New
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Civilittee

اللجنة الأكاديمية للهندسة المدنية

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أساسيات الكيمياء العامة

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*Ch.3:- Mass relationships in chemical reactions.

* SI unit of measuring substance amount = Mole (mol)

* Mole = Number of ^{12}C atoms in 12g Sample.

$$N_A = 6.022 \times 10^{23} \frac{\text{c atoms}}{\text{mole}}$$ (Avogadro's number)

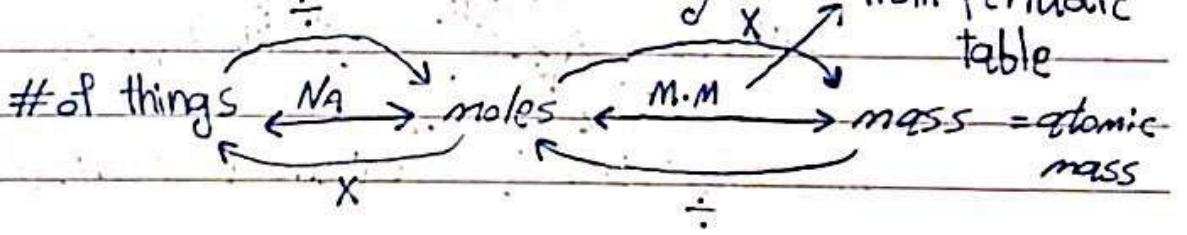
* Mass of 1 mol c = 12g (Molar mass) (M.M) = 12 g/mol

* Mole may refer to anything:

ex 1 mole of books $= 6.022 \times 10^{23}$ books

1 mole of Na $= 6.022 \times 10^{23}$ $_{Na}$ atoms

$$N_A = \frac{\#\text{ of things}}{\#\text{ of moles}} = \frac{\#\text{ of things}}{n}$$ → atoms, molecules, anything



O → atom

O_2 → molecule / compound : 2 or more atoms

*Find:- ① $Ca_3(PO_4)_2 = 3(Ca) + 2(P) + 8(O)$

$= 3(40) + 2(31) + 8(16)$

$= 310$ g/mol

② $H_2O = 2(H) + (O) = 2(1) + (16) = 18$ g/mol

* رقم الجلوس :-

③ $C_6H_4N-NH_2$ $= 6(C)+6(H)+2(N)$

$= 6(12)+6(1)+2(14)$

$= 106\ g/mol$

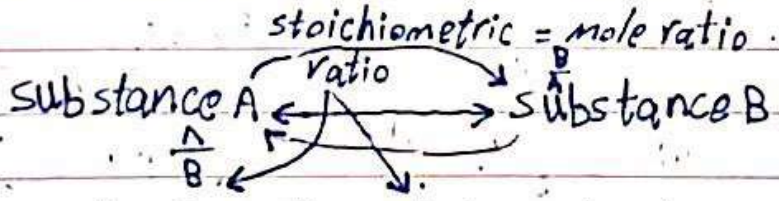
Ex: Calculate number of molecules in 2.5 g sample of $Ca_3(PO_4)_2$

$$n = \frac{m}{M.M} = \frac{2.5\,g}{310\,g/mol} = 8\times10^{-3}\,mol$$

$$\#\text{ of molecules} = n(N_A) = 8\times10^{-3}\,mol \times 6.022\times10^{23}\ \frac{molecules}{mol}$$

$$= 4.8\times10^{21}\ molecules$$

* Convert amounts between different substance :-

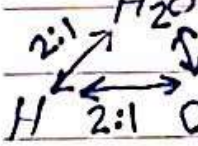


* Molecular Formula of water (H_2O)

2 mol H : 1 mol O

2 mol H : 1 mol H_2O

1 mol O : 1 mol H_2O



Ex: a sample of water has 1.34 mol H, calculate moles of H_2O and O

$$\text{mol O} = 1.34 \text{ mol H} * \frac{1 \text{ mol O}}{2 \text{ mol H}} = 0.67 \text{ mol O}$$

$$\text{mol } H_2O = 1.34 \text{ mol H} * \frac{1 \text{ mol } H_2O}{2 \text{ mol H}} = 0.67 \text{ mol } H_2O$$

$2Na_{(s)} + Cl_{2(g)} \longrightarrow 2NaCl_{(s)}$

* Calculate moles of NaCl produced when 3.5 mol of Cl_2 reacted

$$\text{mol NaCl} = 3.5 \text{ mol } Cl_2 * \frac{2 \text{ mol NaCl}}{1 \text{ mol } Cl_2} = 7 \text{ mol NaCl}$$

* For th Rxn $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(L)}$

if 0.5g O_2 reacted, calculate H_2O produced in g

$$n_{O_2} = \frac{m}{MM} = \frac{0.5 \text{ g}}{32 \text{ g/mol}} = 0.015 \text{ mol } O_2$$

$$n_{H_2O} = 0.015 \text{ mol } O_2 * \frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2} = 0.03 \text{ mol } H_2O$$

$$m_{H_2O} = n(MM) = 0.03(18) = 0.54 \text{ g } H_2O$$

Ex: calculate number of carbon atoms in 0.3g sample of sugar ($C_6H_{12}O_6$)

$$n_{C_6H_{12}O_6} = \frac{m}{MM} = \frac{0.3\,g}{180\,g/mol} = 0.0016\,mol\ C_6H_{12}O_6$$

$$n_C = 0.0016\,mol\ C_6H_{12}O_6 * \frac{6\,mol\ C}{1\,mol\ C_6H_{12}O_6} = 0.01\,mol\ C$$

$$\#\ of\ C = n(N_A) = 0.01\,(6.022\times10^{23}) = 6.022\times10^{21}\ atoms\ C$$

* Molecular Formula (M.F) and Empirical Formula (E.F) calculations.

