains **Gay-Lussac's law.**
- It helps in the determination of **atomicity of gases.**
- **Molecular formula** of gases can be derived using Avogadro's law
- It determine the relation between **molecular mass** and **vapour density**.

7. Calculate the gram molar mass of CH_3COOH.

Atomic mass of C-12, H-1, O-16

Gram molar mass of CH_3COOH $= C \times 1 + H \times 3 + C \times 1 + O \times 2 + H \times 1$

$= 12 \times 1 + 1 \times 3 + 12 \times 1 + 16 \times 2 + 1 \times 1$

$= 12 + 3 + 12 + 32 + 1$

Gram molar mass = **60 g**

Gram molar mass of CH_3COOH is **60 g.**

8. What is the vapour density?

It is the ratio of the mass of a certain volume of a gas or vapour, to the mass of an equal volume of hydrogen, measured under the **same conditions** of temperature and pressure.

9. Prove 1 litre = 1dm³.

$$1000\ L = 1 m^3$$

$$1\ L = \frac{1 m^3}{1000} = \frac{1 m^3}{10^3}$$

$$= 1 \times 10^{-3}\ m^3 \qquad [10^{-1} = \text{deci}]$$

$$\mathbf{1\ L = 1\ (dm)^3}$$

VII. To interpret what happens in the given situation

1. There are 12.046×10^{23} atoms of calcium at STP condition in a container.

a) What is the volume of the container?

b) How many molecules of CO_2 needed to fill that same container at STP.

a) Volume of 6.023×10^{23} atoms of calcium is = **22.4 litre**

Volume of 12.046×10^{23} atoms of calcium is = **44.8 litre**

b) At STP condition, all atoms (or) molecules (or) ions filled are of the same volume (i.e) 22.4 litre. So to fill that same container at STP condition **12.046×10^{23}** molecules of **CO_2** is needed.

2. Atoms of different elements may be similar in some respects.

Atoms of different elements may having same atomic masses are called **isobars.**

3. Water

a) What type of molecule is this?

b) What is the molecular mass of water?

a) Water (H_2O) hetero atomic molecule → **triatomic** molecule

b) Molecular mass of water is $H_2O = H \times 2 + O \times 1$

$= 1 \times 2 + 16 \times 1$

$= 2 + 16 =$ **18.**

VIII. Long answer question:

1. **Differentiate atoms and molecules.** ✶ ✶

S.No.	Atoms	Molecules
1	An atom is the smallest particle of an element.	A molecule is the smallest particle of an element or compound.
2	Atom **doesn't exist** in free state except in a noble gas.	Molecules **exist** in free state.
3	Except atoms of some of the noble gases, other atoms are **highly reactive.**	Molecules are **less reactive.**
4	Atom **does not** have a chemical bond.	Atoms in a molecule are **held** by chemical bonds.
5	Eg : He, Al	Eg. HNO_3, $CaCO_3$

2. **State Avogadro's hypothesis and prove that Avogadro's hypothesis agreed with Dalton's atomic theory.**

Avogadro hypothesis:

Equal volumes of all gases **under similar conditions** of temperature and pressure contain equal number of molecules.

Let us consider the reaction between hydrogen and chlorine to form hydrogen chloride gas.

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

1 vol + 1 vol → 2 volumes

According to Avogadro's law **1 volume** of any gas is occupied by **'n'** number of molecules.

'n' molecules + 'n' molecules = 2 'n' molecules

if n = 1 then,

1 molecule + 1 molecule = 2 molecules

1/2 molecule + 1/2 molecule = 1 molecule

1 molecule of hydrogen chloride gas is made up of 1/2 molecule hydrogen and 1/2 molecule of chloride. Hence the molecules can be subdivided. So hypothesis agrees with **Dalton's atomic theory.**

IX. Solve the following problems

1. **Calculate the number of moles for the following** ✶ ✶
   i) 3.0115×10^{24} molecules of H_2SO_4
   ii) 12.046×10^{23} atoms of Fe

i) $$\text{Number of moles} = \frac{\text{Number of molecules}}{\text{Avagadro's number}}$$

$$= \frac{3.0115 \times 10^{24}}{6.023 \times 10^{23}}$$

$$= \frac{1}{2} \times 10^{24-23} = 0.5 \times 10^{1} = 5$$

3.0115×10^{24} molecules of H_2SO_4 makes **5** moles

Formula used:

