MOLE CONCEPT

Laws of Chemical Combination

(1) Law of Conservation of Mass.
(Lavoisier)

↳ Matter can neither be created, nor be destroyed

→ In a chemical rxn total mass remains conserved.

→ Mass before rxn = Mass after rxn

e.g. → $H_{2(g)} + \frac{1}{2}O_{2(g)} \longrightarrow H_2O_{(g)}$

Exception - Nuclear Reactions

(2) Law of definite proportion.
(Proust)

↳ All chemical compounds have constant ratio by weight independent of their source.

Cupric Carbonate $CCuCO_3$	% Cu	% O_2	% C
Natural Sample	51.35	9.74	38.91
Synthetic Sample	51.35	9.74	38.91

H_2O → Sea, Ocean, R.O., Rain Water

(H:O) mass ratio → 1:8 (in every case)

(3) Law of Multiple proportion.
(Dalton)

↳ When 2 elements combine to give 2 or more product, mass of element which combines with fix mass of other are in simple ratio.

e.g. → H+O

H_2O → 16gm, 2gm

H_2O_2 → 32gm, 2gm

16 : 32

1 : 2

C+O

CO → 16gm, 12gm

CO_2 → 32gm, 12gm

16 : 32

1 : 2

N+O			
N_2O	16	1	
[NO] N_2O_2	32	2	N_2 → Constant
N_2O_3	48	3	
N_2O_4	64	4	
N_2O_5	80	5	

(4) Gaylussac Law.

↳ Gases combine in a reaction by simple ratio of Volume.

→ pressure, temperature = Constant

e.g. → $3H_{2(g)} + N_{2(g)} \longrightarrow 2NH_{3(g)}$

3 mol, 1 mol, 2 mol

3 Vol, 1 Vol, 2 Vol

Ratio of Volume = 3:1:2

$\boxed{\text{for gases} \longrightarrow \text{mole} = \text{Volume}}$

e.g. → $2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(g)}$

100ml, 50ml, 100ml

Ratio of Volume = 2:1:2

(5) Avogadro Law.

↳ at same temperature and pressure, equal Volume of gas contains equal no. of molecules and not atoms.

	1 litre He	1 Litre N_2	1 litre O_3
no. of molecules	1	1	1
no. of atoms	1	2	3

Avogadro Number → 6.023×10^{23}

Atomic Mass / Molecular Mass.

① RAM (Relative Atomic Mass)

↳ number of nucleon.

$$\boxed{RAM = \frac{\text{mass of one atom of element}}{\frac{1}{12} \times \text{mass of an atom of } C\text{-}12}}$$

↓

no unit

② Atomic Mass Unit (amu) / (u)

↳

$$\boxed{1\,amu = \frac{1}{12} \times \text{mass of an atom of } C\text{-}12}$$

$1\,amu = 1.66 \times 10^{-24}$ grams

$= 1.66 \times 10^{-27}$ Kg

③ Atomic Mass.

↳ Mass of 1 atom in amu.

$$\boxed{Am = RAM \times 1\,amu}$$

$Mm = RMM \times 1\,amu$

④ Gram atomic mass.

↳ Mass of 6.02×10^{23} atom or mass of 1 mole atom or molar mass

RAM → Oxygen → 16

AM → Oxygen → 16 amu

GAM → Oxygen → 16 amu × 6.02×10^{23}

$= 16 \times 1.66 \times 10^{-24} \times 6.02 \times 10^{23}$

$= 16$ gram

$$\boxed{1\,amu \times N_A = 1}$$

	RAM	AM	GAM
H	1	1 amu	1 gm
He	4	4 amu	4 gm
C	12	12 amu	12 gm
N	14	14 amu	14 gm

⑤ Molecular Mass.

↳ Sum of atomic mass of elements present in a molecule.