- Molecular Formula: provide exact whole number of atoms in a substance
- Empirical Formula: provide simples whole ratio between atom is a substance

whole number integer

$$M.F = N\,(E.F)$$

$$n = \frac{M.F\ molar\ mass}{E.F\ molar\ mass}$$

M.F	E.F	N
$C_6H_{12}O_6$	CH_2O	6
C_4H_8	CH_2	4
$C_{10}H_{20}$	CH_2	10
C_3H_6	CH_2	3
C_3H_8O	C_3H_8O	1
H_2O	H_2O	1

* E.F calculations :-

1- direct method : using mass or mass precent (% by mass).

2- indirect method : combustion data analysis.

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$$n_{C_6H_{12}O_6} = \frac{m}{MM} = \frac{0.3\,g}{180\,g/mol} = 0.0016\,mol\ C_6H_{12}O_6$$

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* Molecular Formula (M.F) and Empirical Formula (E.F) calculations.

- Molecular Formula: provide exact whole number of atoms in a substance
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whole number integer

$$M.F = N\,(E.F)$$

$$n = \frac{M.F\ molar\ mass}{E.F\ molar\ mass}$$

M.F	E.F	N
$C_6H_{12}O_6$	CH_2O	6
C_4H_8	CH_2	4
$C_{10}H_{20}$	CH_2	10
C_3H_6	CH_2	3
C_3H_8O	C_3H_8O	1
H_2O	H_2O	1

* E.F calculations :-

1- direct method : using mass or mass precent (% by mass).

2- indirect method : combustion data analysis.

Ex: a compound of P and O has 43.64% P was found to have a molar mass (molar Wight) of 284 g/mol, calculat E.F.

$N = \frac{M.F\ MM}{E.F\ MM}$

$= \frac{284}{142} = 2$

$M.F = N(E.F)$

$= 2(P_2O_5)$

$M.F = P_4O_{10}$

$MM_{P_2O_5} = 2(P) + 5(O)$

$MM_{P_2O_5} = 2(31) + 5(16)$

$= 142\ g/mol$

*Indirct method (combustion data) :-

Hydrocarbon + O_2 ⟶ $CO_2 + H_2O$

(H and C)

↓

mol H

mol C

all C converted to CO_2

// H // // H_2O

$mol\ C = mol\ CO_2$

$mol\ H = 2\ mol\ H_2O$

Ex: The combustion of Hydrocarbon that contains C and H gave 7.406 g CO_2 and 4.512 g H_2O, calculat E.F.

$n_{H_2O} = \frac{m}{MM} = \frac{4.512\ g}{18\ g/mol} = 0.25\ mol\ H_2O$

$n_H = 0.25\ mol\ H_2O \times \frac{2\ mol\ H}{1\ mol\ H_2O}$

$= 0.5\ mol\ H$

$n_{CO_2} = \frac{m}{MM} = \frac{7.406\ g}{44\ g/mol} = 0.1683\ mol\ CO_2$

$n_C = 0.1683\ mol\ CO_2 \times \frac{1\ mol\ C}{1\ mol\ CO_2} = 0.1683\ mol\ C$

$mol\ C : mol\ H$

$\frac{0.1683}{0.1683} : \frac{0.5}{0.1683}$

$1 : 3$

$E.F = CH_3$

*If the compound molar mass is 45 g/mol find M.F.

$MM_{CH_3} = 15\ g/mol$

$N = \frac{M.F\ MM}{E.F\ MM}$

$= \frac{45}{15}$

$N = 3$

$M.F = N(E.F)$

$= 3(CH_3)$

$M.F = C_3H_9$

Ex: The combustion of 5.217g of Hydrocarbon that contains C, H and O gave 7.406 g CO_2 and 4.512g H_2O, calculate E.F.

$m_C = n(MM) = 0.1683 mol * 12 g/mol = 2.021 g\ C$

$m_H = n(MM) = 0.5 mol * 1 g/mol = 0.5 g\ H$

$m_O = m_{total} - (m_C + m_H) = 5.217 - (2.021 + 0.5) = 2.69 g\ O$

$n_O = \frac{m}{MM} = \frac{2.69 g}{16 g/mol} = 0.1681 mol\ O$

mol C : mol H : mol O

$\frac{0.168}{0.168} : \frac{0.5}{0.168} : \frac{0.168}{0.168}$

1 : 3 : 1

E.F = CH_3O

*If the MM of the Hydrocarbon was found to be 93 g/mol, determine M.F.