Number of moles $= \dfrac{\text{Number of molecules}}{\text{Avagadro's number}}$

ii) Number of moles = $\frac{\text{Number of atoms}}{\text{Avogadro's number}}$

$$= \frac{12.046 \times 10^{23}}{6.023 \times 10^{23}} = 2$$

12.046×10^{23} atom of Fe forms **2** moles

2. Calculate the vapour density of methane [CH_4]

Molecular mass of methane $CH_4 = C \times 1 + H \times 4$

$= 12 \times 1 + 1 \times 4$

$= 12 + 4 = 16$

Vapour density of methane = $\frac{\text{Relative molecular mass}}{2}$

$= \frac{16}{2} = 8$

Vapour density of methane is **8**

3. Calculate the number of atoms / molecules present in 50 g $CaCO_3$ and 50 g of Fe.

Number of molecules = $\frac{\text{Avogadro number} \times \text{Given mass}}{\text{Gram molecular mass}}$

$= \frac{6.023 \times 10^{23} \times 50}{100}$

$= 3.0112 \times 10^{23}$

Gram molecular mass

$CaCO_3 = Ca \times 1 + C \times 1 + O \times 3$

$= 40 \times 1 + 12 \times 1 + 16 \times 3$

$= 40 + 12 + 48 = 100$

50 g $CaCO_3$ contains **3.0112×10^{23}** molecules.

Number of atoms = $\frac{\text{Avogadro number} \times \text{given mass}}{\text{Gram Atomic mass}}$

$= \frac{6.023 \times 10^{23} \times 50}{55.9}$

$= 5.387 \times 10^{23}$

50 g Fe contains **5.387×10^{23}** atoms.

4. Calculate the gram molecular mass of the following

a) $C_6H_{12}O_6$ **b) H_2SO_4**

a) $C_6H_{12}O_6$

Atomic mass of (C-12; H-1; O-16)

Gram molecular mass of $C_6H_{12}O_6$ = $C \times 6 + H \times 12 + O \times 6$

$= 12 \times 6 + 1 \times 12 + 16 \times 6$

$= 72 + 12 + 96$

Gram molecular mass of $C_6H_{12}O_6$ = **180**

b) H_2SO_4

Atomic mass of H-1; S-32; O-16

Gram molecular mass of $H_2SO_4 = H \times 2 + S \times 1 + O \times 4$

$= 1 \times 2 + 32 \times 1 + 16 \times 4$

$= 2 + 32 + 64 = 98$

Gram molecular mass of H_2SO_4 = **98 g**

5. Calculate the mass of the following :

a) 9.0345×10^{23} atom of sulphur **b) 6.023×10^{20} molecules of H_2O**

a) **9.0345 atom of sulphur**

$$\text{mass of an atom} = \frac{\text{number of atoms}}{\text{Avogadro number}} \times \text{mass of sulphur}$$

$$\text{mass of sulphur} = \frac{9.0345 \times 10^{23}}{6.023 \times 10^{23}} \times 32$$

$$= \frac{3}{2} \times 32 = 48 \text{ g}$$

Mass of 9.0346×10^{23} atoms of sulphur **48g**

b) 6.023×10^{20} molecule of H_2O

Molecular mass of $H_2O = H \times 2 + O \times 1$

$= 1 \times 2 + 16 \times 1 = 2 + 16 = 18$

$$\text{Mass of an atom} = \frac{\text{Number of atoms}}{\text{Avogadro's number}} \times \text{mass of } H_2O$$

$$= \frac{6.023 \times 10^{20}}{6.023 \times 10^{23}} \times 18$$

$= 10^{-3} \times 18 =$ **0.018 g**

6. Calculate % of 'S' in $CaSO_4$ and 'P' in $CaPO_4$

i) % of S in $CaSO_4$

Atomic mass of Ca-40, S-32, O-16

Molecular mass of $CaSO_4 \rightarrow Ca \times 1 + \mathbf{S \times 1} + O \times 4$