	RMM	MM	GMM
O_2	32	32 amu	32 gm
O_3	48	48 amu	48 gm
H_2SO_4	98	98 amu	98 gm

⑥ Average Atomic Mass

Types → 1. (If Isotopes are in %)

$$\text{Avg. Atomic mass} = \boxed{\frac{a_1x_1 + a_2x_2 + a_3x_3 + \dots a_nx_n}{100}}$$

where, a_1, a_2, a_3 → atomic mass.

x_1, x_2, x_3 → % of isotopes

Que). Chlorine has 75% Cl^{35} and 25% Cl^{37}. Calculate avg. atomic mass

Solⁿ → Avg. atomic mass $= \frac{a_1x_1 + a_2x_2}{100}$

$= \frac{35 \times 75 + 25 \times 37}{100}$

$= 35.5$ amu Ans//

Type-2 (If isotopes are in fraction)

avg. atomic mass $= a_1f_1 + a_2f_2 + a_3f_3 \dots + a_nf_n$

Que) $Cl^{35} \rightarrow 0.75$, $Cl^{37} \rightarrow 0.25$

Solⁿ → Avg. mass $= 35 \times 0.75 + .25 \times 37$

$= 35.5$ amu Ans//

⑦ Average Molar mass.

Que.) In air composition —

	Mwt.	% Composition
O_2	32	16%
N_2	28	80%
CO_2	44	3%
SO_2	64	1%

avg. Molecular Mass = ?

Sol^n → $\frac{16 \times 32 + 28 \times 80 + 44 \times 3 + 64 \times 1}{100}$

avg. mass $= \frac{2948}{100} = 29.48$ Ans//

Mole

1 mole $= 6.02 \times 10^{23} = N_A$

1 mole atom $= 6.02 \times 10^{23}$ atom

1 mole molecule $= 6.02 \times 10^{23}$ molecule

1 mole ion $= 6.02 \times 10^{23}$ ion

$$\text{Given mass} \underset{\div \text{molar mass}}{\overset{\times \text{molar mass}}{\rightleftarrows}} \text{Mole} \underset{\div N_A}{\overset{\times N_A}{\rightleftarrows}} \text{No. of particle}$$

Mole $\underset{\div 22.4 \text{ litre}}{\overset{\times 22.4 l}{\rightleftarrows}}$ Given Vol. at STP/NTP → 273K and 1 atm pressure

Que) Calculate number of atoms, molecules in 1gm nitrogen?

Sol.^{n} → mole $= \frac{1}{28}$

$1N_2 \rightarrow 2$ atoms.

1 mol $N_2 \rightarrow 2$ mol atom.

$\frac{1}{28}$ mol $N_2 \rightarrow 2 \times \frac{1}{28}$ mol atom

$\rightarrow \frac{1}{14}$ mol atom

$= \left(\frac{1}{14} \times N_A\right)$ atom

1 mole $\rightarrow N_A$ molecule.

$\frac{1}{28}$ mole $\rightarrow \frac{N_A}{28}$ molecule.

Que) Calculate no. of atoms of Chlorine in 2.08 gm $BaCl_2$ (Ba = 137gm, Cl = 35.5 gm)

Sol.^{n} → Mole $= \frac{2.08}{208} = 0.01$ mol

$1 BaCl_2 \rightarrow 2$ Cl atom

1 mol $BaCl_2 \rightarrow 2$ mol Cl atom

0.01 mol $BaCl_2 \rightarrow 0.02$ mol Cl atom

$\rightarrow 0.02 N_A$.

Que) Calculate No. of atoms, molecules in 1.2 gm Ozone.

Sol.^{n} → $n_{\text{moles}} = \frac{1.2}{48} \rightarrow \frac{1}{40}$.

$1O_3 \rightarrow 3$ atoms.

1 mol $O_3 \rightarrow 3$ mol atom.

$\frac{1}{40}$ mol $\rightarrow \frac{3}{40}$ mol atom

$\rightarrow \frac{3N_A}{40}$

$\rightarrow 1$ mol $O_3 \rightarrow 1$ mol molecule

$\frac{1}{40}$ mol $O_3 \rightarrow \frac{1}{40}$ mole O_3.

$\rightarrow \frac{N_A}{40}$.

Que) Calculate mass of 1 molecule of H_2O in gram

Sol.^{n} → $18 \times 1.6 \times 10^{-24}$ gm

Que) No. of atom in 0.05gm H_2O

Sol.^{n} → $n = \frac{0.05}{18} \rightarrow 0.002$

1 mol $H_2O \rightarrow 3$ mol atom

0.002 mol $\rightarrow 0.006 N_A$.