$MM_{CH_3O} = 31 g/mol$

$N = \frac{M.F\ MM}{E.F\ MM} = \frac{93}{31} = 3$

$M.F = N(E.F) = 3(CH_3O)$

$M.F = C_3H_9O_3$

* Limiting Reactant (Reagent) [L.R] :- المتفاعل المحدد

group A + group B

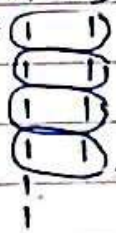
6 parsons + 4 parsons ⟶ Team of 2 (one person from each group)

L.R

Excess Reagent

$A + B \longrightarrow AB$

4 teams max



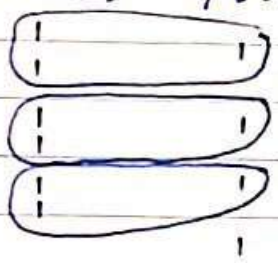
L.R :

- Consume completly during Rxn.
- determine amount of products and reacted amounts.
- realatively lower amount according to the balanced equation.

group A + group B ⟶ Team of 3 (one person from B and 2 persons from A)

6 persons 4 persons

L.R



excess

3 teams max

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

Ex: How many grams of No produced when 28g of NH_3 and 40g of O_2 according to · $4NH_3 + 5O_2 \longrightarrow 4No + 6H_2O$

$n_{NH_3} = \frac{m}{MM} = \frac{28g}{17g/mol} = 1.6\,mol$

$n_{O_2} = \frac{m}{MM} = \frac{40g}{32g/mol} = 1.25\,mol$

$NH_3 = \frac{1.6}{4} = 0.4$

$O_2 = \frac{1.25}{5} = 0.25$

∴ excess is NH_3

∴ L.R is O_2

$n_{No} = 1.25\,mol\,O_2 * \frac{4\,mol\,No}{5\,mol\,O_2} = 1\,mol\,No$

$m_{No} = n(MM) = 1mol * 30g/mol = 30\,g\,No$

* calculate unreacted excess mass in g.

$n_{NH_3} = 1.25\,mol\,O_2 * \frac{4\,mol\,NH_3}{5\,mol\,O_2} = 1\,mol\,NH_3$

(total) (reacted) (reacted)

n_{NH_3} (unreacted) $= 1.64 - 1 = 0.64\,mol\,NH_3$

$m_{NH_3} = n(MM) = 0.64mol * 17g/mol = 11\,g\,NH_3$

↗ by experiment (give)

$$\% \text{ yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100\%$$

↙ by calculations

Ex: When 28g NH_3 react with 40 g O_2, 25 g (actual) of No where produced according to $4NH_3 + 5O_2 \longrightarrow 4No + 6H_2O$, calculate % yield.

(From previous example)

$m_{No} = 30\,g$

$$\%\text{yield} = \frac{25}{30} \times 100 = 83.3\%$$

*If 32.5g of No produced according to Rxn.

$$4NH_3 + 5O_2 \longrightarrow 4No + 6H_2O$$

and the % yield was found to be 85%, calculate NH_3 and O_2 grams reacted.

$$\text{Theo. yield} = \frac{\text{Actual}}{\%\text{ yield}} = \frac{32.5}{0.85} = 39.4\,g\ No$$

$$n_{No} = \frac{m}{MM} = \frac{39.4\,g}{30\,g/mol} = 1.31\ mol$$

$$n_{NH_3} = 1.31\ mol\ No \times \frac{4\ mol\ NH_3}{4\ mol\ No} = 1.31\ mol\ NH_3$$

$$m_{NH_3} = n(MM) = 1.31\ mol \times 17\ g/mol$$

$$= 22.27\,g$$

$$n_{O_2} = 1.31\ mol\ No \times \frac{5\ mol\ O_2}{4\ mol\ No} = 1.64\ mol\ O_2$$

$$m_{O_2} = n(MM) = 1.64\ mol \times 32\ g/mol$$

$$= 52.48\,g$$

* Ch5 :- Gases

* 4 physical interchangeable properties :

	Unit
1- pressure (P)	1 atm = 760 mmHg = 760 torr
2- Volume (V)	m^3 / Liter (L) $1L = 10^3 ml = 10^3 cm^3$
3- Temperature (T)	must be only in Kelvin (K) $°K = 273.15 + °C$
4- amount (mole) (n)	mol

1- Boyle's Law : relation between V and P at constant T, n

$$V \propto \frac{1}{P} \longrightarrow V = K_1 \frac{1}{P} \longrightarrow K_1 = PV \text{ at constant } T, n$$

before change ↗ after change

$$P_1 V_1 = P_2 V_2 = K_1$$

2- Charle's law : relation between V, T at constant P, n

$$V \propto T \longrightarrow V = K_2 T \longrightarrow K_2 = \frac{V}{T} \text{ at constant } P, n$$

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

3- Gay-Lussac's Law : relation between P and T at constant V, n

$$P \propto T \longrightarrow P = K_3 T \longrightarrow K_3 = \frac{P}{T} \text{ at constant } V, n$$

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

4- Avogadro's principle: relation between V and n at constant T, P

$$V \propto n \qquad V = K_4 n \qquad K_4 = \frac{V}{n}$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \quad \text{or} \quad \frac{V_1}{V_2} = \frac{n_1}{n_2}$$

