:— Mole Concept —:

1.) Atomic & Molecular Mass:

The atomic mass of an element can be defined as the number which indicates how many times the mass of one atom of the element is heavier in comparison to the mass of one atom of the hydrogen.

$$\text{Atomic mass of element} = \frac{\text{Mass of one atom of the element}}{\text{Mass of one atom of hydrogen}}$$

Later, Atomic mass of an element can be defined as the number which indicates how many times the mass of one atom of the element is ~~her~~ heavier in comparison to $\frac{1}{12}$th part of the mass of one atom of C-12.

$$\text{Atomic mass of Element} = \frac{\text{Mass of one atom of the element}}{\frac{1}{12}\text{th part of the mass of one atom of C-12}}$$

Atomic Mass Unit: The quantity $\frac{1}{12}$th mass of an atom of carbon-12 is known as Atomic mass unit. (amu).

$$1\,amu = \frac{1.9924 \times 10^{-23}}{12}\,g = 1.66 \times 10^{-24}\,g$$
$$= 1.66 \times 10^{-27}\,g.$$

The average atomic masses of various elements are determined by multiplying the atomic mass of each isotope multiplied by its fractional abundance.

$$\text{Average isotopic mass} = \frac{(m \times a + n \times b)}{(m+n)}$$

Where, a & b are atomic masses of the isotopes in the ratio m:n.

Example: Carbon occur in the nature as a mixture of C-12 & C-13. The average atomic mass of carbon is 12.011, what is

the percentage abundance of C-12 in nature?

Soln:

Isotopes	Atomic Mass	% Abundance
C-12	12 amu	x
C-13	13 amu	100-x

$$\therefore \quad \frac{12x}{100} + \frac{13(100-x)}{100} = 12.011$$

$$x = 98.9\%.$$

Gram Atomic Mass: It is defined as absolute mass in grams of 6.022×10^{23} atom of any Element.

$$\text{No. of gram Atom} = \frac{\text{Mass of the element in grams}}{\text{Atomic mass of the element in grams}}$$

Molecular Mass: Molecular Mass is a number which indicates how many times one molecule of a substance is heavier in comparison to $\frac{1}{12}$ th of mass of one atom of carbon-12.

$$\text{Molecular Mass} = \frac{\text{Molecular mass of the substance}}{\frac{1}{12}\text{th mass of one atom of C-12.}}$$

Gram molecular Mass or Gram molecule: A quantity of substance whose mass in gram is numerically equal to its molecular mass is called gram molecular mass.

$$\text{No. of gram molecules} = \frac{\text{Mass of a substance in grams}}{\text{Molecular mass of the substance in grams}}$$

$$\text{Mass of single Molecule} = \frac{\text{Molar mass in grams}}{6.022 \times 10^{23}}$$

$$= \text{Molar mass in amu} \times 1.66 \times 10^{-24}\ \text{g}.$$

2.) Avogardo's hypothesis:

"Under similar condition of temperature & pressure, equal volume of all gases contain equal number of molecules"

E.g: $H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$

1 vol. 1 vol. 2 vol.

n molecule n molecule 2n molecule.

Applications of Avogadro's Hypothesis:

(1.) Atomicity: It means number of atom present in one molecule of an elementary gas.

(2.) Relationship between Molecular Mass and Vapour density:

$$\text{Vapour density} = \frac{\text{Molecular Mass}}{2}$$

(3.) Gram Molecular Volume: 1 gram mole of any gas occupies 22.4 litres of volume at NTP or STP condition.

(4) Molecular formula.

(5) Loschimdt number: No. of molecules in $1cm^3$ or 1 mL of gas at STP.

$$= \frac{6.023 \times 10^{23} \text{ molecule}}{22400 \text{ mL}} = 2.68 \times 10^{18} \text{ molecule/mL.}$$

(3) Mole Concept:

Several definations of Moles are presents:

a.) A mole is defined as the no. of atoms in the 12g of Carbon-12. This is known as Avogadro's number (6.022×10^{23})

b.) The mass of one mole of atoms of any element is exactly equal to the atomic mass in gram (gram atomic mass or gram atom) of that element.

Mass of one atom of aluminium $= 27 \times 1.66 \times 10^{-24} g$.

mass of one mole of aluminium $= 27 \times 1.66 \times 10^{-24} g \times 6.022 \times 10^{23}$

$= 27g$

c.) Mass of 6.022×10^{23} molecules of a substance is equal to its molecular mass in gram or gram molecular mass.