Percentage Composition (mass %)

$$\text{mass \% of an element} = \frac{\text{mass of that element in 1 mole compound}}{\text{Molar mass}} \times 100$$

example → C_2H_5OH

→ mass % of C $= \left(\frac{24}{46} \times 100\right)\%$

→ mass % of H $= \left(\frac{6}{46} \times 100\right)\%$

→ mass % of O $= \left(\frac{16}{46} \times 100\right)\%$

example → H_2O

→ mass % of H $= \left(\frac{2}{18} \times 100\right)\% = 11.18\%$.

→ mass % of O $= \left(\frac{16}{18} \times 100\right)\% = 88.79\%$.

Empirical / Molecular formula

→ Molecular formula
↳ Formula having actual no. of atoms in a molecule.

→ Empirical formula
↳ Simplest whole no. ratio of atoms.

$\boxed{MF = EF \times n}$ $\boxed{n = \frac{MF\ mass}{EF\ mass}}$

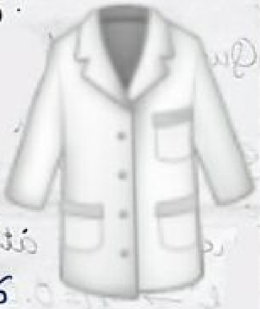
e.g. → $C_6H_{12}O_6$ → Molecular Formula.
CH_2O → Empirical Formula

$(CH_2O)_6 \to \boxed{n}$ *

Que) Acetylene & Benzene → EF = CH.
Molecular mass = 26 and 78.
MF = ?

Sol.ⁿ → EF = CH
EF mass = 13

Acetylene	Benzene
$n = \frac{26}{13} = 2$	$n = \frac{78}{13} = 6$
$MF = C_2H_2$	$MF = C_6H_6$



Que) C → 40.687%, H → 5.085%,
O → 54.228%.
Molecular wt → 118, MF = ?

Sol.ⁿ →	%	at. wt.	%/at wt	Simplest	Whole no. ratio
C	40.687	12	$\frac{40.687}{12} = 3.390$	$\frac{3.390}{3.389} \to 1$	2
H	5.085	1	$\frac{5.085}{1} = 5.085$	$\frac{5.085}{3.389}$ 1.5	3
O	54.228	16	$\frac{54.228}{16} = 3.389$	1	2

↓ relative no. of atom

$Ef = C_2H_3O_2$
Ef mass = 59

$n = \frac{118}{59} = 2$

$\boxed{MF = C_4H_6O_4}$

Stoichiometry

↳ Balanced Reaction

$CaCO_3$	+ $2HCl$	→ $CaCl_2$	+ H_2O	+ $CO_2(g)$
1 mol	2 mol	1 mol	1 mol	1 mol / 22.4 l
100 gm	73 gm	111 gm	18 gm	44 gm

N_2	+ $3H_2$	→ $2NH_3$
1 mol	3 mol	2 mol
28 gm	6 gm	34 gm
22.4 l	3 × 22.4 l	2 × 22.4 l
1 lit	3 lit.	2 lit
1 molecule	3 molecule	2 molecule

In gases mole = Vol.

↳ avogadro law →
No. of molecule = No. of Vol = no. of mol

↳ Mass - Mass Relation
Mass - Vol Relation
Vol - Vol Relation
} of Stoichiometry

Que) What gram of AgCl is formed by reaction of 5.85 g NaCl on excess of $AgNO_3$

Sol.ⁿ → $n = \frac{5.85}{58.5} = \underline{0.1}$

$\underset{58.5gm}{NaCl} + AgNO_3 \longrightarrow \underset{?}{AgCl} + NaNO_3$

1 mol NaCl ⟶ 1 mol AgCl
0.1 mol ⟶ 0.1 mol AgCl
(0.1 × 143.5) gm
= 14.35 gm

Que) In a rx.ⁿ, 10 gm H_2 react with N_2, what will be Volume of NH_3 at STP.

Sol.ⁿ → $N_2 + \underset{10gm}{3H_2} \longrightarrow \underset{??}{2NH_3}$

$n = \frac{10}{2}$
$n = 5$

3 mol H_2 ⟶ 2 mol NH_3
1 mol H_2 ⟶ $\frac{2}{3}$ mol NH_3

5 mol H_2 ⟶ $\frac{10}{3}$ mol NH_3

Ans → $(\frac{10}{3} \times 22.4)$ litre

Que) At 100°C, for complete combustion of 1.12 litre butane (C_4H_{10}) The produced volume of $H_2O(g)$ and $CO_2(g)$ at STP will be.

