



2. Solutions

Topic To be Covered

- Concentration terms
- Vapour pressure
- Colligative properties
 - i) Relative lowering in V.P
 - ii) Elevation in B.P
 - iii) Depression in F.P.
 - iv) Osmotic Pressure
- Van't Hoff factor
- Solubility of Gases

Solution :- A solution is a homogeneous mixture of two or more substances which lose their individual identities and can't be separated by simple method.

On the basis of no. of components, the solution may be of the ~~two~~ two types.

i) Binary Solution :- The solution which contains two components is called binary solution,
e.g. Salt solution.

ii) Ternary Solution :- The solution which contains three components is called ^{ternary} binary solution.
Either two solvents and one solute or one solvent and two solutes. e.g. Salt, Sugar and water solution.

We will focus on Binary Solution.

Note:- The component that is present in the target largest quantity is known as solvent.

- One or more components present in the solution other than solvent are called solutes.
- Solvent determines the physical state in which solution exists.

e.g:- 20% ethanol solution.



20% ethanol + 80% water.

Concentration of Solutions

- | Volume Related
(Temperature dependent) | Mass Related
(Temperature independent) |
|---|---|
| → % by Volume (v/v) | → %. by mass (wt/wt) |
| → % by mass by volume (% w/v) | → Mole fraction |
| → Molarity (M) | → Molality |
| → Normality (N) | → Parts per million / billion. |



1) Mass Percent (w/w)

→ The mass percent of a component in a given solution is the mass of the component per 100 g of the solution.

$$\text{mass \% of a component} = \frac{\text{Mass of the component in the solution}}{\text{Total mass of the solution}} \times 100$$

Let w_B be the mass of solute (B) and w_A be the mass of solvent (A) then

$$\text{Mass \%} = \frac{w_B}{w_A + w_B} \times 100$$

e.g. A 10% glucose solution in water means 10 g of glucose is dissolved in 90 g of water resulting in a 100 g of solution.

Example Calculate the mass percentage of benzene and CCl_4 if 22 g of benzene is dissolved in 122 g of CCl_4 .

Solution:-

$$\text{mass \% of } \text{C}_6\text{H}_6 = \frac{\text{mass of benzene}}{\text{mass of solution}} \times 100$$

$$= \frac{22}{144} \times 100 = 15.28 \%$$

$$\text{mass \% of } \text{CCl}_4 = \frac{\text{mass of } \text{CCl}_4}{\text{mass of solution}} \times 100$$

$$= \frac{122}{144} \times 100 = 84.72 \%$$

Concentration

Date _____



Terms

Molarity

Molality

Normality

Mol fraction

}

Studied in

Class 11

Equivalent Mass / wt

$$\text{Equivalent Mass} = \frac{\text{Molar mass}}{\text{Valency factor } (\alpha)}$$

For Acids (α = Basicity)

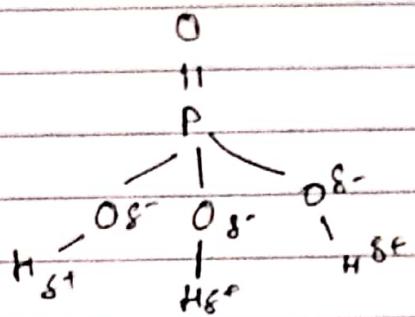
Eg. ① H_2SO_4

Basicity \rightarrow no. of H^+ ions released by acids in the solution

$$\text{Eq. mass of } H_2SO_4 = \frac{\text{molar mass of } H_2SO_4}{\text{Basicity}} = \frac{98}{2} = 49 \text{ g.}$$

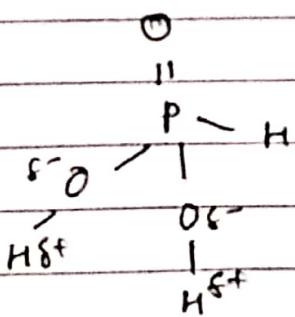
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② H_3PO_4



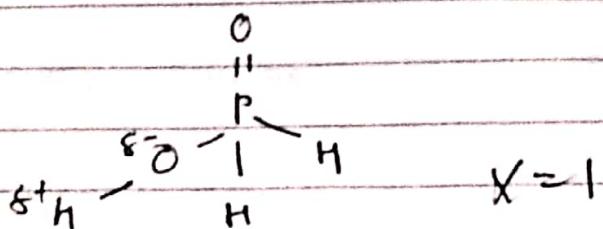
$$\alpha = 3$$

③ H_3PO_3

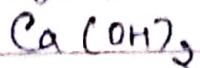


$$\alpha = 2$$

④ H_3PO_2



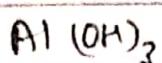
$$\alpha = 1$$

For Bases $(X = \text{Acidity})$ $28+ 28-$ 

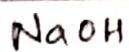
$X = 2$

Acidity: no. of OH⁻ ions released by bases into the solution.

$$\frac{\text{Eq. mass of bases}}{\text{Molar mass of base}} = \frac{1}{\text{Acidity}}$$



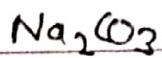
$X = 3$



$X = 1$

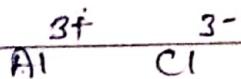
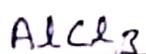
For Salts $[x = \text{total positive charge on cation}]$
~~or~~ total negative charge on anion

2nd

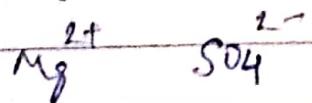
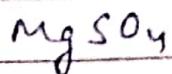
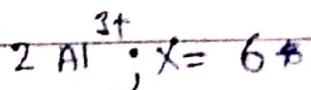
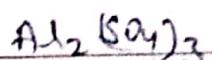


$$\boxed{\text{Eq. mass} = \frac{\text{Molar mass}}{x}}$$

$\therefore X = 2$



$X = 3$

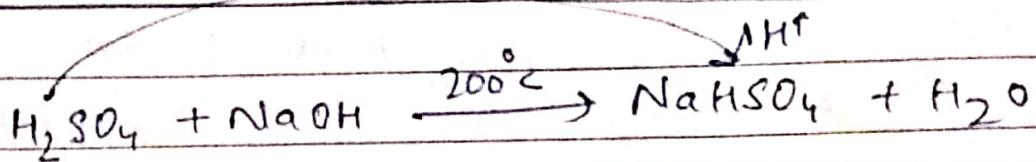


$\therefore X = 2$

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* Equivalent weight depends on reaction.

E.g.



Here, $\text{Eq. wt of H}_2\text{SO}_4 = \frac{\text{Mol. mass of H}_2\text{SO}_4}{x}$

Here $x = 1$

$$\text{no. of moles} = \frac{\text{given mass}}{\text{Molar mass}}$$

$$\text{Eq. wt} = \frac{\text{Molar mass}}{x}$$

$$\text{no. of g. eq.} = \frac{\text{Given mass}}{\text{Eq. wt}}$$

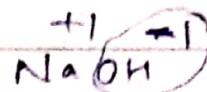


Q. Find no. of gram equivalent present in

i) 0.4 g of NaOH

Solution

X for NaOH is 1



$$\text{Equivalent wt of NaOH} = \frac{\text{Molar mass of NaOH}}{X}$$

$$= \frac{23 + 16 + 1}{1} \\ = 40$$

Now,

$$\text{Gram Eq. of } 0.4 \text{ g of NaOH} = \frac{\text{Given mass}}{\text{Eq. mass / wt}}$$

$$= \frac{0.4}{40}$$

$$= 0.01 \text{ g. eq.}$$

A.

ii) 0.98 g H₂SO₄

Q. find no. of gm eq. present in 53 g of Na_2CO_3 .

Solution: Eq. mass of $\text{Na}_2\text{CO}_3 = \frac{\text{molar mass of } \text{Na}_2\text{CO}_3}{x}$

*+ total val. charst
+ oxidation state
here 2⁺ 2
∴ + 2*

$$\begin{aligned} &= \frac{23 \times 2 + 12 + 16 \times 3}{2} \\ &= \frac{46 + 12 + 48}{2} \\ &= 53 \text{ g.} \end{aligned}$$

Gram eq. of 53 g of $\text{Na}_2\text{CO}_3 = \frac{\text{Given mass}}{\text{Eq. mass}}$

$$\begin{aligned} &= \frac{53}{53} \\ &= 1 \text{ eq.} \end{aligned}$$

6. Normality = no. of gram equivalents of solute present in 1L of solution.

unit gm.eq./L or N.

$$N = \frac{\text{no. of g. Eq. of solute}}{V \text{ of solution (in L)}}$$



Date _____

a. If 0.98g of H_2SO_4 are present in 500 ml solution. find Normality.

