INTRODUCTION TO CHEMISTRY

ATOMIC HYPOTHESIS :

Keeping in view various laws of chemical combination, a theoretical proof for the validity of different laws was given by John Dalton in the form of hypothesis called Dalton's atomic hypothesis. Postulates of Dalton's hypothesis are as follows :

(i) Elements are composed of extremely small particles called atoms.

(ii) All atoms of a given element are identical, having the same size, mass and chemical properties. The atoms of one element are different from the atoms of all other elements.

(iii) Compounds are composed of atoms of more than one element. In any compound, the ratio of the numbers of atoms of any two of the elements present is either an integer or a simple fraction.

(iv) A chemical reaction involves only the separation, combination or rearrangement of atoms ; it does not result in their creation or destruction.

John Dalton (1766 - 1844) , an Englishman, began teaching at a Quaker school when he was 12. His fascination with science included an intense interest in meterology (he kept careful daily weather records for 46 years), which led to an interest in the gases of the air and their ultimate components, atom. Dalton is best known for his atomic theory, in which he postulated that the fundamental differences among atoms are their masses. He was the first to prepare a table of relative atomicweight.

Modern atomic hypothesis : The main modifications made in Dalton's hypothesis as a result of new discoveries about atoms are :

(i) Atom is no longer considered to be indivisible.

(ii) Atoms of the same element may have different atomic weights. e.g. isotopes of oxygen O^{16}, O^{17} and O^{18}.

(iii) Atoms of different element may have same atomic weights. e.g. isobars Ca^{40} and Ar^{40}.

(iv) Atom is no longer indestructible. In many nuclear reactions, a certain mass of the nucleus is converted into energy along with a, b and g rays.

(v) Atoms may not always combine in simple whole number ratios. e.g. in sucrose ($C_{12}H_{22}O_{11}$) , the elements carbon, hydrogen and oxygen are present in the ratio of 12 : 22 : 11 and the ratio is not a simple whole number ratio.

ATOMIC & MOLECULAR MASSES :

DIFFERENT TYPES OF ATOMIC MASSES :

The mass of an atom depends on the number of electrons, protons, and neutrons it contains. Knowledge of an atom's mass is important in laboratory work. But atoms are extremely small particles - even the smallest speck of dust that our unaided eyes can detect contains as many as 1×10^{16} atoms ! Clearly we cannot weigh a single atom, but it is possible to determine the mass of one atom relative to another experimentally. The first step is to assign a value to the mass of one atom of a given element so that it can be used as a standard.

RELATIVE ATOMIC MASS :

Hydrogen, being lightest atom was arbitrarily assigned a mass of 1 (without any units) and other elements were assigned masses relative to it. However, the present system of atomic masses is based on carbon - 12 as the standard and has been agreed upon in 1961. Here, Carbon - 12 is one of the isotopes of carbon and can be represented as ^{12}C. In this system, ^{12}C is assigned a mass of exactly 12 atomic mass unit **(amu)** and masses of all other atoms are given relative to this standard.

Relative Atomic Mass is defined as the number which indicates how many times the mass of one atom of an element is heavier in comparison to 1/12th part of the mass of one atom of C-12.

$$\text{Relative atomic mass of an element} = \frac{\text{mass of one atom of an element}}{\frac{1}{12}[\text{mass of one C-12 atom}]}$$

$$= \frac{\text{Mass of one atom of an element}}{1\text{amu}}$$

ATOMIC MASS UNIT (a.m.u. or u) : The quantity 1/12th mass of an atom of C^{12} is known as atomic mass unit.

Since mass of 1 atom of C - 12 $= 1.9924 \times 10^{-23}$ g

$\therefore$ 1/12th part of the mass of 1 atom $= \frac{1.9924 \times 10^{-23}\text{g}}{12} = 1.67 \times 10^{-24}$ g $= \frac{1}{6.022 \times 10^{23}}$ g

It may be noted that the atomic masses as obtained above are the relative atomic masses and not the actual masses of the atoms. These masses on the atomic mass scale are expressed in terms of atomic mass units (abbreviated as amu). Today, 'amu' has been replaced by 'u' which is known as **unified mass**.

GRAM ATOMIC MASS OR MASS OF 1 GRAM ATOM :

When numerical value of atomic mass of an element is expressed in grams then the value becomes gram atomic mass or GAM.

gram atomic mass (GAM) = mass of 1 **gram atom** = mass of 1 **mole atoms**

= mass of N_A atoms = mass of 6.022×10^{23} atoms.

Ex. GAM of oxygen = mass of 1 **g atom** of oxygen = mass of 1 **mol atoms** of oxygen.

$$= \text{mass of } N_A \text{ atoms of oxygen} = \left(\frac{16}{N_A}\text{g}\right) \times N_A = 16 \text{ g}$$

Ex. Mass of one atom of Oxygen = 16 amu or $16 \times 1.67 \times 10^{-24}$ g

Mass of N_A atoms of Oxygen = $16 \times 1.67 \times 10^{-24} \times 6.022 \times 10^{-23}$ g = 16 g

Now see the table given below and understand the definition given before.