Mass of 1 molecule of water = 18amu $= 18 \times 1.66 \times 10^{-24} g$

Mass of 1 mole of water $= 18 \times 1.66 \times 10^{-24} \times 6.022 \times 10^{23} = 18g$.

d) The mass of 6.02×10^{23} formula units represents one mole of ionic compound.

One mole of $BaCl_2$ = 6.022×10^{23} $BaCl_2$ units

= 6.022×10^{23} Ba^{2+} ions + $2 \times 6.02 \times 10^{23}$ Cl^- ions

= 137.2 g + 71.0 g

= 208.2 g

One mole of substance will have equal mass to formula mass of that substance expressed in grams.

e) 1 mole i.e 6.022×10^{23} molecule of any gaseous substance occupies 22.4 litres as volume at STP

Important formulaes:

(1) No. of moles of substance = $\frac{\text{Mass of substance in grams}}{\text{Mass of 1 mole of substance in gram}}$

(2) No. of Moles = $\frac{\text{No. of particles}}{6.02 \times 10^{23}}$

(3) Mass of 1 atom of an element = $\frac{\text{Gram Atom of Element}}{6.02 \times 10^{23}}$

(4) Mass of 1 molecule of substance = $\frac{\text{Gram molecular mass of substance}}{6.02 \times 10^{23}}$

(5) No. of molecules = $\frac{\text{Vol. of gas in litres at NTP}}{22.4} \times 6.02 \times 10^{23}$

Example: From 200mg of CO_2, 10^{21} molecules are removed. How many moles of CO_2 are left?

Solution: Mass of 10^{21} molecule of CO_2 = $\frac{10^{21}}{6.022 \times 10^{23}} \times 44\,g = 0.073\,g$

Mass of CO_2 left = $(0.2 - 0.073) = 0.127\,g$

No. of moles of CO_2 left = $\frac{0.127}{44} = 2.88 \times 10^{3}$.

Example-3 : The maximum number of Molecules is present in:

a) 15 L of H_2 gas STP b) 5L of N_2 gas at STP

c) 0.5g of H_2 gas d) 10g of O_2 gas.

Soln: No. of molecule in 15L of H_2 gas $= \frac{15L}{22.4L} \times N_A = 0.669 N_A$.

No. of molecule in 5L of N_2 gas $= \frac{5L}{22.4L} \times N_A = 0.223 N_A$

No. of molecules in 0.5g H_2 $= \frac{0.5}{2} \times N_A = 0.25 N_A$.

No. of molecules in 10g O_2 $= \frac{10}{32} \times N_A = 0.312 N_A$

Example : 4.) 25g of MCl_4 contains 0.5 mole chlorine then its Molecular Mass is:

a) 100g/mol b) 200g/mol c) 150g/mol d) 400g/mol.

Soln: 1 mole of MCl_4 contains 4 mole of chlorine

∴ 0.5 mole of chlorine present in 25g of MCl_4.

∴ 4 mole of chlorine will be present in $\frac{25}{0.5} \times 4 = 200g$ of MCl_4.

Example: 5.) Aspirin has the formula $C_9H_8O_4$. How many atoms of oxygen are those in tablet weighing 360g?

soln: Molar Mass of Aspirin = 180g/mole.

Moles of Aspirin in 360g $= \frac{360g}{180g/mole} = 2$ mole

1 mole of $C_9H_8O_4$ contain 4 mole of oxygen atom.

2 mole of $C_9H_8O_4$ contains 4×2 mole = 8 mole of oxygen

No. of oxygen atom = $8 \times N_A$.

Example: 6 : one atom of an Element x weighs 6.643×10^{-23}g.

No. of moles of atom present in 20kg is: ____

Soln; Molar Mass of atom = $6.022 \times 10^{23} \times 6.643 \times 10^{-23}$ g

= 40 g/mole

No. of moles in 20kg = $\frac{20{,}000\text{g}}{40\text{g/mole}}$ = 500 mole

Example:7: Density of dry air containing only N_2 & O_2 is 1.15 g/L at 740mm and 300K. What is the composition of N_2 by weight in the mix?

Soln: Density (ρ) = $\frac{PM}{RT}$. Where, P = Pressure
M = molecular weight
R = Gas constant
T = Temperature

Derivation: Ideal Gas Equation.