$= 40 \times 1 + \mathbf{32 \times 1} + 16 \times 4$

$= 40 + \mathbf{32} + 64$

= 136 g

$$\text{\% of an element in a compound} = \frac{\text{mass of that element in the compound}}{\text{molar mass of the compound}} \times 100$$

$$\text{\% of S in } CaSO_4 = \frac{32}{136} \times 100 = \frac{4}{17} \times 100 = 23.53\%$$

% of S in $CaSO_4$ is **23.53 %**

ii) % of P in $Ca(PO_4)$

molar mass of $Ca_3(PO_4)_2 = Ca \times 3 + P \times 2 + O \times 8$

$= (40.8 \times 3) + (30.97 \times 2) + (16 \times 8)$

$= 120.24 + 61.94 + 128 = 310.18$

$$\% \text{ of an element in a compound} = \frac{\text{mass of that element in the compound}}{\text{molar mass of the compound}} \times 100$$

$$\% \text{ of 'P' in } Ca_3PO_4 = \frac{30.97}{310.18} \times 100 = 9.98\%$$

% of 'P' in $Ca_3(PO_4)_2$is **9.98 %**

7. Calculate the density of 1 mole of CO_2 at STP

Molar mass of $CO_2 = C \times 1 + O \times 2$

$$= 12 \times 1 + 16 \times 2 = 12 + 32 = 44 \text{ g}$$

$$\text{Density of } CO_2 = \frac{\text{molar mass of } CO_2}{\text{molar volume of } CO_2}$$

$$= \frac{44}{22.4}$$

Density of CO_2 is **1.96 kg / m^3**

X. Higher Order Thinking Skill (HOTS)

1. i) Why do we use unit amu to measure mass of atoms (or) molecules?
ii) What is the need of the average atomic mass of an element?
iii) Why do atoms form molecules?

i) Mass of atoms (or) molecules are very very small. So measuring mass of an individual atom is too difficult. Generally mass is measured in gram (or) kilograms. It is only for macroscopical level. It is difficult to understand the difference in mass of different atoms, if we measure in grams (or) kilograms. So we need microscopic units to measure mass of an atom (or) molecules. So we use unit amu to measure mass of atoms (or) molecules.

ii) Naturally occuring elements exist as a mixture of isotopes, each of which has its own mass. So we have to consider this isotopic mixture while calculating the atomic mass of an element.

iii) Atoms combine to form molecules because the gain, loss or share of electrons is such that the outer shells become chemically complete.

Unit Test -7

Atoms and Molecules

Time : 1 hr **Marks : 30**

I. Choose the most suitable answer and write the code with the corresponding answer. $5 \times 1 = 5$

1. Which of the following is a triatomic molecule?
   a) Glucose b) Helium
   c) Carbon dioxide d) Hydrogen

2. Which of the following represents 1 amu?
   a) Mass of a C – 12 atom b) Mass of a hydrogen atom
   c) $1/12^{th}$ of the mass of a C – 12 atom d) Mass of O – 16 atom

3. The volume occupied by 1 mole of a diatomic gas at S.T.P is
   a) 11.2 litre b) 5.6 litre
   c) 22.4 litre d) 44.8 litre

4. The gram molecular mass of oxygen molecule is
   a) 16 g b) 18 g
   c) 32 g d) 17 g

5. In Einstein mass energy equivalence $E = mc^2$, 'c' is
   a) Charge of the atom b) Mass of carbon atom
   c) Number of moles d) Velocity of light in vaccum

II. Answer the following questions in one or two lines. $5 \times 2 = 10$

1. What is the molar volume of gas?
2. Find the percentage of nitrogen in ammonia.
3. State Avogadro's law
4. State: Gay-lussac's law.
5. Write the applications of Avogadro's law.

III. Answer the following questions in brief. $2 \times 4 = 8$

1. Calculate the number of water molecules present in one drop of water which weight 0.18 g.
2. i) State Avogadro's law
   ii) Calculate the gram molar mass of CH_3COOH.

IV. Answer the following questions in detail. $1 \times 7 = 7$

1. Calculate the mass of the following:
   i) 9.0345×10^{23} atom of sulphur
   ii) 6.023×10^{20} molecules of H_2O