Element	R.A.M. (Relative Atomic Mass)	Atomic mass (mass of one atom)	Gram Atomic mass or weight
N	14	14 amu	14 gm
He	4	4 amu	4 gm
C	12	12 amu	12 gm

Ex. The atomic mass of an element is 50

(i) Calculate the mass of one atom, in amu

(ii) Calculate the mass of 6.022×10^{23} atoms, in gm

(iii) Calculate the number of atoms in its 10 gm

(iv) What mass of the element contains 3.011×10^{20} atoms

Sol. (i) 50 amu (ii) 50 gm

(iii) $\because$ 50 gm of element contains 6.022×10^{23} atoms

$\therefore$ 10 gm of element will contain $\frac{6.022 \times 10^{23}}{50} \times 10 = 1.2044 \times 10^{22}$ atoms

(iv) $\because$ 6.022×10^{23} atoms weighs 50 gm

$\therefore$ 3.011×10^{20} atoms weighs $\frac{50}{6.022 \times 10^{23}} \times 3.011 \times 10^{20} = 0.025$ gm

RELATIVE MOLECULAR MASS :

The number which indicates how many times the mass of one molecule of a substance is heavier in comparison to 1/12th part of the mass of an atom of C–12.

OR

The molecular mass of a substance is the sum of atomic masses of the elements present in a molecule. It is obtained by multiplying the atomic mass of each element by the number of its atoms and adding them together.

Ex. molecular mass of oxygen (O_2) = 32
molecular mass of (O_3) = 48
molecular mass of HCl = 1 + 35.5 = 36.5
molecular mass of H_2SO_4 = 2 + 32 + 64 = 98

GRAM MOLECULAR MASS (MASS OF 1 GRAM MOLECULE) :

When numerical value of molecular mass of the substance is expressed in grams then the value becomes gram molecular mass or GMM.

gram molecular mass (GMM) = mass of 1 **gram molecule** = mass of 1 **mole molecules**
= mass of N_A molecules = mass of 6.022×10^{23} molecules

Ex. GMM of H_2SO_4 = mass of 1 **gram molecule** of H_2SO_4
= mass of 1 **mole molecules** of H_2SO_4
= mass of N_A molecules of H_2SO_4
= $\left(\frac{98}{N_A}g\right) \times N_A$ = 98 g

Ex. Molecular Mass of N_2 = 28 amu = $28 \times 1.67 \times 10^{-28}$ g
Mass of N_A molecules of N_2 = $28 \times 1.67 \times 10^{-24} \times 6.022 \times 10^{23}$ g = 28 g

INTRODUCTION TO MOLE

Atoms and molecules are extremely small in size and their numbers in even a small amount of any substance is really very large. To handle such large numbers, a unit of similar magnitude is required. The 14th Geneva conference on weight and measures adopted mole as a ***seventh basic SI unit of the amount of a substance.*** Mole concept is essential tool for the fundamental study of chemical calculations. This concept is simple but its application requires a thorough practice. There are many ways of measuring the amount of substance, weight and volume being the most common, but basic unit of chemistry is the atom or a molecule and measuring the number of molecule is more important.

DEFINITION OF MOLE AND MOLAR MASS :

- A mole is the amount of a substance that contains as many entities (Atoms, Molecules, Ions or any other particles) as there are atoms in exactly 12 g of C-12 isotope.
- A mole of a substance contains Avogadro's number (6.022×10^{23}) of particles.

The term mole, like a dozen or a gross, thus refers to a particular number of things. A dozen eggs equals 12 eggs, a gross of pencils equals 144 pencils, and a mole of ethanol equal 6.022×10^{23} ethanol molecules.

- The ***molar mass*** of a substance is the mass of one mole of the substance. Carbon-12 has a molar mass of exactly 12 g/mol , by definition.

- 1 gram-atom = 1 mole atoms = N_A atoms
- 1 gram-molecule = 1 mole molecules = N_A molecules
- 1 gram-ion = 1 mole ions = N_A ions
- **S.T.P.** (Standard Temperature and Pressure)

At S.T.P. condition : temperature = 0°C or 273 K
pressure = 1 bar

and volume of one mole of gas at STP is found to be experimentally equal to 22.7 litres which is known as molar volume.

Methods to calculate moles :

(i) If number of particles (molecules or atoms) is given then,

$$\text{mole} = \frac{\text{Given number of molecule / atom}}{N_A}$$

(ii) If mass is given then, number of mole = $\frac{\text{Given mass of substance (in gm)}}{\text{GAM / GMM}}$

(iii) If volume of gas is given then, mole

$$= \frac{\text{Volume of gas at STP}}{22.7\ \text{L}} = \frac{\text{Volume of gas at } 0^\circ\text{C and 1 atm}}{22.4\text{L}}$$

(Standard molar volume is the volume occupies by 1 mole of any gas at STP, which is equal to 22.7 L)

(iv) Under any condition of temperature and pressure, moles of gases may be calculated using IDEAL GAS EQUATION : PV = nRT,

where, R = Universal Gas Constant
= 0.0821 L-atm/K-mol
= 8.314 J/K-mol
$\approx$ 2 cal/K-mol

Units of pressure and their relation:

1 atm = 76 cm Hg
= 760 mm Hg
= 760 torr (1 torr = 1 mm Hg)
= 1.01325×10^6 dyne/cm^2
= 1.01325×10^5 N/m^2 or Pa
= 1.01325 bar (1 bar = 10^5 Pa)

1 bar = 75 cm Hg

Units of Volume and their relation :

1 ml = 1 cm^3 = 1 c.c.