5- Combined gas law:

$$V \propto \frac{T}{P} \qquad V = K_5 \frac{T}{P} \qquad K_5 = \frac{PV}{T}$$

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

at constant T, P

$$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$$

1 mol ⟶ 3 mol ⟶ 2 mol

1 L 3 L ⟶ 2 L

*If 0.5 L of H_2 reacted, calculate NH_3 volume at same T, P

$$V_{NH_3} = 0.5\,L\,H_2 \times \frac{2\,L\,NH_3}{3\,L\,H_2} = 0.333\,L\,NH_3$$

*If 50 L H_2 react with 150 L N_2, calculate NH_3 volume at same T, P

N_2 H_2 → LR

$$\frac{150}{1} > \frac{50}{3}$$

$$V_{NH_3} = 50\,L\,H_2 \times \frac{2\,L\,NH_3}{3\,L\,H_2} = 33.33\,L\,NH_3$$

$V \propto \frac{nT}{P}$ $\quad V = K\frac{nT}{P}$ $\quad K = \frac{PV}{nT}$

$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ always

$PV = RnT$

$PV = nRT$ Ideal gas law

atm ← P, L; n: mol; R: → K

Universal gas constant

$R = 0.0821 \frac{atm.L}{mol.K}$

- calculate an amount (property) from other amount (properties) amounts

$n = \frac{m}{MM} = \frac{\#\text{ of things}}{N_A} = \frac{PV}{RT}$

in general — only for gases

Ex. If 150g NaN_3 decomposed according to

$2NaN_{3(s)} \longrightarrow 2Na_{(s)} + 3N_{2(g)}$

- calculate N_2 Volume (in L) produced at 1 atm and 25°C.

$n_{NaN_3} = \frac{m}{MM} = \frac{150g}{65g/mol} = 2.3\ mol\ NaN_3$

$T = 25 + 273 = 298°K$

$n_{N_2} = 2.3\ mol\ NaN_3 * \frac{3\ mol\ N_2}{2\ mol\ NaN_3} = 3.45\ mol\ N_2$

$V = \frac{nRT}{P} = \frac{3.45\ mol * 0.0821 \frac{atm.L}{mol.K} * 298\ K}{1\ atm} = 84.62L$

- Calculate amount of $CaCO_3$ in grams required to produce 5 L CO_2 gas at 35°C and 239 torr, according to

35°C → 308°K ; 239 torr → 0.31 atm

$$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$$

$PV = nRT$

$$n_{CO_2} = \frac{PV}{RT} = \frac{0.31\ atm * 5\ L}{0.0821 \frac{atm.L}{mol.K} * 308\ K} = 0.61\ mol\ CO_2$$

$$n_{CaCO_3} = 0.61\ mol\ CO_2 * \frac{1\ mol\ CaCO_3}{1\ mol\ CO_2} = 0.61\ mol\ CaCO_3$$

$$m_{CaCO_3} = n(MM) = 0.61\ mol * 100\ g/mol = 61\ g\ CaCO_3$$

* Molar mass and density of gases :- Density (d) = mass (m) / Volume (V)

$PV = nRT \longrightarrow PV = \frac{m}{MM} RT \longrightarrow MM = \frac{mRT}{PV}$, $d = \frac{m}{V}$

$d = \frac{P(MM)}{RT} \longleftarrow MM = \frac{dRT}{P}$

↓ must be in g/L

- Calculate density of CO_2 gas at STP → 1 atm, 273°K

$MM = 44\ g/mol$

$$d = \frac{P(MM)}{RT} = \frac{1\ atm * 44\ g/mol}{0.0821 \frac{atm.L}{mol.K} * 273\ K} = 1.96\ g/L = \frac{1.96}{1000}\ g/mL$$

Ex. a gas of P and F only has an empirical formula of PF_2, if the gas density was found to be 5.6 g/L at 23°C and 750 torr - calculate M.F = N (E.F).

$MM = P + 2(F)$

$= 31 + 2(19)$

$= 69$ g/mol

$MM = \frac{dRT}{P} = \frac{5.69\,g/L \times 0.0821 \frac{atm.L}{mol.K} \times 296°K}{\frac{750}{760}\,atm}$

$= 138$ g/mol

$N = \frac{M.F\ MM}{E.F\ MM} = \frac{138}{69} = 2$ ∴ $M.F = 2(PF_2)$

$= P_2F_4$

*Dalton's Law of partial pressure:-

(Mixture of gases in the same container)

1 atm	O_2
0.5 atm	N_2
0.3 atm	He

→ V = 1 L at 25°C

$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ have the same V and T

$\frac{P_1}{n_1} = \frac{P_2}{n_2}$

$\frac{P_1}{P_2} = \frac{N_1}{N_2}$

$P_{Total} = 1 + 0.5 + 0.3$

$= 1.8$ atm

$n_{total} = n_{N_2} + n_{O_2} + n_{He} = \frac{P_{N_2}V}{RT} + \frac{P_{O_2}V}{RT} + \frac{P_{He}V}{RT}$