Solution: Eq. wt of $\text{H}_2\text{SO}_4 = \frac{\text{Mol. mass of } \text{H}_2\text{SO}_4}{\text{X (Basicity)}}$

$$= \frac{98}{2} = 49 \text{ g.}$$

Gram Eq. of 0.98g of $\text{H}_2\text{SO}_4 = \frac{\text{Given mass}}{\text{Eq. wt of } \text{H}_2\text{SO}_4}$

$$= \frac{0.98 \text{ g}}{49 \text{ g}} = 0.02$$

\therefore Normality = $\frac{\text{no. of gram eq. of } \text{H}_2\text{SO}_4}{\text{V of solution (in L)}}$

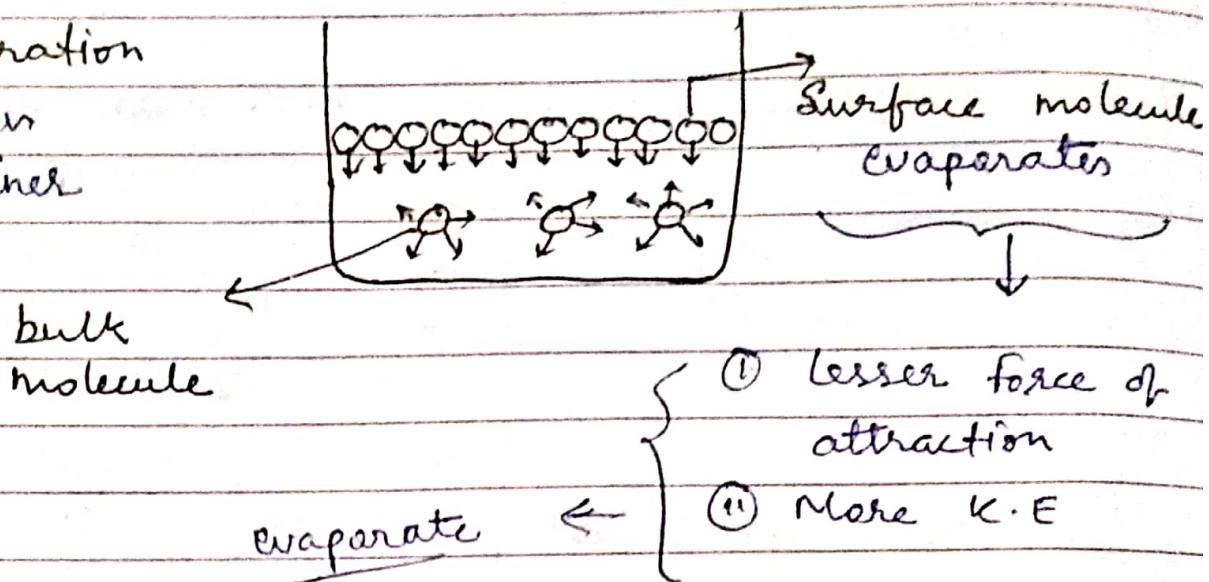
$$\begin{aligned} \text{Normality} &= \frac{0.2}{\frac{500}{1000}} \\ &= \frac{0.2}{0.5} = 0.4 \text{ N} \end{aligned}$$

Ans.

Vapour Pressure

Evaporation

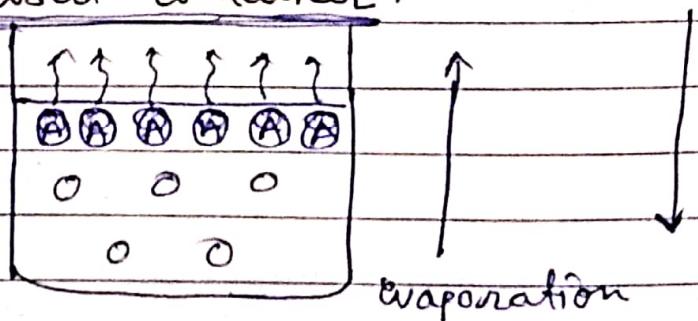
In open container



- if container is open then weight of liquid will decrease because of the evaporation of surface molecule. And the vapours escape.
- We will never talk about vapour pressure if the container is open.

Evaporation in closed container.

Condensation.



In closed container vapours can't escape so, it will exert pressure ^{above the liquid,} which is called vapour pressure.

$$P_A^\circ = V.P \text{ of pure liquid A.}$$



Liq \rightleftharpoons Vapour and achieves Equilibrium

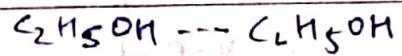
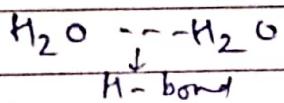
→ we will talk about Vapour pressure only in equilibrium condition.

→ Vapour Pressure does not depends on the shape or size of the container

→ V.P depends on the nature of liquid/substance and temperature.

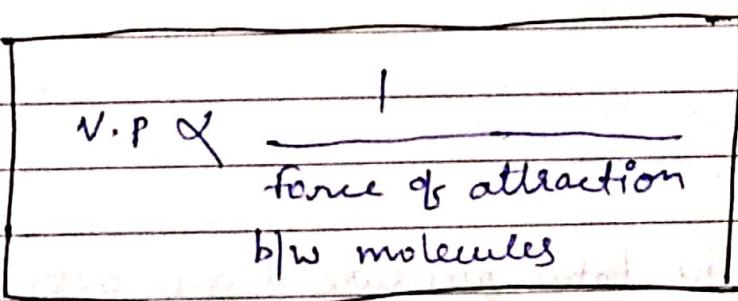
e.g. H_2O
(water)

C_2H_5OH
(ethanol)



$$V.P \text{ of } C_2H_5OH > V.P \text{ of } H_2O$$

$$P^\circ_{C_2H_5OH} > P^\circ_{H_2O}$$



1 molecule of
 H_2O makes
4 H-bond

and 1 molecule
of C_2H_5OH make
only 1 H-bond

$\therefore H_2O$ molecules have
more attraction
force

Substance

Volatile

$$P^{\circ} \neq 0$$

e.g. H_2O, CH_3OH

C_2H_5OH, C_6H_6

$C_6H_5CH_3$ (toluene)

Non Volatile (Solids)

$$P^{\circ} = 0$$

(No tendency to evaporate)

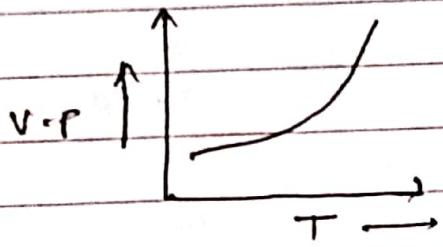
e.g.: - urea (CH_2CONH_2) 60

glucose (CH_2O_6) 180

sucrose ($C_{12}H_{22}O_{11}$) 342

→ Vapour pressure depends on Temperature.

Temp $\uparrow \rightarrow$ evaporation $\uparrow \rightarrow$ v.p \uparrow



Class 11

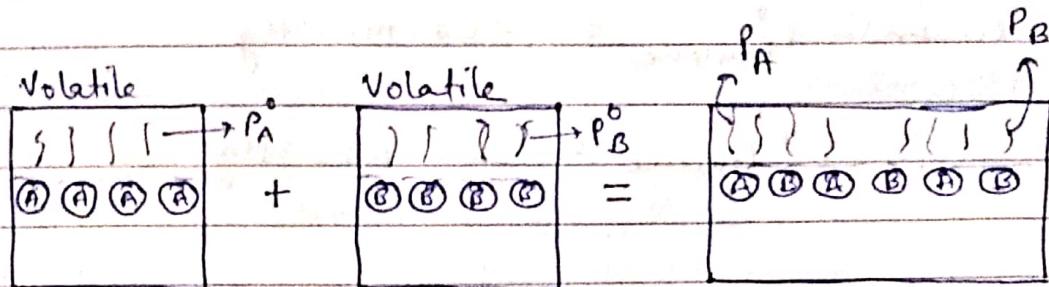
Dalton's law:- The total pressure (P_{total}) over the solution in the container will be sum of the partial pressure of the components of the solution.

$$P_{total} = P_A + P_B$$



Vapour Pressure of Liquid-Liquid Solution.

i.e. Solute (Volatile) B
Solvent (Volatile) A



Pure Liquid A

Pure Liquid B

 P_A → Partial V.P. of A P_A^0 → VP of pure A P_B^0 → VP of pure B P_B → Partial V.P. of B.

Raoult's Law

In a solution, the partial VP of each component is directly proportional to the mole fraction of that component at a given temperature.

$$P_A \propto X_A$$

$$P_B \propto X_B$$

$$\left. \begin{array}{l} X_A = \frac{n_A}{n_A + n_B} \\ X_B = \frac{n_B}{n_A + n_B} \\ X_A + X_B = 1 \end{array} \right\}$$

Now,

$$P_A \propto X_A$$

$$\Rightarrow P_A = K X_A \quad \text{--- (1)}$$

Let us consider Pure A.

$$X_B = 0, X_A = 1$$

$$P_A = K X_A \quad [\text{from (1)}]$$

$$\Rightarrow P_A = K \cdot 1$$

$$\Rightarrow K = P_A^0$$

$$\text{i.e. } P_A = P_A^0 X_A \quad [\text{from (1)}]$$

$$P_B = P_B^0 X_B \leftarrow (\text{Similarly})$$

Total VP of solution

$$P_T = P_A + P_B \quad (\text{Dalton's law})$$

$$P_T = P_A^0 X_A + P_B^0 X_B$$

G.