1 Litre = 1000 ml = 1 dm^3

1 m^3 = 1000 L

Units of Temperature and their relation :

T = 273 + t

where, T = Absolute temperature (in Kelvin) and t = temperature in °C

Relation between °F and °C is $\frac{^{o}C}{5} = \frac{^{o}F - 32}{9}$

AVERAGE MOLECULAR MASS OF NON-REACTING GAS MIXTURE :

$$M_{avg.} = \frac{\text{Total mass of mixture}}{\text{Total mole}}$$

Ex. ***A gaseous mixture contains 40% H_2 and 60% He, by volume. What is the average molecular mass of mixture ?***

Sol. $M_{av} = \frac{\Sigma(\%\,\text{by vol.} \times \text{molecular mass})}{100} = \frac{40 \times 2 + 60 \times 4}{100} = 3.20$

AVERAGE ATOMIC MASS :

If an element exists in different isotopic forms (or allotropic forms) having relative abundance X_1%, X_2% ..... X_n%, with relative atomic masses M_1, M_2 ..... M_n respectively then ,

Avg. Atomic mass of element = $\frac{X_1}{100}(M_1) + \frac{X_2}{100}(M_2) + ... + \frac{X_n}{100}(M_n) = \sum_{i=1 \text{to } n} \frac{X_i}{100}(M_i)$

Ex. ***An element exist in nature in two isotopic forms : X^{30} (90%) and X^{32}(10%). What is the average atomic mass of element ?***

Sol. Av. atomic mass = $\frac{\Sigma(\%\text{abundance} \times \text{atomic mass})}{100} = \frac{90 \times 30 + 10 \times 32}{100} = 30.2$

Ex. ***The molecular mass of a compound is 75***
(i) Calculate the mass of 100 molecules, in amu.
(ii) Calculate the mass of 5000 molecules, in gm.
(iii) What is the mass of 6.022×10^{20} molecules, in gm
(iv) How many molecules are in its 2.5 mg

Sol. (i) mass of 1 molecules = 75 amu

$\therefore$ mass of 100 molecules = 7500 amu

(ii) Mass of 5000 molecules = 5000 × 75 amu

= $5000 \times 75 \times 1.67 \times 10^{-24} = 6.26\,25 \times 10^{-19}$ gm

(iii) $\therefore$ 6.022×10^{23} molecules weighs 75 gm

$\because$ 6.022×10^{20} molecules weighs $\frac{75}{6.022 \times 10^{23}} \times 6.022 \times 10^{20}$ = 0.075 gm

(iv) $\therefore$ 75 gm compound contains 6.022×10^{23} molecules

$\because$ 2.5×10^{-3} gm will contain $\frac{6.022 \times 10^{23}}{75} \times 2.5 \times 10^{-3}$ = 2.007×10^{19} molecules.

Ex. ***Calculate the number of g-molecules (mole of molecules) in the following : (i) 3.2 gm CH_4 (ii) 70 gm nitrogen (iii) 4.5 × 10^{24} molecules of ozone (iv) 2.4 × 10^{21} atoms of hydrogen (v) 11.2 L ideal gas at 0ºC and 1 atm (vi) 4.54 ml SO_3 gas at STP (vii) 8.21 L C_2H_6 gas at 400K and 2atm (viii) 164.2 ml He gas at 27ºC and 570 torr [N_A = 6 × 10^{23}]***

Sol. (i) 3.2 gram CH_4

number of moles (CH_4) = $\frac{w}{M}=\frac{3.2}{16}$ = 0.2 moles

(ii) 70 gram N_2

Number of moles = $\frac{w}{M}=\frac{70}{28}=2.5$

(iii) 4.5 × 10^{24} molecules of O_3

Number of moles = $\frac{\text{no. of molecules}}{N_A}=\frac{4.5\times10^{24}}{6\times10^{23}}=7.5$

(iv) 2.4 × 10^{21} atoms of hydrogen

Number of gram molecules of H_2 = $\frac{\text{no. of molecules}}{N_A}=\frac{2.4\times10^{21}}{2\times6\times10^{23}}$ = 0.002

(v) 11.2 litre ideal gas at 0ºC and 1 atm

Number of moles = $\frac{\text{Volume at } 0^\circ\text{C \& 1 atm}}{22.4\,\text{litre}}=\frac{11.2}{22.4}$ = 0.5

(vi) 4.54 ml SO_3 gas at STP

Number of moles = $\frac{V_{STP}(\text{ml})}{22700\,\text{ml}}=\frac{4.54}{22700}$

= 2 × 10^{-4}

(vii) 8.21 litre C_2H_6 at 400 K and 2 litre

n = $\frac{PV}{R.T}=\frac{2\times8.21}{0.0821\times400}$ = 0.5

(viii) 164.2 ml He gas at 27ºC and 570 torr

n = $\frac{PV}{RT}=\left(\frac{570}{760}\text{atm}\right)\times\frac{164.2\times10^{-3}\text{litre}}{0.0821\times300}$ = 0.005

Ex. ***Find no. of protons in 180 ml H_2O. Density of water = 1 gm/ml.***

Sol. Mass of water = density × volume = 180 g

Moles of water = $\frac{180}{18}=10$

1 mol water has 10 mol protons

10 mol water has 100 mol protons

10 mol water has 100 N_A protons

10 mol water has 6.023 × 10^{25} protons

Ex. ***What mass of $Na_2SO_4.7H_2O$ contains exactly 6.023×10^{22} atoms of oxygen ?***

Sol. Molar mass of $Na_2SO_4.7H_2O$ = 275 gm.