$n_{total} = \frac{P_{total}\,V}{RT}$

$= \frac{V}{RT}(P_{N_2} + P_{O_2} + P_{He})$

$P_{total} = \sum$ Partail pressures

*Mole Fraction (X) :- For gas A : $X_A = \frac{n_A}{\text{Total moles}}$

$\frac{P_AV/RT}{P_{total}V/RT} = \frac{P_A}{P_{total}} = X_A$

$X_{O_2} = \frac{n_O}{n_{total}} = \frac{1}{1.5} = 0.67$

O_2	1 mol
N_2	0.3 mol
He	0.2 mol

$P_A = X_A \cdot P_{total}$

$n_A = X_A \cdot n_{total}$

$\frac{P_1}{P_2} = \frac{n_1}{n_2}$ at constant V and T

$X_{N_2} = \frac{0.3}{1.5} = 0.2$

$X_{He} = \frac{0.2}{1.5} = 0.13$

or $X_{He} = 1 - [X_{O_2} + X_{N_2}] = 1 - [0.67 + 0.2] = 0.13$

$\sum X_i = 1$

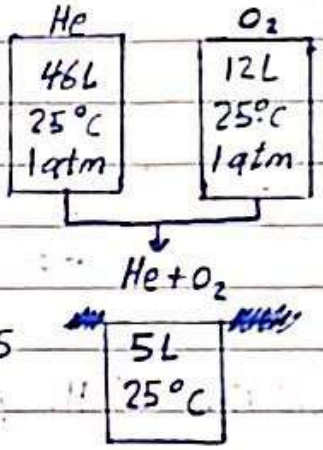
O_2 0.5 atm
N_2 0.5 atm
He 0.2 atm

$X_{O_2} = \frac{P_{O_2}}{P_{total}} = \frac{0.5}{1.2} = 0.41 = X_{N_2}$

$X_{He} = 1 - (0.41 + 0.41) = 0.18$

Ex. 4 L of He gas at 25°C and 1 atm were mixed with 12 L O_2 gas at 25°C and 1 atm in a 5 L container at 25°C.

- calculate partial pressure of each gas.
- // mole fraction // // //.



$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ $\quad P_1V_1 = P_2V_2$

For He $\quad 1 * 4 = P_2 * 5$

$P_2 = \frac{4}{5} = 0.8$ atm

For O_2 $\quad 1 * 12 = P_2 * 5$

$P_2 = \frac{12}{5} = 2.4$ atm

$X_{He} = \frac{0.8}{3.2} = 0.25$ $\quad X_{O_2} = \frac{2.4}{3.2} = 0.75$ or $X_{O_2} = 1 - 0.25 = 0.75$

* Kinetic theory of gases :-

Kinetic energy (K.E)

$K.E \propto T \longrightarrow K.E = K.T$

$K.E = \frac{3}{2}RT$

$J = \frac{atm.L}{mol.°K} . °K$

$Ke = \frac{3}{2}RT.n$

$= \frac{J}{mol.K} . °K . mol$

1 atm.L = 101.3 J

للغازات ← $R = 0.0821 \frac{atm.L}{mol.°K}$

للطاقة الحركية ← $R = 0.0821 (101.3)\ J/mol.k = 8.314\ J/mol.°K$

$K.E = \frac{1}{2}mU^2$

$\frac{3}{2}RT.n = \frac{1}{2}n.mn.U^2$

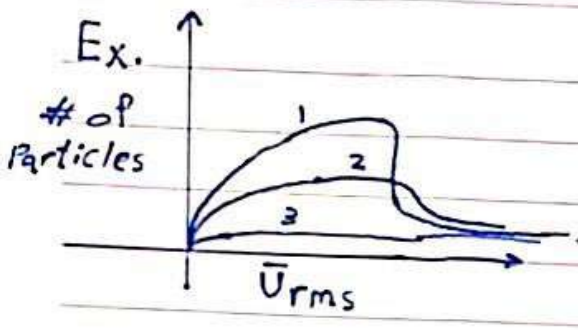
$U^2 = \frac{3RT}{MM}$

$U = \sqrt{\frac{3RT}{MM}}$ ← mean square speed

$\overline{U}_{rms} = \sqrt{\frac{3RT}{MM}}$ ← must be in °K, MM must be in Kg

root mean Squar Speed

Ex.



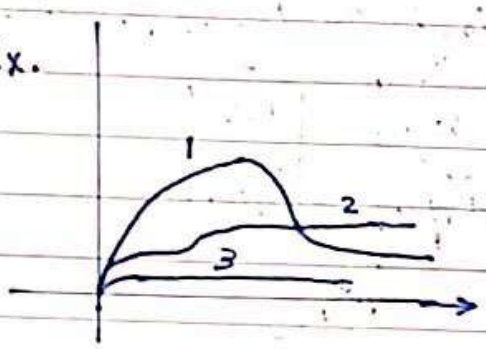
*Same gas (N_2) at different T

② ← 100°C

① ← 25°C

③ ← 500°C

Ex.



*Same gas at ~~different~~ same T (100°C)

	MM (g/mol)
② ← N_2	28
① ← Cl_2	71
③ ← He	4

Ex. calculate rms of He and N_2 gases at 25°C / 298°K.

$$\bar{U}_{rms_{He}} = \sqrt{\frac{3(8.314)(298)}{4\times10^{-3}}} = 1360\ m/s \qquad \bar{U}_{rms_{N_2}} = 515\ m/s$$

*Graham's law of Effusion and Difusion :-

*Rate of effusion or diffusion between two gases (A and B).

$$\frac{\text{rate A}}{\text{rate B}} = \frac{\bar{U}_{rms\ A}}{\bar{U}_{rms\ B}} \text{ or } \frac{\text{Speed A}}{\text{Speed B}}$$

$$\frac{\text{rate A}}{\text{rate B}} = \frac{\sqrt{\frac{3RT}{MM_A}}}{\sqrt{\frac{3RT}{MM_B}}} = \sqrt{\frac{\frac{1}{MM_A}}{\frac{1}{MM_B}}} = \sqrt{\frac{MM_B}{MM_A}}$$

$$\frac{\text{rate A}}{\text{rale B}} = \sqrt{\frac{MM_B}{MM_A}} = \frac{d_A/t_A}{d_B/t_B} = \frac{d_A \cdot t_B}{d_B \cdot t_A}$$

Ex. a gas effuses 2.5 times faster than Cl_2 gas at 25°C.