Q. If 0.78 g of benzene (C_6H_6) & 0.92 g of Toluene ($C_6H_5CH_3$) are mixed. find

- (i) Partial pressure of benzene & toluene
- (ii) Total V.P

$$\text{Given:- } P_{\text{benzene}}^{\circ} = 400 \text{ mm Hg}$$

$$P_{\text{Toluene}} = 200 \text{ mm Hg.}$$

Solution:-

$$n_{\text{benzene}} = \frac{\text{Given Mass of benzene}}{\text{Molar mass of benzene}} = \frac{0.78}{78} = 0.01 \text{ mole}$$

$$n_{\text{Toluene}} = \frac{\text{Given mass of toluene}}{\text{Molar mass of toluene}} = \frac{0.92}{92} = 0.01 \text{ mole}$$

$$X_{\text{Benzene}} = \frac{n_{\text{benzene}}}{n_{\text{benzene}} + n_{\text{Toluene}}} = \frac{0.01}{0.01 + 0.01} = \frac{1}{2}$$

$$X_{\text{Toluene}} = \frac{n_{\text{Toluene}}}{n_{\text{Toluene}} + n_{\text{benzene}}} = \frac{0.01}{0.01 + 0.01} = \frac{1}{2}$$

$$(i) P_{\text{Benzene}} = P_{\text{Benzene}}^{\circ} \cdot X_{\text{Benzene}}$$

$$= 400 \times \frac{1}{2} = 200 \text{ mm Hg}$$

$$P_{\text{Toluene}} = P_{\text{Toluene}}^{\circ} \cdot X_{\text{Toluene}}$$

$$= 200 \times \frac{1}{2} = 100 \text{ mm Hg}$$

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$$\begin{aligned}P_{\text{total}} &= P_{\text{Benzene}} + P_{\text{Toluene}} \\&= 200 + 100 \\&= 300 \text{ mm Hg}\end{aligned}$$

Q. Ethanol + methanol

3 moles 1 moles

Given: $P_E^{\circ} = 50 \text{ mm Hg}$ & $P_m^{\circ} = 55 \text{ mm Hg}$

Find P_{total} .

Solution:



Q. Ethanol + Methanol

$$0.92\text{ g} \quad 0.32\text{ g}$$

$$P_e^{\circ} = 55 \text{ mm Hg}$$

$$P_m^{\circ} = 50 \text{ mm Hg}$$

find (i) P_e & P_m

(ii) P_{Total}

(iii) Mole fraction of ethanol and methanol
in Vapour phase (X_e & X_m)

given

solution:- (i) $n_e = \frac{\text{mass of ethanol}}{\text{molar mass of ethanol}} = \frac{0.92\text{ g}}{46\text{ g}} = 0.02$

$$n_m = \frac{\text{Given mass of Methanol}}{\text{molar mass of Methanol}} = \frac{0.32\text{ g}}{32} = 0.01$$

$$X_e = \frac{0.02}{0.03} = \frac{2}{3} \quad \text{and} \quad X_m = \frac{0.01}{0.03} = \frac{1}{3}$$

$$P_e = P_e^{\circ} \times X_e = 55 \times \frac{2}{3} = 36.66 \text{ mm Hg Ans}$$

$$P_m = P_m^{\circ} \times X_m = 50 \times \frac{1}{3} = 16.66 \text{ mm Hg Ans}$$

(ii) $P_{\text{Total}} = P_e + P_m$

$$= 36.66 + 16.66$$

$$= 53.32 \text{ mm Hg}$$

Ans

Date _____



(iii) mole fraction of ethanol
in vapour phase

$$y_c = \frac{P_e}{P_T} \quad \begin{array}{l} \text{from Dalton's} \\ \text{Law} \\ \text{for gases} \end{array}$$
$$\approx \frac{36.66}{53.32} = 0.68$$

mole fraction of
component 1 in
vapour phase (y_1)

$$y_1 = \frac{\text{Partial Pressure}}{\text{Total Pressure}}$$

$$y_m = \frac{P_m}{P_T} = \frac{16.66}{53.33} = 0.32$$

A₂

$$\therefore \text{e} \boxed{y_1 = \frac{P_L}{P_T}}$$

Class 11
Dalton's Law

Dalton's Law

for gases

$$P_{O_2} = y_{O_2} + P_{\text{total}}$$

* Graphical Representation of Raoult's Law

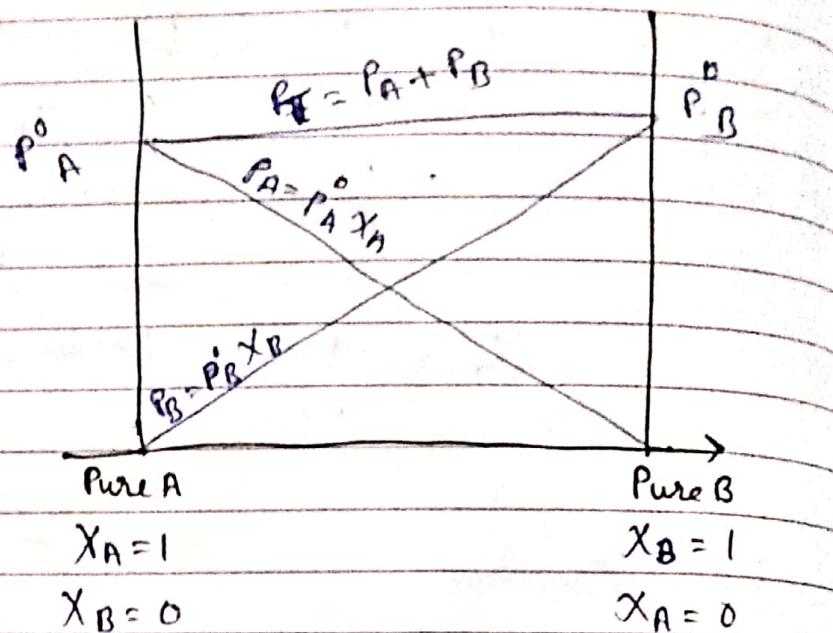
$A + B$
Volatile

P_A^0, P_B^0

P_A

$P_A = P_A^0 X_A$

$P_B = P_B^0 X_B$



Q. Benzene + Toluene

Total VP is $P_T = 100 + 60 X_B$; X_B = mole fraction of Benzene

find Pure V.P of Benzene (P_{Benzene}^0) and pure V.P of Toluene (P_{Toluene}^0).

Solution:-

$$P_T = 100 + 60 X_B \quad (\text{Given}) \rightarrow ①$$

we know,

$$X_B + X_T = 1$$

$$\Rightarrow X_T = 1 - X_B \rightarrow ②$$

$$P_T = P_B + P_T$$

$$\Rightarrow P_T = P_B^0 X_B + P_T^0 X_T$$

$$\Rightarrow P_T = P_B^0 X_B + P_T^0 (1 - X_B) \quad [\text{from } ②]$$

$$\Rightarrow P_T = P_B^0 X_B + P_T^0 - P_T^0 X_B$$

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$$P_T = P_T^0 + x_B (P_B^0 - P_T^0) \quad \text{--- (iii)}$$

Comparing (i) and (iii)

we get $P_T^0 = 100$

A₂

and $P_B^0 - P_T^0 = 60$

$$\Rightarrow P_B^0 - 100 = 60$$

$$\Rightarrow P_B^0 = 160$$

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Vapour Pressure of Solutions of Solids and Liquids

i.e Solute: Non-volatile (B)

Solvent: Volatile (A)

Solute :-

formula Molar mass

Urea (NH_2CONH_2) (60 g/mol)

Glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) (180 g/mol)

Sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$) (342 g/mol)