1 mole $Na_2SO_4.7H_2O$ has 11 mol O-atoms.

$\Rightarrow$ 11 N_A O – atoms are in 275 g $Na_2SO_4 . 7H_2O$

$\Rightarrow$ 6.023×10^{22} O – atoms are in

$$= \frac{275}{11 \times 6.023 \times 10^{23}} \times 6.023 \times 10^{22} \text{ g} = 2.5 \text{ g}$$

Ex. ***What is number of atoms and molecules in 112 L of O_3(g) at 0ºC and 1atm ?***

Sol. Moles of molecules $= \frac{112}{22.4} = 5$

Moles of atoms = $5 \times 3 = 15$

No. of molecules = $5N_A$

No. of atoms = $15N_A$.

Prefixes used in the SI System

Multiple	Prefix	Symbol
10^{-24}	yocto	y
10^{-21}	zepto	z
10^{-18}	atto	a
10^{-15}	femto	f
10^{-12}	pico	p
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m
10^{-2}	centi	c
10^{-1}	deci	d
10	deca	D
10^{2}	hecto	h
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G
10^{12}	tera	T
10^{15}	peta	P
10^{18}	exa	E
10^{21}	zeta	Z
10^{24}	yotta	Y

EXERCISE

PART - I : SUBJECTIVE QUESTIONS

1. A flask contains 16 gm helium $\left(^{4}_{2}\mathrm{He}\right)$ gas (Gram atomic mass of He = 4). Find
(i) Moles of He
(ii) Moles of proton
(iii) Total number of neutrons

2. The weight of one atom of Uranium is 238 amu. Its actual weight is ..... g.

3. Calculate the weight of 12.044×10^{23} atoms of carbon.

4. How many grams of silicon is present in 35 gram atoms of silicon (Given at. wt. of Si = 28).

5. Find the total number of nucleons present in 12 g of ^{12}C atoms.

6. Calculate the number of electrons, protons and neutrons in 1 mole of $^{16}O^{-2}$ ions.

7. How much time (in years) would it take to distribute one Avogadro number of wheat grains if 10^{10} grains are distributed each second ?

8. How many atoms are there in 100 amu of He ?

9. The density of liquid mercury is 13.6 g/cm^3. How many moles of mercury are there in 1 litre of the metal ? (Atomic mass of Hg = 200.)

10. Calculate the atomic mass (average) of chlorine using the following data :

	% Natural Abundance	**Molar Mass**
^{35}Cl	75.77	34.9689
^{37}Cl	24.23	36.9659

11. 2 moles of H_2SO_4 is kept in a beaker. Find
(i) Moles of H-atom
(ii) Moles of S-atom
(iii) Moles of O-atom
(iv) Number of O-atoms

12. The number of molecules in 16 g of methane is :

13. Calculate the number of molecules in a drop of water weighing 0.09 g.

14. 6.4 gm of SO_2 will contain how many
(i) Moles of SO_2 molecule
(ii) Number of SO_2 molecules

15. Glycine ($H_2N - CH_2 - COOH$) is one of the proteinogenic amino acid. Find moles of glycine in it's 7.5 gm

16. The number of neutrons in 5 g of D_2O (D is ^2_1H) are :

17. Calculate the weight of 6.022×10^{23} formula units of $CaCO_3$.

18. Find the total number of H, S and 'O' atoms in the following :
(a) 196 gm H_2SO_4 (b) 196 amu H_2SO_4
(c) 5 mole $H_2S_2O_8$ (d) 3 molecules $H_2S_2O_6$.

19. If, from 10 moles NH_3 and 5 moles of H_2SO_4 , all the H-atoms are removed in order to form H_2 gas, then find the number of H_2 molecules formed.

20. If the components of air are N_2 - 78% ; O_2 - 21 % ; Ar - 0.9% and CO_2 - 0.1% by volume (or mole), what would be the molecular weight of air ?

21. A flask of 8.21 litre contains CH_4 gas at a pressure of 2 atm. Find moles of CH_4 gas at 400K?

22. Find moles of O-atom in 5.6 litres of O_3 at 0°C, 1 atm?

23. The volume of a gas at 0º C and 700 mm pressure is 760 cc. The number of molecules present in this volume is :

24. The weight of 350 mL of a diatomic gas at 0ºC and 2 atm pressure is 1 g. The weight of one atom is :

25. Fill in the blanks :
(i) 1μm = ... nm (ii) 10 MJ = ... J (iii) 100 Pa = ... kPa
(iv) 1dm = ... mm (v) 10 pm = ... cm

PART - II : OBJECTIVE QUESTIONS

SINGLE CORRECT QUESTIONS (SCQ)

1. Which is not a basic postulate of Dalton's atomic theory ?
(A) Atoms are neither created nor destroyed in a chemical reaction.
(B) Different elements have different types of atoms.
(C) Atoms of an element may be different due to presence of isotopes.
(D) Each element is composed of extermely small particles called atoms.