$PV = nRT$

$PV = \frac{m}{M}RT$ $\left[n = \text{no. of moles} = \left(\frac{m}{M}\right)\right]$.

$\frac{PM}{RT} = \left(\frac{m}{V}\right) = \rho$ = density.

Coming to the question:

$$1.15\text{g/L} = \frac{\frac{740\text{mm}}{760\text{mm/atm}} \times M}{0.0821 \times 300\text{K}}$$

$$M_{ave.} = \left(\frac{1.15\text{g} \times 0.0821 \times 300 \times 760}{740}\right)\text{g} = 29.09\text{g}$$

$M_{average} = \sum M_i x_i$ Where M_i = Molecular wt. of individual species

x_i = % of each species.

$29.09 = \frac{28x}{100} + \frac{32(100-x)}{100}$

$x = 72.75\%$ wt. of $N_2 = \left(28 \times \frac{72.75}{100}\right) =$

$\%\text{wt. of } N_2 = \frac{\text{wt. of } N_2}{\text{Total wt. of air}} \times 100 = \frac{28 \times \frac{72.75}{100} \times 100}{29.09}$

$= 70.02\%$.

Example:8: Suppose two Elements X and Y combines to form two compound XY_2 & X_2Y_3 when 0.05 mole of XY_2 weighs 5g while 3.011×10^{23} molecules of X_2Y_3 weighs 8.5g. The atomic mass of X and Y are respectively :

Soln: Molecular wt. of $XY_2 = \frac{5}{0.05} = 100g$.

Molecular wt. of $X_2Y_3 = \frac{85}{3.011 \times 10^{23}} \times N_A = 170g$.

Let molar mass of X and Y are: a & b respectively.

$$a + 2b = 100 \quad \text{—(1)}$$
$$2a + 3b = 170 \quad \text{—(2)}$$

∴ on solving eq (1) & (2): $a = 40g/mole$ $b = 30g/mole$.

Exercise:

1.) 4.62×10^{22} atom of an element weighs 13.8 gm. The atomic mass of the element is: _____.

(2) The total number of moles in a closed beaker (containing) 58.5g of NaCl + 602.2×10^{20} molecule of O_2 + 2g of hydrogen gas + 22.4 L of SO_2 gas at NTP + 30 lts. of Cl_2 at 0.0821 atm and 27°C. (Take R = 0.0821 atmL/Kmol.)

(3.) Calculate the % Na in a breakfast cereals which is advertised to contain 110 mg of sodium per 100g of cereals.

(4.) 1.12 L of CO_2 at STP + 0.44g CO_2 — 6.022×10^{21} molecules of CO_2 = _____ moles of CO_2.

(5) How many neutrons are present in 180 mL water at (i) 4°C (ii) 127°C at 8.21 atm pressure.

(6.) An element (atomic mass z) has isotopic masses (z+2) and (z-1). Find the percentage abundance of the heavier isotopes.

(7) The abundance of three isotopes of oxygen are as follow:

% O^{16} = 90%.

% O^{17} + % O^{18} = 10%

Assume atomic mass same as mass number. Find out % of O^{17} & O^{18}, if the isotopic mass 16.12.

(8) Vitamin C, ascorbic Acid, has the formula $C_6H_8O_6$

a.) The recommended daily dose of vitamin C is 60 mg. How many moles are you consuming if you ingest ~~60g~~ 60mg of the vitamin?

b.) A typical tablet contains 1g of vitamin C. How many moles of vitamin C does this represent?

c.) When you consume 1g of vitamic C, how many oxygen atoms are you eating?

(9.) 'Diocin' has chemical formula $C_{12}H_{04}Cl_4O_2$. If you have sample of diet (28.3g) that contains 1.0×10^{-4}% diocin, how many moles of diocin are in the diet sample?

(10.) Nitrogen (N), Phosphorus (P) & potassium (K) are the main nutrients in the plant feetilizers. According to the industry convention, the number of moles label refers to the %-N, P_2O_5 & K_2O in that order. Calculate the N:P:K ratio of a 30:10:10 feetilizers in terms of moles of each elements & express it as x:y:10.

(11) One mole of Mixture of N_2, NO_2 & N_2O_4 has mean molar mass of 55.4g. on heating to a temperature at which N_2O_4 may be dissociated: $N_2O_4 \longrightarrow 2NO_2$, the mean molar mass tends to lower value of 39.6. what is the mole ratio of N_2 : NO_2 : N_2O_4 in the original mixtuee?