Solvent :-

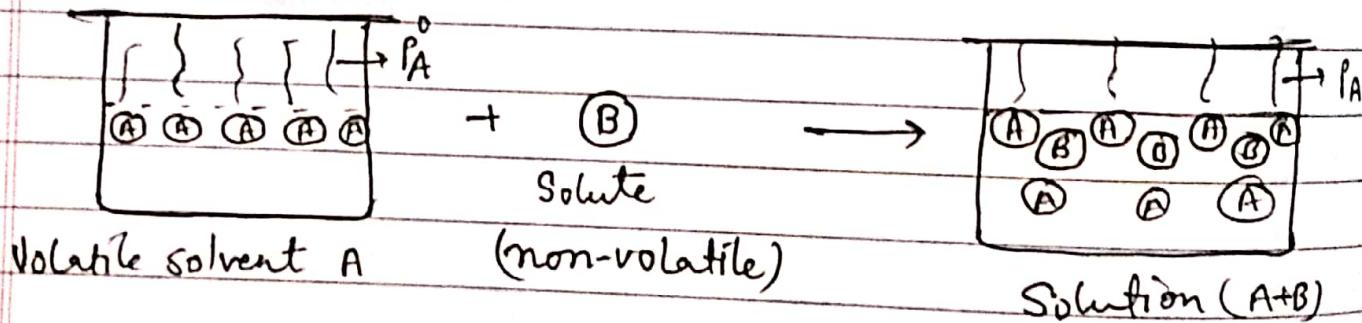
H_2O (Water) (18 g/mol)

CH_3OH (Methanol) (32 g/mol)

$\text{C}_2\text{H}_5\text{OH}$ (Ethanol) (46 g/mol)

C_6H_6 (Benzene) (78.11 g/mol)

$\text{C}_6\text{H}_5\text{CH}_3$ (Toluene) (92.14 g/mol)



→ On addition of non-volatile solute VP is lowered

Now,

$$P_A \propto X_A \quad [\text{Raoult's Law}]$$

$$\Rightarrow P_A = P_A^0 X_A$$

where

P_A = partial pressure of A

P_A^0 = v.p. of pure solvent A.

$$\Rightarrow P_A = P_A^0 (1 - X_B) \quad [\because X_A + X_B = 1]$$

$$\Rightarrow P_A = P_A^0 - P_A^0 X_B$$

$$\Rightarrow P_A^0 X_B = P_A^0 - P_A$$

$\{ P_A^0 - P_A = \text{Lowering in v.p.} \}$

$$\Rightarrow X_B = \frac{P_A^0 - P_A}{P_A^0}$$

V.V.T

→ Relative lowering in v.p.
(Colligative property)

Note:- Relative lowering in v.p. is equal to mole fraction of solute B.

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this

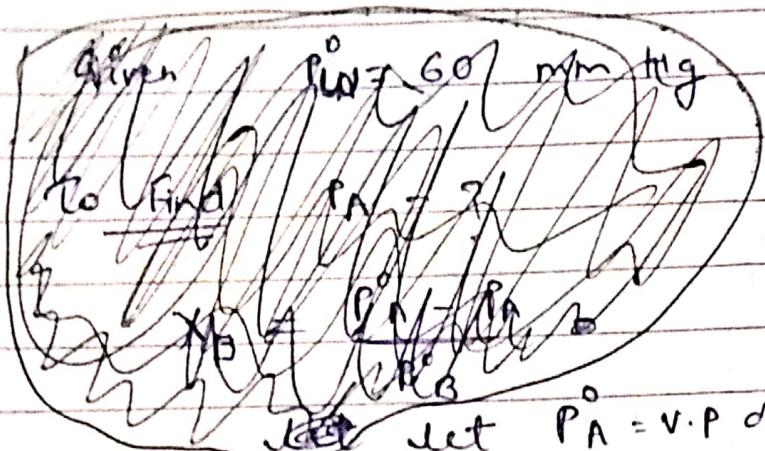
* Colligative Property

The properties of solution which depend upon no. of solute particles. [i.e. depend upon no. of moles of solute, no. of molecules of solute, no. of ions of solute, no. of mole fraction of solute] and does not depend upon nature of solute particles.

Eg:- Relative lowering in v.p. is directly proportional to the no. of moles of solute.

Q. The vapour pressure of pure water is 60 mm Hg at some temp. Find the v.p. of a solution containing 30 g urea (NH_2CONH_2) dissolved in 72 g water.

Solution:-



$$\text{Given: } P_A^0 = 60 \text{ mm Hg}$$

P_A = Partial v.p. of solution (solvent)

Now,

$$n_{\text{urea}} = \frac{30}{60} = 0.5$$

$$n_{\text{water}} = \frac{72}{18} = 4$$

Let X_B = mole fraction of urea

$$X_B = \frac{0.5}{4+0.5} = \frac{0.5}{4.5} = \frac{1}{9}$$

$$\text{Now, } \frac{P_A^0 - P_A}{P_A^0} = X_B$$

$$\Rightarrow \frac{60 - P_A}{60} = \frac{1}{9}$$

$$\Rightarrow P_A = 60 - \frac{60}{9} = \frac{480}{9} = 53.33 \text{ mm Hg}$$

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2nd Method

$$P_A = P_A^0 \chi_A$$

$$n_{\text{urea}} = 0.5$$

$$n_{\text{water}} = 4$$

$$\chi_A / \chi_{\text{water}} = \frac{n_{\text{water}}}{n_{\text{water}} + n_{\text{urea}}} = \frac{4}{4.5}$$

Now,

$$P_A = P_A^0 \chi_A$$

$$= 60 \times \frac{4}{4.5}$$

$$= 53.33 \text{ mm Hg}$$

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Q. Calculate the mass of a non volatile solute whose molar mass is 40 g/mol, required to be dissolved in 114 g of octane to lower VP to 80%.

Solution:- Let $P_A^0 = 100 \text{ mm Hg}$

$A \rightarrow \text{octane}$
 $B \rightarrow \text{Solute}$

then $P_A = 80 \text{ mm Hg}$

Now

$$\frac{P_A^0 - P_A}{P_A^0} = x_B$$

$$\Rightarrow \frac{100 - 80}{100} = x_B$$

$$\Rightarrow \left[x_B = \frac{1}{5} \right].$$

(Ans octane)

Now,

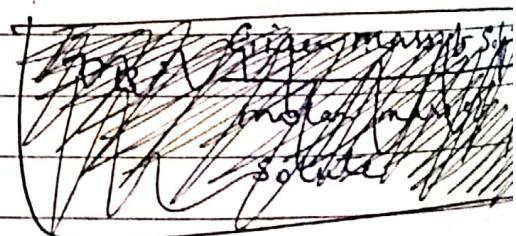
$$x_B = \frac{n_B}{n_A + n_B}$$

$$\Rightarrow \frac{1}{5} = \frac{n_B}{1 + n_B}$$

$$\Rightarrow 1 + n_B = 5n_B$$

$$\Rightarrow \left[n_B = \frac{1}{4} \right]$$

Given
 molar mass of octane
 molar mass of octane
 $\Rightarrow n_A = \frac{114}{114} = 1.$



Now,

$$n_B = \frac{\text{Required mass of solute } B}{\text{Molar mass of solute } B}$$

$$\Rightarrow \frac{1}{4} = \frac{\text{Required mass of } B}{40}$$

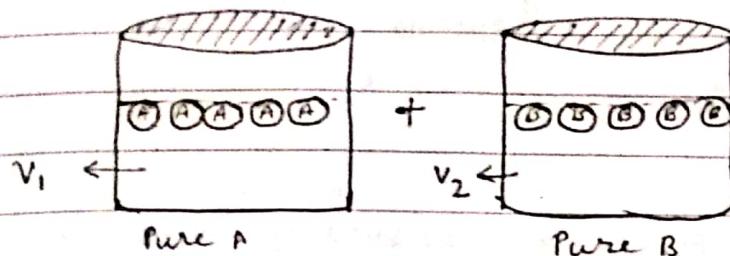
$$\Rightarrow \text{Required mass of } B = 10 \text{ g Ans}$$



Ideal & Non-Ideal solutions

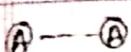
ΔV_{mix} = Change in

Volume on mixing

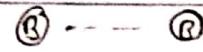


i) If $\Delta V_{\text{mix}} = 0$

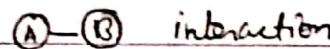
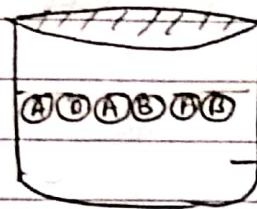
then ideal solution



bond break
heat absorbed



bond break
heat absorbed



Heat released

$$\Delta V_{\text{mix}} = V_f - (v_1 + v_2)$$

ii) ΔH_{mix} change in Enthalpy on mixing.

iii) Interaction between

$$\begin{aligned} (A-A) \\ (B-B) \end{aligned} \left. \begin{array}{l} \{ \\ \} \end{array} \right\} = (A-B) \quad \text{or} \quad \neq$$

iv) $\Delta S_{\text{mix}} > 0$

$\Delta G_{\text{mix}} < 0$



ΔS_{mix} Change in Entropy

ΔG_{mix} Change in Gib's free energy.

always

v) Raoult's law

If follow \rightarrow ideal

Class 11

Entropy (S)

(Spontaneous reaction) → process happens itself or by little push
nature ↑ process