2. The modern atomic weight scale is based on :
(A) ^{12}C (B) ^{16}O (C) ^{1}H (D) ^{18}O

3. 1 amu is equal to
(A) $\frac{1}{12}$ of $C-12$ (B) $\frac{1}{14}$ of $O-16$ (C) 1g of H_2 (D) 1.66×10^{-23} kg

4. If the atomic mass of Sodium is 23, the number of moles in 46 g of sodium is :
(A) 1 (B) 2 (C) 2.3 (D) 4.6

5. The Kohinoor diamond was the largest diamond ever found. How many moles of carbon atom were peresent in it, if it is weigh 3300 carat. [Given: 1 carat = 200 mg]
(A) 110 (B) 55 (C) 60 (D) 120

6. How many grams are contained in 1 gram-atom of Na ?
(A) 13 g (B) 23 g (C) 1 g (D) $\frac{1}{23}$ g

7. 1.0 g of hydrogen contains 6×10^{23} atoms. The atomic weight of helium is 4. It follows that the number of atoms in 1 g of He is :
(A) $\frac{1}{4}\times6\times10^{23}$ (B) $4\times6\times10^{23}$ (C) 6×10^{23} (D) 12×10^{23}

8. One atomic mass unit in kilogram is
(A) $1/N_A$ (B) $12/N_A$ (C) $1/1000\ N_A$ (D) $1000/N_A$

9. The atomic weights of two elements A and B are 40u and 80u respectively. If x g of A contains y atoms, how many atoms are present in 2x g of B?
(A) $\frac{y}{2}$ (B) $\frac{y}{4}$ (C) y (D) 2y

10. A sample of aluminium has a mass of 54.0 g. What is the mass of the same number of magnesium atoms? (At. wt. Al = 27, Mg = 24)
(A) 12 g (B) 24 g (C) 48 g (D) 96 g.

11. The number of atoms in 558.5 g of Fe (at wt.= 55.85) is :
(A) Twice that in 60 g carbon (B) 6.022×10^{22}
(C) Half in 8 g He (D) $558.5\times6.023\times10^{23}$

12. Which of the following has the Maximum mass ?
(A) 1 g-atom of C (B) $\frac{1}{2}$ mole of CH_4
(C) 10 mL of water (D) 3.011×10^{23} atoms of oxygen

13. The charge on 1 gram ions of Al^{3+} is : (N_A = Avogadro number, e = charge on one electron)
(A) $\frac{1}{27}N_Ae$ coulomb (B) $\frac{1}{3}\times N_Ae$ coulomb (C) $\frac{1}{9}\times N_Ae$ coulomb (D) $3\times N_Ae$ coulomb

14. It is known that an atom contains protons, neutrons and electrons. If the mass of neutron is assumed to half of its original value whereas that of proton is assumed to be twice of its original value, then the atomic mass of $^{14}_{6}C$ will be :
(A) same (B) 114.28 % less (C) 14.28 % more (D) 28.56 % less

15. Which of the following contain largest number of carbon atoms?
(A) 15 gm ethane, C_2H_6 (B) 45 gm Oxalic acid, $H_2C_2O_4$
(C) 72 gm glucose, $C_6H_{12}O_6$ (D) 35 gm pentene, C_5H_{10}

16. The number of molecules of CO_2 present in 44 g of CO_2 is :
(A) 6.0×10^{23} (B) 3×10^{23} (C) 12×10^{23} (D) 3×10^{10}

17. The number of mole of ammonia in 4.25 g of ammonia is :
(A) 0.425 (B) 0.25 (C) 0.236 (D) 0.2125

18. Which one of the following pairs of gases contains the same number of molecules :
(A) 16 g of O_2 and 14 g of N_2 (B) 8 g of O_2 and 22 g of CO_2
(C) 28 g of N_2 and 22 g of CO_2 (D) 32 g of O_2 and 32 g of N_2

19. The weight of a molecule of the compound $C_{60}H_{22}$ is :
(A) 1.09×10^{-21} g (B) 1.24×10^{-21} g (C) 5.025×10^{-23} g (D) 16.023×10^{-23} g

20. Number of electrons in 1.8 mL of $H_2O(\ell)$ is about :
(A) 6.02×10^{23} (B) 3.011×10^{23} (C) 0.6022×10^{21} (D) 60.22×10^{20}

21. One mole of P_4 molecules contain :
(A) 1 molecule (B) 4 molecules
(C) $\frac{1}{4}\times6.022\times10^{23}$ atoms (D) 24.088×10^{23} atoms

22. The number of electron in 3.1 mg NO_3^- is
($N_A = 6\times10^{23}$)
(A) 32 (B) 1.6×10^{-3} (C) 9.6×10^{20} (D) 9.6×10^{23}