- Calculate the gas MM.

$$\frac{\text{rate } X}{\text{rate } Cl_2} = \sqrt{\frac{MM\,Cl_2}{MM\,X}}$$

$$2.5 = \sqrt{\frac{71}{MM_X}} \qquad MM_X = 11.4 \text{ g/mol}$$

$MM = 64$ g/mol

Ex. If it takes So_2 gas 3 min to diffuse a 10m distance.

- how long it will takes CH_4 gas to travel same distance.
- how far at same time. $MM = 16$ g/mol

$$\frac{\text{rate } CH_4}{\text{rate } So_2} = \sqrt{\frac{MM\,So_2}{MM\,CH_4}} = \sqrt{\frac{64}{16}} = 2 \qquad \frac{\text{rate } CH_4}{\text{rate } So_2} = 2 = \frac{t_{So_2}}{t_{CH_4}}$$

rate CH_4 = 2 rate So_2

CH_4 is 2 times faster than So_2

needs $\frac{\text{time } So_2}{2} = \frac{3}{2} = 1.5$ min or $2 = \frac{3}{t_{CH_4}}$ $t_{CH_4} = \frac{3}{2} = 1.5$ min

$$2 = \frac{d_{CH_4}}{10} \qquad d_{CH_4} = 20 \text{ m}$$

* Collecting gas over water :-

Ex. a 0.0873 sample of gas was collected over water at 20°C and 738 torr, the volume was 310 mL

- Calculate the gas partial pressure

from Tables P_{H_2O} at 20°C = 17.5 torr

$P($ collected gas$)$ = $P_{measured} - P_{H_2O\,(g)}$ at T

$= 738 - 17.5 = 720.5$ torr

$$X_{gas} = \frac{P_{gas}}{P_{total}} = \frac{720.5}{738}$$

$$X_{H_2O\,(g)} = \frac{17.5}{738} \quad \text{or} \quad 1 - X_{gas}$$

$$n_{H_2O} = \frac{PV}{RT} = \frac{\left(\frac{17.5}{760}\right)(0.31)}{(0.0821)(293)} =$$

- Calculate the gas MM.

$$MM = \frac{m}{n} = \frac{mRT}{PV}$$

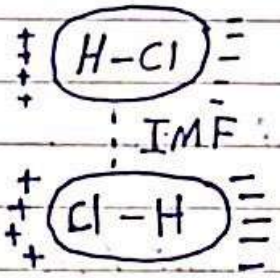
Ch.11 / Intermoleculer forces (IMF)

*Electronegativity :- ability of an atom to attract electrons toward it sulf (E.N)

E.N →
N O F.
↑
E.N

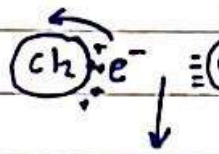
Partialy Positive $H^{\delta+}—Cl^{\delta-}$ " negative → higher e^- density

$E.N_{Cl} > E.N_H$



1- Dipole-Dipole IMF : between polar molecules (atoms with different E.N)

$H_{2\,(g)}$ $Cl_{2\,(g)}$



Instantaneous Diple moment

2- London Dispression Forces [L.D.F] : Special case for non-polar molecules (atom with the same E.N)

*All Hydrocarbons (contain C&H only) are non-polar

$E.N_C = E.N_H$

$C_{11}H_{20}$ (non-polar) (LDF)

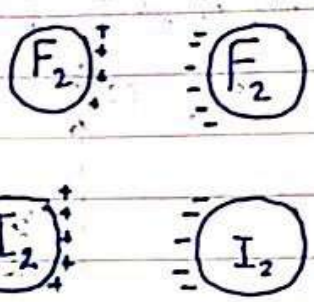
CH_4 (LDF)

CH_3Cl (D-D) & (LDF)

* factors affecting L.D.F :-

F_2 (g)
Cl_2 (g)
Br_2 (L)
I_2 (s)
] L.D.F

Size / Mass (Molar Mass)



I.M.F types ① D-D ⟶ a. H-bonding

* one molecule must be polar
* the other molecule must have a high E.N atom (N, O, F)

* " " " have H-atom bonded directly to a high E.N atom (N, O, F)

H-N
or
H-O
or
H-F

Ex. Determine all types of IMF.

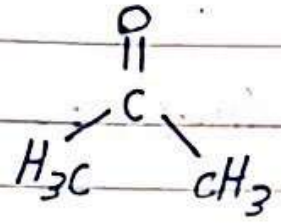
① HBr ⟶ L.D.F, D-D

② $Ar_{(g)}$ ⟶ L.D.F

③ C_6H_{10} ⟶ L.D.F

④ H_2O ($H-\overset{\delta-}{O}-\overset{\delta+}{H}$; $\overset{\delta+}{H}-O-H$) ⟶ L.D.F, D-D, H-bond