Randomness increase

• Entropy (S) → measure of Randomness

Entropy can't be measured but change in entropy ΔS can be measured.

$$\boxed{\Delta S = S_f - S_i}$$

If ΔS = +ve than spontaneous

ΔS = -ve than non-spontaneous

Ideal solution

i) which follows Raoult's law at all concentration and temperature.

$$\text{iii) } \Delta V_{\text{mix}} = 0$$

(A-A) interaction = (B-B) interaction = (A-B) interaction

$$iii) \Delta H_{\text{mix}} = 0$$

Heat absorbed = Heat released

(when A-A bond and)
 B-B bond break formation of
 (A-B) bond

iv) force of attraction

$$A - A = B - B = A - B$$

$$v) \quad \Delta S_{\text{mix}} > 0 \quad \text{and} \quad \Delta G_{\text{mix}} < 0$$

Non Ideal Solution

i) Do not follow Raoult's law

$$P_{A \text{ obs}} \neq P_A^* x_A$$

$$P_{\text{Total}} \neq P_A^* x_A + P_B^* x_B$$

$$P_{B \text{ obs}} \neq P_B^* x_B$$

ii) $\Delta V_{\text{mix}} \neq 0$ iii) $\Delta H_{\text{mix}} \neq 0$ iv) $A-A \neq A-B$
 $B-B$ v) $\Delta S_{\text{mix}} > 0$

$$\Delta G_{\text{mix}} < 0$$

Non-ideal Solution

Shows +ve deviation
from Raoult's law



Shows -ve deviation
from Raoult's law



* Non ideal solution showing -ve deviation from Raoult's Law :-

$$\text{i) } P_{\text{Total}} < P_A^\circ x_A + P_B^\circ x_B \quad P_{A \text{ obs}} < P_A^\circ x_A$$

$$\begin{matrix} (\text{Experimental}) \\ \text{obs.} \end{matrix} \quad P_{B \text{ obs}} < P_B^\circ x_B$$

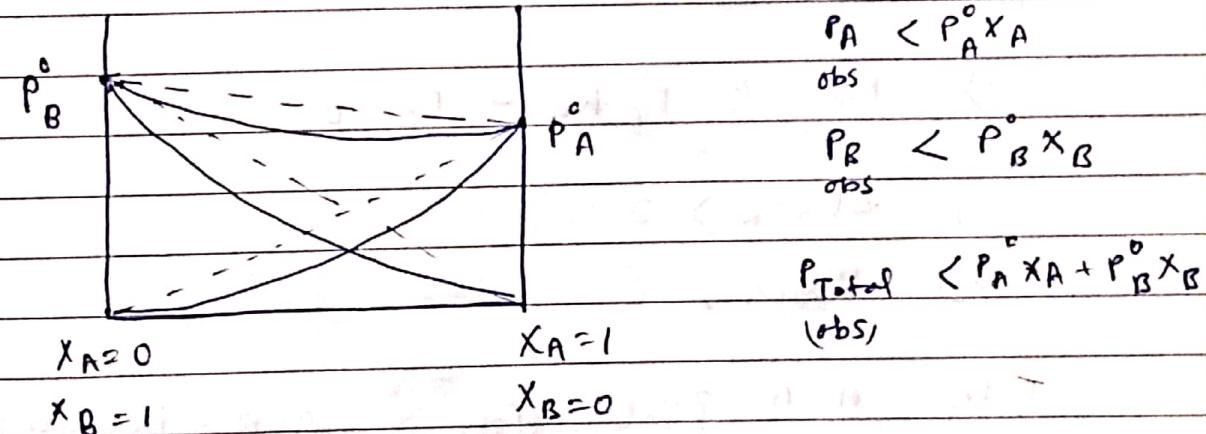
ii) force of attraction

$$\begin{matrix} A-A \\ B-B \end{matrix} \text{ interaction} < (A-B) \text{ interaction}$$

$$\text{iii) } \Delta V_{\text{mix}} < 0$$

$$\text{iv) } \Delta H_{\text{mix}} < 0 \quad \begin{matrix} \text{Heat released} \\ \text{in formation} \end{matrix} \quad \begin{matrix} \text{Heat absorbed} \\ \text{in breaking} \\ \text{of A-B bond} \end{matrix}$$

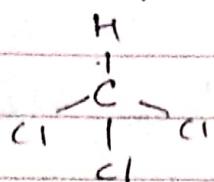
$$\left. \begin{matrix} \Delta H = -\text{ve} & \text{Heat released} \\ \Delta H = +\text{ve} & \text{Heat absorbed} \end{matrix} \right\}$$



81



Chloroform

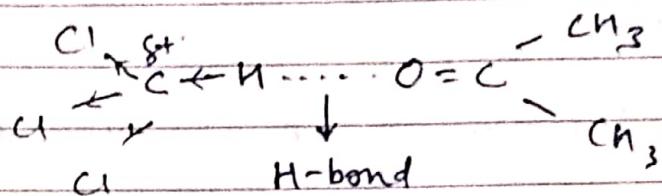
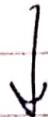


Acetone

Acetone

weak Van der Waal force

weak N.W.F



We know H-bond is stronger than van der Waal force.

∴ After mixing attraction force b/w molecules increases, so due to which volume will decrease, and pressure will also decrease.

* Non-ideal solution showing the deviation from Raoult's law.

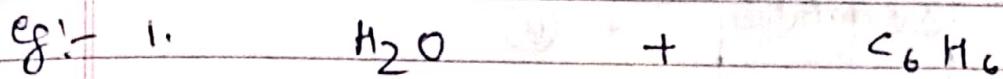
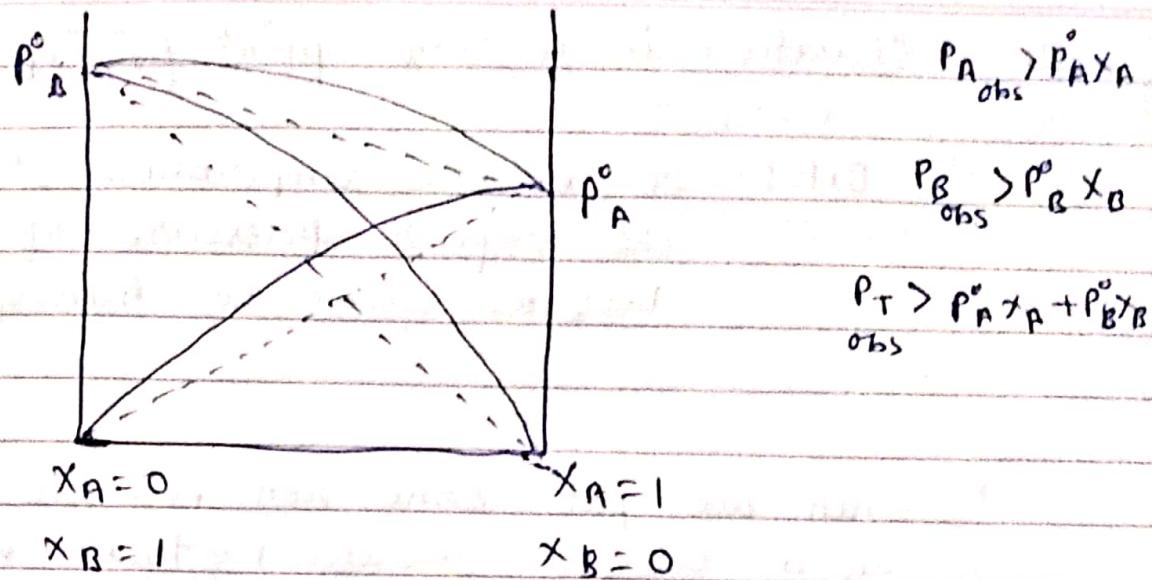
$$i) \quad P_T^{obs} > P_A^o x_A + P_B^o x_B$$

$$\text{ii) } \Delta V_{\text{mix}} > 0$$

$$\text{iii) } \Delta H_{\text{mix}} > 0$$

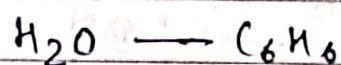
iv) $\frac{A-A}{B-B}$ } interaction \rightarrow A-B interaction.

Date _____



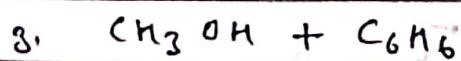
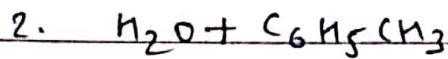
H-bond

V.W force



force of attraction
decreases

$\therefore V$ will increase
and P will increase



} Shows +ve deviation
from Raoult's law.