23. An iodized salt contains 0.5 % of NaI. A person consumes 3 gm of salt everyday. The number of iodide ions going into his body everyday is (I = 127)
(A) 10^{-4} (B) 6.02×10^{-4} (C) 6.02×10^{19} (D) 6.02×10^{23}

24. A sample of ammonium phosphate $(NH_4)_3PO_4$ contains 3.18 mole of H atoms. The number of mole of O atoms in the sample is :
(A) 0.265 (B) 0.795 (C) 1.06 (D) 3.18

25. The percentage by mole of NO_2 in a mixture of NO_2(g) and NO(g) having average molecular mass 34 is :
(A) 25% (B) 20% (C) 40% (D) 75%

26. Torr is unit of :
(A) Temperature (B) Pressure (C) Volume (D) Density

27. The atmospheric pressure on Mars is 0.61 kPa. What is the pressure in mm Hg ?
(A) 0.63 (B) 4.6 (C) 6.3 (D) 3.2

28. At what temperature, both Celsius and Fahrenheit scale read the same value :
(A) 100º (B) 130º (C) 60º (D) –40º

29. The value of universal gas constant R depends on :
(A) temperature of gas (B) volume of gas
(C) number of moles of gas (D) units of volume and pressure

30. The value of gas constant in calorie per degree temperature per mol is approximately :
(A) 1 cal (B) 2 cal (C) 3 cal (D) 4 cal

31. The value of R in SI unit is :
(A) 8.314×10^{-7} erg K^{-1} mol^{-1} (B) 8.314 JK^{-1} mol^{-1}
(C) 0.082 litre atm K^{-1} mol^{-1} (D) 2 cal K^{-1} mol^{-1}

32. The pressure of sodium vapour in a 1.0 L container is 10 torr at 1000ºC. How many atoms are in the container ?
(A) 9.7×10^{7} (B) 7.6×10^{19} (C) 4.2×10^{17} (D) 9.7×10^{19}

33. The pressure of a gas having 2 mole in 44.8 litre vessel at 546 K is :
(A) 1 atm (B) 2 atm (C) 3 atm (D) 4 atm

34. Equal volumes of oxygen gas and a second gas weigh 1.00 and 2.375 grams respectively under the same experimental conditions. Which of the following is the unknown gas?
(A) NO (B) SO_2 (C) CS_2 (D) CO

35. Four 1-1 litre flasks are separately filled with the gases H_2, He, O_2 and O_3 at the same temperature and pressure. The ratio of total number of atoms of these gases present in different flask would be :
(A) 1 : 1 : 1 : 1 (B) 1 : 2 : 2 : 3 (C) 2 : 1 : 2 : 3 (D) 3 : 2 : 2 : 1

36. Under the same conditions, two gases have the same number of molecules. They must
(A) be noble gases (B) have equal volumes
(C) have a volume of 22.4 dm^3 each (D) have an equal number of atoms

37. 16 g of an ideal gas SO_x occupies 5.6 L. at 0°C and 1atm. The value of x is
(A) x = 3 (B) x = 2 (C) x = 4 (D) none of these

38. Avogadro number is :
(A) Number of atoms in one gram of the element
(B) Number of mililitre which one mole of a gaseous substance occupies at 1 atm & 0ºC.
(C) Number of molecules present in one gram molecular mass of a substance.
(D) All are correct

39. The weight of 1×10^{22} molecules of $CuSO_4 . 5H_2O$ is **:**
(A) 41.59 g (B) 415.9 g (C) 4.159 g (D) None of these

40. How many moles of electron weigh one kilogram :
(A) 6.023×10^{23} (B) $\frac{1}{9.108} \times 10^{31}$ (C) $\frac{6.023}{9.108} \times 10^{54}$ (D) $\frac{1}{9.108 \times 6.023} \times 10^{8}$

41. Number of atoms in 560 g of Fe (atomic mass 56 $gmol^{-1}$) is :
(A) Twice that in 70 g N (B) Half that in 20 g H
(C) Both (A) and (B) (D) None of these

42. Which has maximum number of atoms :
(A) 24 g of C (12) (B) 56 g of Fe (56) (C) 27 g of Al (27) (D) 108 g Ag (108)

43. How many moles of magnesium phosphate, $Mg_3(PO_4)_2$ will contain 0.25 mole of oxygen atoms ?
(A) 0.02 (B) 3.125×10^{-2} (C) 1.25×10^{-2} (D) 2.5×10^{-2}

44. Given that the abundances of isotopes ^{54}Fe, ^{56}Fe and ^{57}Fe are 5%, 90% and 5% respectively, the atomic mass of Fe is :
(A) 55.85 (B) 55.95 (C) 55.75 (D) 56.05

MULTIPLE CORRECT QUESTIONS (MCQ)

45. Which property of an element may have non-integral value.
(A) Atomic weight (B) Atomic number (C) Atomic volume (D) None of these

46. Which of the following would contain 1 mole of particles :
(A) 0.5 mole of H_2 (B) 1 g of H-atoms (C) 16 g of O-18 (D) 16 g of methane

47. Which of the following will have the same number of electrons :
(A) 1 g Hydrogen (B) 2 g Oxygen (C) 2 g Carbon (D) 2 g Nitrogen

48. Which the following is equal to 10^{-2} atm :
(A) 0.76 cm of Hg (B) 7.6 torr (C) 0.076 dm of Hg (D) 0.0076 torr

49. Pressure exerted by a sample of oxygen is same for the following conditions :
(A) 2 L, 27ºC (B) 1 L, 150 K (C) 4 L, 54ºC (D) 10 L, 1227ºC

ASSERTION / REASONING (A/R)

Each question has 5 choices (A), (B), (C), (D) and (E) out of which ONLY ONE is correct.