⑤ CH_3-OH ⟶ L.D.F, D-D, H-bond

⑥  : LDF > D-D

⑦ CH_3OH and $H_3C-\overset{O}{\overset{\|}{C}}-CH_3$ LDF , D-D , H-bond

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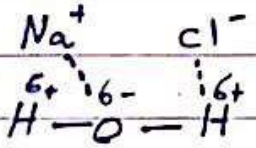
③ Ion-Dipole IMF (I-D)

between Ionic compound and polar compound



* IMF Strength :- I-D > H-bond > D-D > L.D.F

⑧ H_2O and F^- ⟶ L.D.F , I-D , H-bond

* Physical properties that depend on IMF :-

1- Vapor pressure (V.P) :

as IMF ↑ → V.P ↓

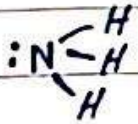
Vapor

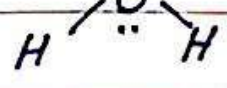
① CH_3OH , ② $H_3C-\overset{O}{\overset{\|}{C}}-CH_3$, ③ H_2O

①	②	③
LDF	LDF	LDF
D-D	D-D	D-D
1 H-bond		2 H-bond

V.P ② > V.P ① > V.P ③

IMF ③ > ① > ②

 (1 H-bond)

 (2 H-bond)

g L → g S → L

2- Boiling point (b.p) and melting point (m.p) :-

as IMF ↑ ⟶ B.p or m.p ↑

B.p ③ > ① > ②

g L → g S → L

2- Boiling point (b.p) and melting point (m.p) :-

as IMF ↑ ⟶ B.p or m.p ↑

B.p ③ > ① > ②

3- Viscosity : Resistance to flow . as IMF ↑ → Viscosity ↑

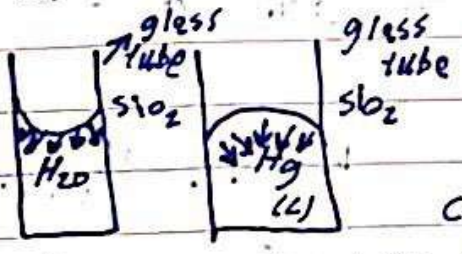
4- Surface Tension (S.T) : // to increase in surface area.

as IMF ↑ ⟶ S.T ↑

5- adhesive and cohesive forces.

between different types // Same //
of substances. " "

(Polar liquids)
water from a concave miniscus inside a narrow glass tube
(non " ")
Hg (mercurry) " " convex " " " " " "



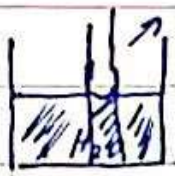
adhesive
H_2O - glass

cohesive
H_2O - H_2O

adhesive > cohesive

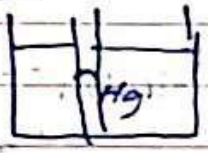
cohesive > adhesive
Hg - Hg Hg - glass

* Liquid in Capillary tube



adh > coh

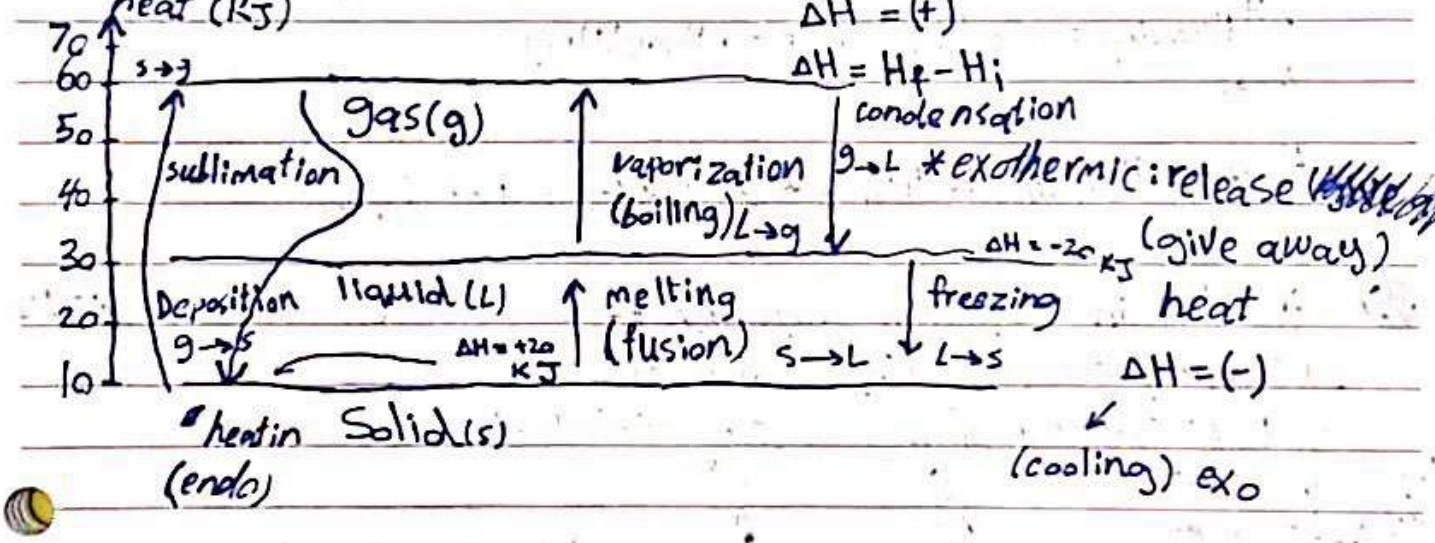
- Water level inside capillary tube is higher than outside
- $Hg_{(L)}$ " " " " " lower " "



coh > adh

* Heating & cooling

* endothermic: absorb (need) heat



$\Delta H_{sub} = -\Delta H_{Depo} = \Delta H_{melting} + \Delta H_{vap}$

60 - 10 = 50 KJ or 20 + 30 = 50 KJ

or $\Delta H_{Depo} = -50$ KJ

Ex. a substance has an enthalpy of vaporisation 40 KJ/mole and an enthalpy of freezing of 26 KJ/mole.