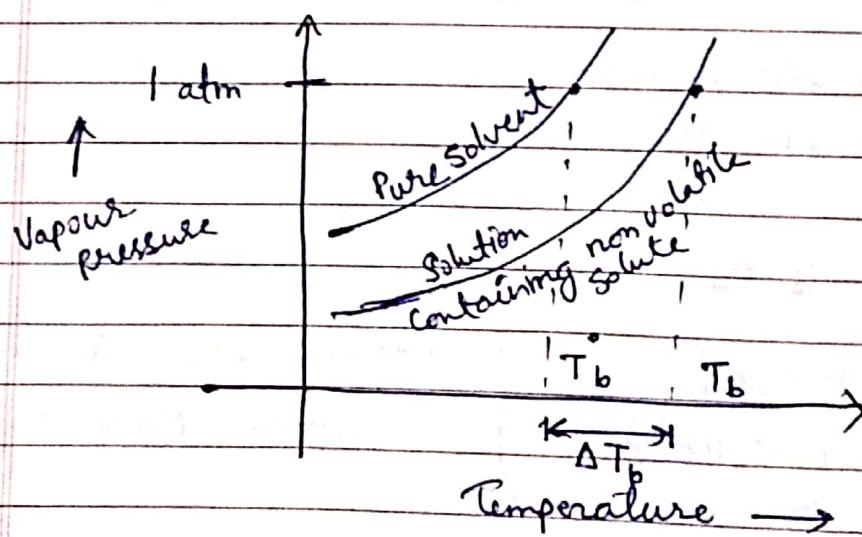
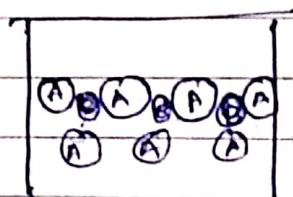
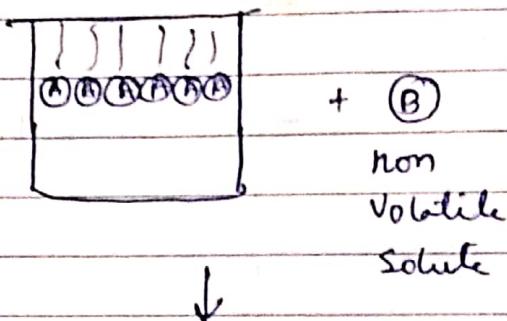
colligative property

Date _____

* Elevation in Boiling point (ΔT_b)

B.P :- It is the temperature at which the vapour pressure of solution becomes equal to Atmospheric pressure.

→ When we put some non-volatile solute in a solvent (volatile) then V.P decreases.



$$\Delta T_b = T_b - T_b^{\circ}$$

$\Delta T_b \rightarrow$ elevation in
boiling point

11

Experimentally it is observed that

$$\Delta T_b \propto \text{molarity (m)}$$

$$\text{molarity} = \frac{\text{no. of moles of non-volatile Solute}}{\text{Mass of solvent (in kg)}}$$

$$\Rightarrow \boxed{\Delta T_b \propto \frac{\text{no. of moles of solute}}{\text{mass of solvent (in kg)}}}$$

This proves that elevation in B.P. is a colligative property.

Now,

$$\Delta T_b \propto m$$

$$\Rightarrow \Delta T_b = K_b m \quad \text{where } K_b = \text{molal elevation constant}$$

$\rightarrow K_b$ depends on Solvent

\rightarrow unit of K_b is $\text{K} \cdot \text{kg/mol}$

Q. Define K_b .

$$\text{if } m=1 \quad \Delta T_b = K_b m$$

$$\Rightarrow \Delta T_b = K_b \cdot 1$$

$$\Rightarrow \Delta T_b = K_b$$

\therefore Molal elevation constant is equal to elevation in B.P. of a solution when 1 mole of solute is dissolved in 1 kg of solvent.

Date _____

Q. 18g glucose $C_6H_{12}O_6$ is dissolved in 1kg water. Find the B.P of solution.

Given: B.P of pure water = 373 K

K_b for water = 0.52 K kg/mol

Solution:

$$\Delta T_b = K_b \cdot m$$

$$= K_b \cdot \frac{\text{no. of moles of solute}}{\text{mass of solvent (in kg)}}$$

$$= 0.52 \times \frac{\frac{18}{180}}{1\text{kg}}$$

$$= 0.052$$

Now,

$$\Delta T_b = T_b - T_b^0$$

$$\Rightarrow 0.052 = T_b - 373$$

$$\Rightarrow T_b = 373.052 \text{ K}$$

ΔT_b



Date _____

Q. 6g of urea and 3g of glucose are dissolved in 300g of water. Find the B.P of solution.

Given:- B.P of pure water = 100°C

K_b for water = 0.52 K kg/mol .

Solution:

$$\text{no. of moles of urea } (\text{NH}_2\text{CONH}_2) = \frac{6}{60} = 0.1$$

$$\text{no. of moles of glucose } (\text{C}_6\text{H}_{12}\text{O}_6) = \frac{3}{180} = 0.05$$

$$\text{Total no. of moles of solutes} = 0.1 + 0.05$$

$$= 0.15 \text{ moles}$$

$$\Delta T_b = K_b \times m$$

$$= 0.52 \times \frac{0.15}{\frac{300}{1000}}$$

$$= 0.26$$

$$\therefore \Delta T_b = T_b - T_b^{\circ}$$

$$\Rightarrow T_b = \Delta T_b + T_b^{\circ}$$

$$\Rightarrow T_b = 0.26 + 100 \\ = 100.26^{\circ}\text{C}$$

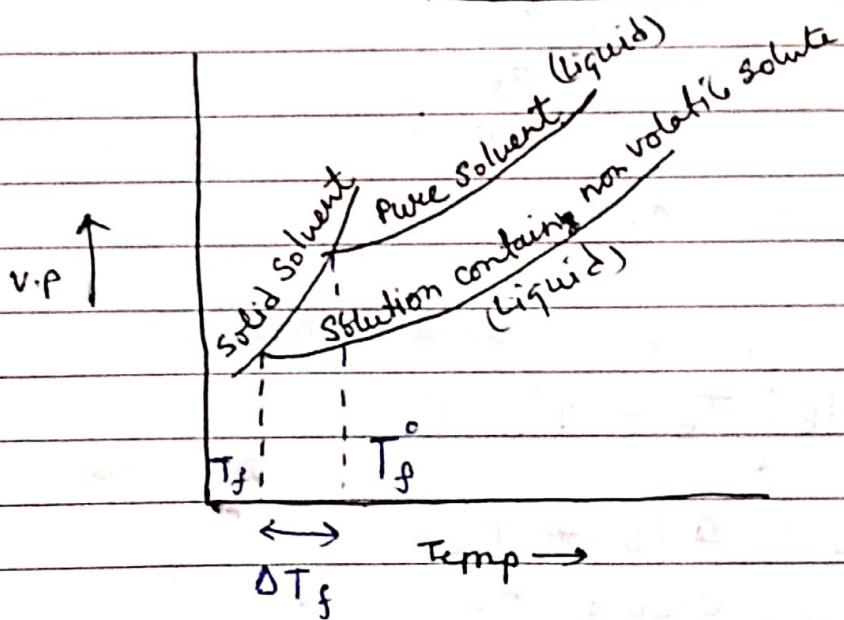
Ayaz



* Depression in Freezing point

Ques :- freezing point :- The freezing point is that temperature at which the solid and the liquid states of the substance have the same v.p.

→ when a non-volatile solute is added to a solvent the freezing point of thus formed solution is always lower than that of pure solvent as the vapour pressure of the solvent decreases in the presence of non-volatile solute. This difference in the freezing point is known as depression in Freezing point.



ΔT_f : Depression in F.P.

$$\boxed{\Delta T_f = T_f^o - T_f}$$

Note:-

→ When a liquid freezes, it tends to then the molecules of liquid try to arrange itself in a pattern ~~in~~ an ordered pattern, so, when we put non-volatile solutes in a liquid then it disturbs the arrangement / pattern of molecules, that is why the freezing point decreases.



By Experiment we find that

$$\Delta T_f \propto m \quad [m: \text{molality}]$$

$$\Delta T_f \propto \frac{\text{no. of moles of non-volatile solute}}{\text{mass of solvent (in kg)}}$$

This proves that Depression in Freezing point is a colligative property.

$$\Delta T_f \propto m$$

$$\Rightarrow \boxed{\Delta T_f = k_f m}$$

k_f = molal depression constant

k_f depends upon solvent.

OR

osmotic constant

unit of k_f : kg/mol

* Define K_f

$$\Delta T_f = K_f \cdot m$$

If $m = 1$ molal, then $\Delta T_f = K_f$

Thus, K_f (molal Freezing point depression constant) is defined as the depression in freezing point for 1 molal solution i.e. a solution containing 1g mole of solute dissolved in 1000 g of solvent.

mp
NCERT

Q. A 5% solution (By mass) of Sugar cane in water has freezing point of 271 K. Calculate the freezing point of a 5% glucose in water, if freezing point of pure water is 273.15 K.