(A) STATEMENT-1 is true, STATEMENT-2 is true and STATEMENT-2 is correct explanation for STATEMENT-1.

(B) STATEMENT-1 is true, STATEMENT-2 is true and STATEMENT-2 is not correct explanation for STATEMENT-1.

(C) STATEMENT-1 is true, STATEMENT-2 is false.

(D) STATEMENT-1 is false, STATEMENT-2 is true.

(E) Both STATEMENTS are false.

50. **STATEMENT-1 :** Gram molecular weight of O_2 is 32 g.
STATEMENT-2 : Relative atomic weight of oxygen is 32.

51. **STATEMENT-1 :** 1 mole of all ideal gases exert same pressure in same volume at same tempera ture.

STATEMENT-2 : Behaviour of ideal gases is independent of their nature.

52. **STATEMENT-1 :** Value of the universal gas constant depends upon the choice of sytem of units.
STATEMENT-2 : Values of universal gas constant are 8.314 J/molK, 0.0821 L.atm/molK, 2 cal/ molK.

COMPREHENSION

A vessel of 25 L contains 20 g of ideal gas X at 300K. The pressure exerted by the gas is 1 atm. 20 g of ideal gas Y is added to the vessel keeping the same temperature. Total pressure became 3 atm. Upon further addition of 20 g ideal gas Z the presurre became 7 atm. Answer the following questions. (Hint: Ideal gas equation is applicable on mixture of ideal gases)
[Take R = 1/12 L.atm / mol K]

53. Find the molar mass of gas X.

(A) 20 g (B) 10 g (C) 30 g (D) 5 g

54. Identify the correct statement(s) :
I. gas Y is lighter than gas X
II. gas Z is lighter than gas Y

(A) I only (B) II only

(C) Both I and II (D) None of the statements

55. Find the average molar mass of the mixture of gases X,Y and Z.

(A) 40/7 (B) 50/7 (C) 20 (D) 60/7

56. The recommended daily dose is 17.6 milligrams of vitamin C (ascorbic acid) having formula $C_6H_8O_6$.

Match the following. Given : $N_A = 6 \times 10^{23}$

Column I	**Column II**
(A) O-atoms present in daily dose	(P) 10^{-4} mole
(B) Moles of vitamin C in 1 gm of vitamin C	(Q) 5.68×10^{-3}
(C) Moles of vitamin C that should be consumed daily	(R) 3.6×10^{20}

57. **Match The Column**

	Column-I (Atomic mass (M))			**Column-II (% composition of heavier isotope)**
	Isotope-I	Isotope-II	Average	
(A)	(z – 1)	(z + 3)	z	(p) 25% by moles
(B)	(z + 1)	(z + 3)	(z + 2)	(q) 50% by moles
(C)	z	3z	2z	(r) % by mass dependent on z
(D)	(z – 1)	(z + 1)	z	(s) 75% by mass

ANSWER KEY

PART - I

1. (i) Ans. 4 (ii) Ans. 8 (iii) Ans. $8N_A$

2. 3.95×10^{-22}

No. of atoms = mole $\times N_a$

$1 = \frac{x}{238} \times N_a$ (x is wt. of uranium)

$x = \frac{238}{6} \times 10^{-23}$

$x = 3.95 \times 10^{-22}$

3. No. of moles of C = $\frac{12.044 \times 10^{23}}{6.022 \times 10^{23}} = 2.$

Wt. of C atoms = $2 \times 12 = 24$ g.

4. 980 g of Si

mass of Si = mole × Atomic mass

$= 35 \times 28 = 980$gm

5. $12 \times 6.022 \times 10^{23}$.

6. $10 \times 6.022 \times 10^{23}$, $8 \times 6.022 \times 10^{23}$, $8 \times 6.022 \times 10^{23}$.

7. 10^{10} grains are distributed in 1 second

$\therefore$ 6.02×10^{23} grains are distributed in $\frac{6.02 \times 10^{23}}{10^{10}}$ sec = $\frac{6.02 \times 10^{23}}{10^{10} \times 60 \times 60 \times 24 \times 365}$ years

$= 1.9 \times 10^{6}$ years (approx.)

8. We know that, 1 amu = $\frac{1}{12}$ × weight of one ^{12}C atom

or weight of one ^{12}C atom = 12 amu (at. wt. of C = 12 amu).

Similarly, as the atomic weight of He is 4 amu,

weight of one He atom = 4 amu.