Sol.ⁿ → $n = \frac{1.12}{22.4} = \frac{1}{20}$ mol

$$C_4H_{10} + \frac{13}{2}O_2 \longrightarrow \underset{?}{\underline{4CO_2}} + \underset{?}{\underline{5H_2O}}$$

1 mol $\longrightarrow$ 4 mol   5 mol

$\frac{1}{20}$ mol $\longrightarrow$ $\frac{4}{20}$ mol $\frac{5}{20}$ mol

$\left(\frac{4}{20} \times 22.4\right) l$ $\left(\frac{5}{20} \times 22.4\right) l$

Limiting Reagent

↳ Balanced Reaction

→ The reactant which is completely consumed in a reaction.

$$A + 5B \longrightarrow C + 3D$$

Given 10 mol 10 mol

for LR $\frac{10}{1}$ $\frac{10}{5}$

10 $\boxed{2}$ → L.R. → stoichiometry

Que). 6 mole of Na_2CO_3 is reacted with 4 mole of HCl solution.
Find volume of CO_2 gas produced at STP. ?

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$

$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$

6 mol 4 mol

$\frac{6}{1}$ $\frac{4}{2}$

6 $\boxed{2}$ → L.R.

2 mol HCl → 1 mol CO_2

1 mol HCl → $\frac{1}{2}$ mol CO_2

4 mol HCl → 2 mol CO_2

(2×22.4) litre.

Que) 50 Kg N_2 and 10 Kg H_2 are mixed to form NH_3. Calculate NH_3 produced. Identify L.R. in reaction?

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

50 Kg 10 Kg

mole → $\frac{50 \times 10^3}{28}$ $\frac{10 \times 10^3}{2}$

→ 1785   5000

L.R. → $\frac{1785}{1}$ $\frac{5000}{3}$

$\boxed{1667}$ → L.R.

3 mol H_2 → 2 mol NH_3

1 mol H_2 → $\frac{2}{3}$ mol NH_3

5000 mol H_2 → $\frac{10000}{3}$ mol NH_3

$\left(\frac{10{,}000}{3} \times 17\right) = 56.67$ Kg

Solution

(Solute + Solvent)

1. Mass %
2. Mole fraction
3. Molarity → Temperature dependent. $\boxed{M \propto \frac{1}{T} \propto \frac{1}{V}}$
4. Molality

① Mass % → $\boxed{\frac{\text{Mass of Solute}}{\text{Mass of Solution}} \times 100}$

② Mole fraction (χ) → wt

$\boxed{\chi_A = \frac{n_A}{n_A + n_B}}$ $\boxed{\chi_B = \frac{n_B}{n_A + n_B}}$

$$\boxed{\chi_A + \chi_B = 1}$$

③ Molarity (M) → V

$$M = \frac{\text{no. of moles of solute}}{\text{Volume of Sol.}^n \text{ (litre)}}$$

$$M = \frac{\text{Weight of Solute}}{\text{molar mass} \times \text{Vol. of solution (litre)}}$$

Unit = mol/litre or Molar (M)

→ Molarity of Sol.^{n} after dilution.

$$\underbrace{M_1V_1}_{\text{initial}} = \underbrace{M_2V_2}_{\text{final}}$$

→ for mixing two Solution of Same substance.

$M_1V_1 + M_2V_2 = M_R(V_1+V_2)$

$$\boxed{M_R = \frac{M_1V_1 + M_2V_2}{V_1+V_2}}$$

④ Molality (m)

$$m = \frac{\text{no. of moles of Solute}}{\text{mass of solvent in Kg}}$$

Kg, g → ×100

Unit = mol/Kg = Molal (m)

Density →

① For liquid and Solids →

Absolute density = $\frac{\text{mass}}{\text{Vol.}}$

Relative density / Specific gravity

$$\boxed{= \frac{\text{density of substance}}{\text{density of water at } 4^\circ C}}$$

② for gases →

Absolute density

$$\boxed{\left(\frac{\text{mass}}{\text{Vol}}\right) = \frac{PM}{RT}}$$

P → pressure, M → mol.wt., T → Temp, R → gas const.

③ Relative Density / Vapour Density →

Vapour density $= \frac{d_{gas}}{d_{H_2}}$

$$\boxed{M_{gas} = 2\,V.D.}$$