Solution for Sugarcane solution.

$$\text{let } w_{\text{Sugar}} = 5 \text{ g} \quad w_{\text{water}} = 95 \text{ g}$$

$$M_{\text{sugar}} = 342 \text{ g/mol} \quad (\text{molar mass})$$

$$\text{molality} = \frac{\text{no. of moles of sugar}}{\text{mass of water (in kg)}}$$

$$= \frac{\frac{\text{given mass of sugar}}{\text{molar mass of sugar}}}{\text{mass of water}}$$

$$= \frac{\frac{5}{342}}{\frac{95}{1000}} = 0.154$$



$$\Delta T_f (\text{for sugar solution}) = 273.15 - 271 \\ = 2.15 \text{ K}$$

$$\text{Now, } \Delta T_f = K_f \times m$$

$$\Rightarrow 2.15 = K_f \times 0.154$$

$$\Rightarrow K_f = \frac{2.15}{0.154}$$

For glucose solution

$$W_{\text{glucose}} = 5 \text{ g}$$

$$M_{\text{glucose}} = \cancel{180}^{180} \text{ g mol}^{-1}$$

$$W_{\text{water}} = 95 \text{ g}$$

$$\text{Molality} = \frac{\text{no. of moles of glucose}}{\text{mass of water (in kg)}}$$

$$= \frac{\text{Given mass of glucose}}{\text{Molar mass of glucose}} \times \frac{1}{\text{mass of water in (kg)}}$$

$$\frac{W_{\text{glucose}}}{M_{\text{glucose}}} =$$

$$\frac{5}{180} = \frac{1}{36}$$

$$= \frac{5}{180} \times \frac{1000}{95} = 0.2924$$

\therefore F.P of glucose

Solution

$$= 273.15 - 4.08$$

$$= 269.07 \text{ K}$$

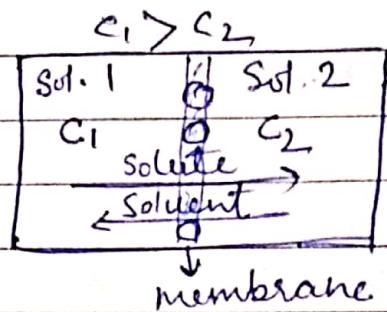
Ans

$$\Delta T_f = K_f M$$

$$= \frac{2.15}{0.154} \times 0.2924 = 4.08$$

* Osmotic Pressure

Diffusion :- It is the process where the net movement of any substance is from the region of their higher concentration to lower concentration.



Solute \rightarrow higher concentration to lower concentration.
solvent \rightarrow lower concent. to higher concentration.

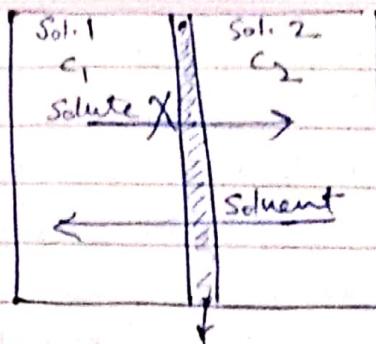
Osmosis :- The phenomenon of the flow of solvent molecules through a semipermeable membrane from pure solvent to solution (lower concentration to higher concentration) is known as osmosis.

\rightarrow Semipermeable membranes contain a network of submicroscopic pores.

\rightarrow Semipermeable membrane allows solvent molecules like water to pass through their pores but binds the passage for molecules of solute like salts.

$$c_1 > c_2$$

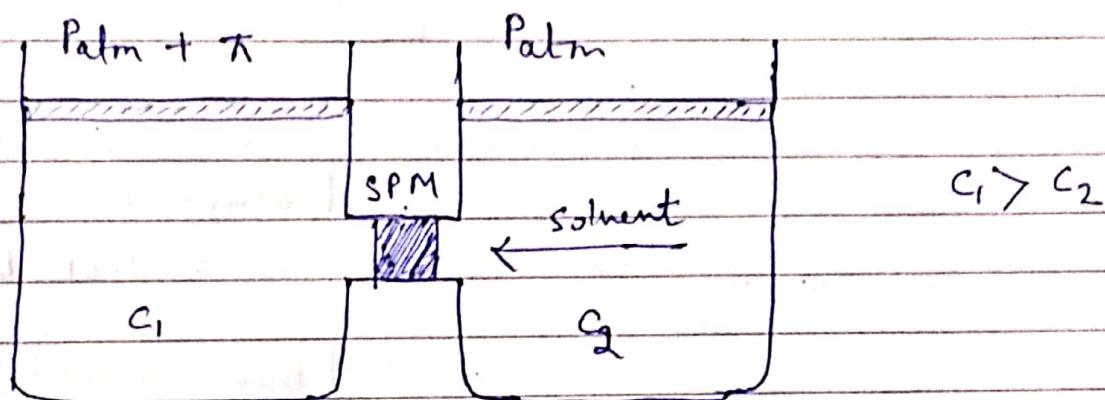
Date _____



Semi permeable
membrane

The flow will continue till the equilibrium is attained.

Osmotic Pressure :- (π)



→ The osmotic pressure of a solution is the excess pressure that must be applied to a solution to prevent osmosis i.e. to stop the passage of solvent molecules through a semipermeable membrane into the solution.

→ It is a colligative property as it depends upon the no. of solute molecules and not on their nature.

Experimentally we get

$$\pi \propto M \quad (\text{Molarity})$$

M = no of moles of Solute
v of solution (L)

$$\pi \propto T \quad (T \text{ in Kelvin})$$

$$\begin{aligned} \pi &\propto M T \\ \Rightarrow \pi &= M R T \end{aligned}$$

R = ~~Gas constant~~ Solution

~~constant~~
~~experiments of Monk~~

$$R = 8.314 \times 10^3 \text{ Pa L K}^{-1} \text{ mol}^{-1}$$

$$R = 0.0831 \text{ atm L K}^{-1} \text{ mol}^{-1}$$

$$PV = n RT$$

universal
R = Gas Constant



Gas Law

$$1 \text{ atm} = 10^5 \text{ pa}$$

$$= 1.01 \text{ bar}$$

$$1 \text{ bar} = 0.987 \text{ atm}$$



NCERT intext Question

- Q. Calculate the osmotic pressure (in pa) exerted by a solution prepared by dissolving 1.0g of polymer of molar mass 185000 in 450ml of water at 37°C.

Solution:-

$$[\Pi = MRT]$$

Given Mass of polymer = 1g

Molar mass of polymer = 185000 g/mol

$$\therefore \text{no. of moles of solute} = \frac{1}{185000} \text{ mol}$$

$$V = 450 \text{ mL} = 0.450 \text{ L}$$

$$T = 37^\circ\text{C}$$

$$= 37 + 273$$

$$= 310 \text{ K}$$

$$R = 8.314 \text{ kPa L K}^{-1} \text{ mol}^{-1}$$

$$= 8.314 \times 10^3 \text{ Pa L K}^{-1} \text{ mol}^{-1}$$

$$\Pi = MRT$$

$$= \frac{\text{no. of moles of solute}}{\text{V of solvent (in L)}} \times R \times T$$

$$= \frac{1}{185000} \times \frac{1}{0.450} \times 8.314 \times 10^3 \times 310$$

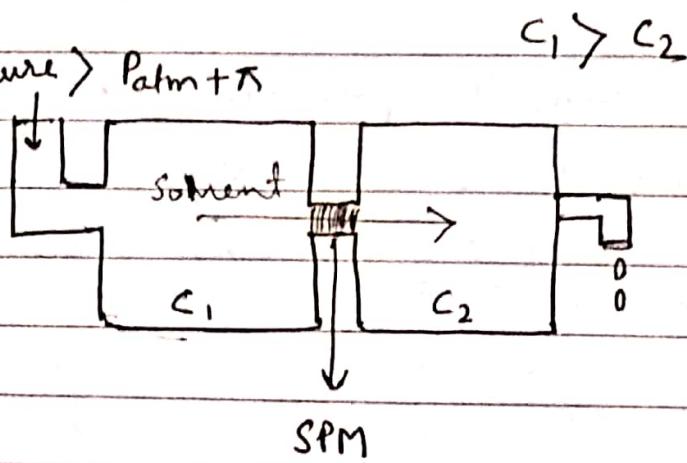
$$= 30.96 \text{ Pa.}$$

Avg
2

Date: 2023-09-07

Reverse Osmosis (R.O)

Pressure > $P_{atm} + \pi$



Pressure = $P_{atm} + \pi$ (osmosis stopped)

If

Pressure > $P_{atm} + \pi$ (Reverse osmosis)

It is used in Desalination.