- calculate enthalpy of sublimation
- " " " condesition
- " " " fusion
- " " " Deposition

② $\Delta H_{cond} = -\Delta H_{vap} = -40\ KJ/mol$

③ $\Delta H_{fusion} = -\Delta H_{freezing} = +26\ KJ/mol$

① $\Delta H_{vap} = +40\ KJ/mol$ (L → g)

④ $\Delta H_{Depo} = -\Delta H_{sub} = -66\ KJ/mol$

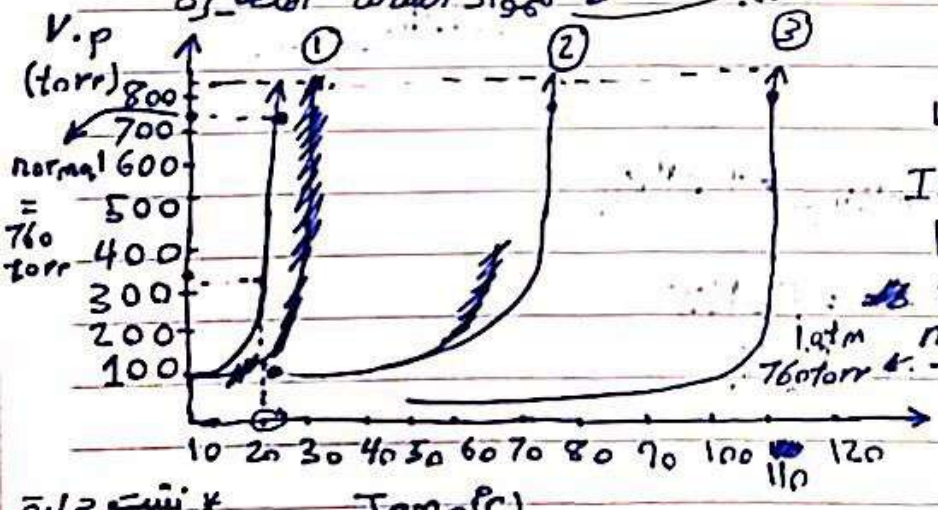
$\Delta H_{freezing} = -26\ KJ/mol = -\Delta H_{melting}$ (L → s)

$\therefore \Delta H_{sub} = \Delta H_{melting} + \Delta H_{vap} = +26 + +40 = +66\ KJ/mol$

* Clausin clapeyron Equation :-

- Vapor pressure (V.P) calculations ← →

للمواد السائلة المتطايرة ← ماد - أستون - تحول



V.P ① > ② > ③

IMF ③ > ② > ①

B.P ③ > ② > ①

normal boiling point (n.b.p)

③ 110°C ② 70°C ① 25°C

* نثبت حرارة معينة 20°C

① 350 Torr

② 100 Torr

③ Zero

$$Ln\frac{P_1}{P_2} = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

ΔH_{vap}: J/mol

R: 8.314 J/mol.°K

T: °K

- Calculate the normal (760 torr) boiling point of a substance that has a V.p of 150 torr at 23°C (296°K) and an enthalpy of vaporization of 58 KJ/mol (58×10³ J/mol)

$$\ln \frac{P_1}{P_2} = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\ln \frac{150}{760} = \frac{58\times10^3}{8.314}\left(\frac{1}{T_2} - \frac{1}{296}\right)$$

$$-1.62 = 6976.2\left(\frac{1}{T_2} - 0.0038\right)$$

$$\frac{1}{T_2} = 0.0035 \qquad T_2 = \frac{1}{0.0035} = 317^\circ K$$

- calculate the water V.p at 50°C (323°K) given that the enthalpy of vaporization is 40.7 KJ/mol ⇒ 40.7×10³ J/mol

water density = 1 g/ml

n.B.p = 100°C → 373°K

n.f.p = 0°C → 273°K

V.p 760 torr = 1 atm

$$\ln \frac{P_1}{P_2} = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\ln \frac{1}{P_2} = \frac{40.7\times10^3}{8.314}\left(\frac{1}{323} - \frac{1}{373}\right)$$

$$\ln \frac{1}{P_2} = 2.0316 \qquad \frac{1}{P_2} = e^{2.0316} = 7.626$$

760 torr ↑ 1 atm — (100°C → 373°K)

$$P_2 = \frac{1}{7.626} = 0.13 \text{ atm}$$

(H.W) - calculate the enthalpy of vaporization of water given that it has a V.p of 41.2 torr at 35°C (308°K).

$$\ln \frac{P_1}{P_2} = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

$$\ln \frac{41.2}{760} = \frac{\Delta H_{vap}}{8.314}\left(\frac{1}{373} - \frac{1}{308}\right)$$

$$-2.91 = \frac{\Delta H_{vap}}{8.314} * -0.00056$$

$$\Delta H_{vap} = \frac{2.91 * 8.314}{0.00056} = 43203.12 \text{ J/mol}$$