Thus, the number of atoms in 100 amu of He = $\frac{100}{4} = 25.$

9. 68 mole

1 litre Hg metal

volume = 1000

$d = \frac{m}{v}$ mass = d × V = 13.6 × 1000

No of mole of Hg metal = $\frac{13.6 \times 1000}{200}$ = 68 mole

10. Fractional abundance of $^{35}Cl = 0.7577$, Molar mass = 34.9689
Fractional abundance of $^{37}Cl = 0.2423$, Molar mass = 36.9659
$\therefore$ Average atomic mass = (0.7577) (34.9689 amu) + (0.2423) (36.9659 amu)
= 26.4959 + 8.9568 = 35.4527

11. (i) Ans. 4 (ii) Ans. 2 (iii) Ans. 8 (iv) Ans. $8N_A$

12. 6.02×10^{23}

No. of molecules = mole $\times N_a = \frac{16}{16} \times N_a$

$N_a = 6.02 \times 10^{23}$

13. 3.01×10^{21} molecules of H_2O
In 18 g, no. of molecules = N_A

so in 0.09 g no. of molecules = $\frac{N_A}{18} \times 0.09 = \frac{N_A}{2 \times 100} = 3.01 \times 10^{21}$.

14. (i) Ans. 0.1 mole (ii) Ans. $(0.1 \times N_A)$

15. 0.1 mole

16. $2.5\, N_A$

17. No. of moles of $CaCO_3 = \frac{\text{no. of molecules}}{\text{Av. cons.}} = \frac{6.022 \times 10^{23}}{6.022 \times 10^{23}} = 1$

Weight of $CaCO_3 = 1 \times 100 = 100$ g.

18. (a) $H = 4N_A$, $S = 2N_A$, $O = 8N_A$ atoms
(b) H = 4 atoms, S = 2 atoms, O = 8 atoms.
(c) $H = 10N_A$, $S = 10N_A$, $O = 40\, N_A$ atoms
(d) H = 6 atoms, S = 6 atoms, O = 18 atoms.

(a) mole of $H_2SO_4 = \frac{\text{mass}}{\text{molar mass}} = \frac{196}{98} = 2.$

1 molecule H_2SO_4 contains 2 atom hydrogen, 1 atom sulphur and 4 atom of oxygen.
Hence : $H = 4N_A$ atoms, $S = 2N_A$ atoms, $O = 8N_A$ atoms

(b) molecule of $H_2SO_4 = \frac{196}{98} = 2.$

Hence : H = 4 atoms, S = 2 atoms, O = 8 atoms.
(c) 5 mole $H_2S_2O_8$ contains
$H = 10N_A$ atoms, $S = 10N_A$ atoms, $O = 40\, N_A$ atoms
(d) 3 molecules $H_2S_2O_6$ contains
H = 6 atoms, S = 6 atoms, O = 18 atoms.

19. $20\,N_A$
10 mole NH_3 have mole of 'H' atom = 10 × 3
5 mole of H_2SO_4 have mole of 'H' atom = 10
Total mole of 'H' atom = 40
mole of H_2 = 20
Hence : number of H_2 molecules = $20N_A$

20. Mol. wt. of air = $\frac{78\times 28+21\times 32+0.9\times 40+0.1\times 44}{78+21+0.9+0.1}$ = 28.964.

(N_2 = 28 , O_2 = 32 , Ar = 40 and CO_2 = 44)

21. 0.5 mole

22. 0.75 moles

23. 1.88×10^{22}
PV = nRT, N = n × N_A

24. 16 amu
PV = nRT,
n = W/M 16 AMU

25. (i) 1000 (ii) 10^7 (iii) 0.1 (iv) 100 (v) 10^{-9}

PART - II

SINGLE CORRECT QUESTIONS (SCQ)

1.	(C)	**2.**	(A)	**3.**	(A)	**4.**	(B)	**5.**	(B)	**6.**	(B)	**7.**	(A)
8.	(C)	**9.**	(C)	**10.**	(C)	**11.**	(A)	**12.**	(A)	**13.**	(D)	**14.**	(C)
15.	(D)	**16.**	(A)	**17.**	(B)	**18.**	(A)	**19.**	(B)	**20.**	(A)	**21.**	(D)
22.	(C)	**23.**	(C)	**24.**	(C)	**25.**	(A)	**26.**	(B)	**27.**	(B)	**28.**	(D)
29.	(D)	**30.**	(B)	**31.**	(B)	**32.**	(B)	**33.**	(B)	**34.**	(C)	**35.**	(C)
36.	(B)	**37.**	(B)	**38.**	(C)	**39.**	(C)	**40.**	(D)	**41.**	(C)	**42.**	(A)
43.	(B)	**44.**	(B)										

MULTIPLE CORRECT QUESTIONS (MCQ)

45.	(AC)	**46.**	(BD)	**47.**	(ABCD)	**48.**	(ABC)	**49.**	(ABD)

ASSERTION / REASONING (A/R)

50.	(C)	**51.**	(A)	**52.**	(B)

COMPREHENSION

53.	(A)	**54.**	(C)	**55.**	(D)

56. (A–R), (B-Q), (C-P)

57. (A) - (p,r) ; (B) - (q,r) ; (C) - (q,s) ; (D) - (q,r)