(Making sea water drinkable)



V.V.I.
NEET
IIT

Van't Hoff Factor

four colligative properties

$$\text{i)} \frac{P_A^0 - P_A}{P_A^0} = X_{\text{solute}} = \frac{n_{\text{solute}}}{n_{\text{solute}} + n_{\text{solvent}}}$$

$$\text{ii)} \Delta T_b = k_b \times m = k_b \times \frac{\text{no. of moles of solute}}{\text{mass of solvent (kg)}}$$

$$\text{iii)} \Delta T_f = k_f \times m = k_f \times \frac{n_{\text{solute}}}{\text{mass(solvent)}}$$

$$\text{iv)} \kappa = MRT = \frac{n_{\text{solute}}}{V_{\text{solution}} (\text{L})} \times R T$$

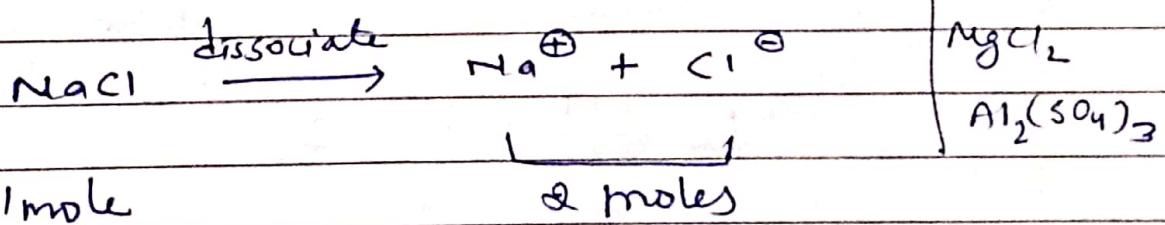
→ all depends on no. of moles of solute.

→ all solutes were non-electrolyte

(Urea, glucose, sugar, Sucrose)

∴ No association or dissociation.

Now, assume solutes are electrolytes.



* Some times Associate.

Then, observed colligative properties f Calculated colligative properties

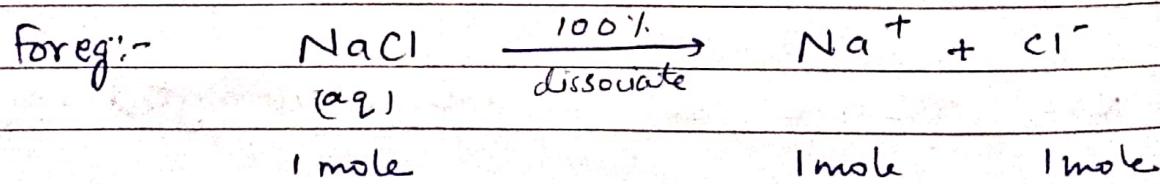
Van't Hoff factor (i)

- used to account for the extent of dissociation or association.
- It is defined as the ratio of the experimental value of the colligative property to the calculated value of the colligative property.

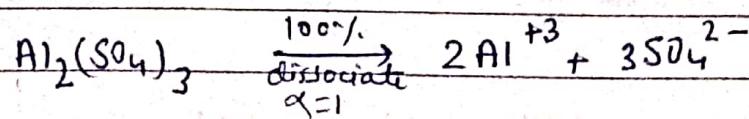
$$i = \frac{\text{observed colligative property}}{\text{calculated colligative property}}$$

$$i = \frac{\text{observed colligative property}}{\text{calculated colligative property}}$$

$$i = \frac{\text{Total no. of moles of Solute (After Dissociation/Association)}}{\text{Total no. of moles of Solute before dissociation/association}}$$



$$i = \frac{1+1}{1} = \frac{2}{1} = 2.$$



$$i = \frac{5}{1} = 5$$

in case of dissociation

$$i > 1$$

also, obs. colligative properties $>$ calculated colligative properties.

Degree of dissociation (α)

→ It is defined as the fraction of the total substance that undergoes dissociation.

[$i = \alpha$ moles dissociated from 1 mole substance.]



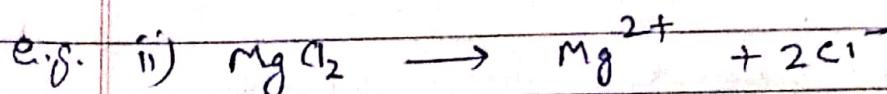
initial : 1 0 0

equilibrium: $1-\alpha$ α α

$$i = \frac{\alpha + \alpha + 1-\alpha}{1}$$

$$\Rightarrow i = \alpha + 1$$

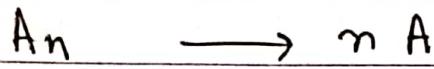
100% dissociation
 $\alpha = 1$



initial: 1 0 0

equilibrium: $1-\alpha$ α 2α

$$i = \frac{1-\alpha + \alpha + 2\alpha}{1} = 1 + 2\alpha$$



initial 1 0

equilibrium: $1 - \alpha$ $n\alpha$

$$i = \frac{1 - \alpha + n\alpha}{1}$$

$$\Rightarrow i - 1 = \alpha(n - 1)$$

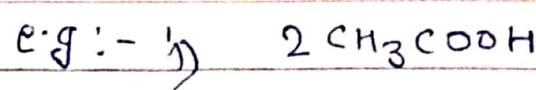
$$\Rightarrow \alpha = \frac{i - 1}{n - 1}$$

dissociation

100 %	$\alpha = 1$
40 %	$\alpha = 0.4$
80 %	$\alpha = 0.8$

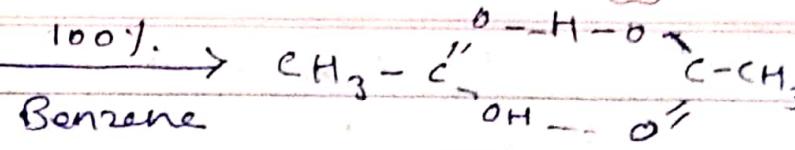
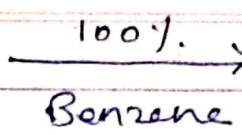
Association

Date _____



2 moles

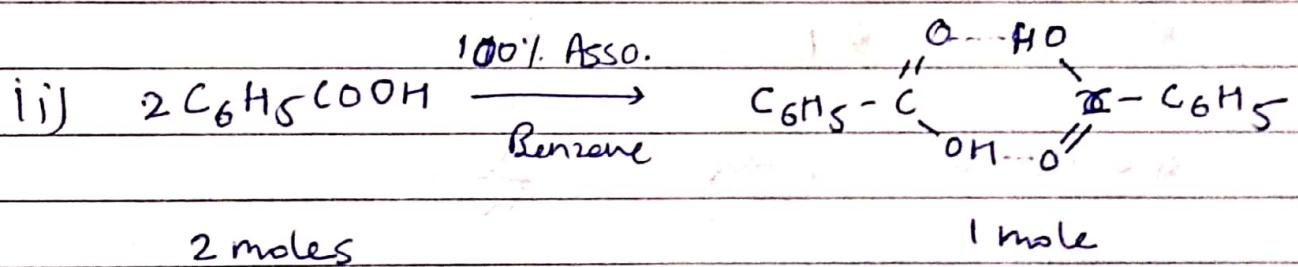
Association



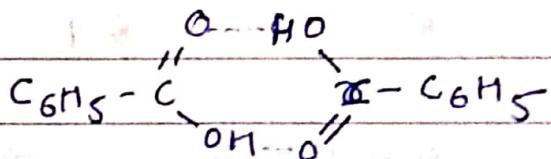
1 mole

$$i = \frac{1}{2}$$

* [Carboxylic + Benzene] \rightarrow associate
Acids



2 moles



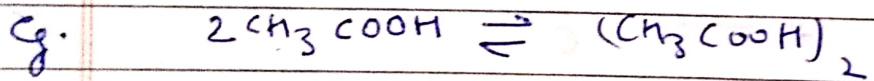
1 mole

$$i = \frac{1}{2}$$

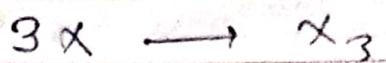
Degree of Association : It is defined as the fraction of the total substance which exists in the form of associated molecules.

denoted by α

[α moles associated from 1 mole]



initial	1	x	0
	$1 - \alpha$	x	$\frac{x}{2}$
i =	$\frac{1 - \alpha + \frac{x}{2}}{1}$		



Initial	1	0
Equilibrium	$1-\alpha$	$\frac{\alpha}{3}$

$$i = \frac{1-\alpha + \frac{\alpha}{3}}{1} = 1 - \frac{2\alpha}{3}$$

General form



Initial	1	0
Equilibrium	$1-\alpha$	$\frac{\alpha}{n}$

$$i = \frac{1-\alpha + \frac{\alpha}{n}}{1}$$

$$i-1 = \alpha \left(\frac{1}{n} - 1 \right)$$

$$\boxed{\alpha = \frac{i-1}{\frac{1}{n}-1}}$$



Obs C.P & no. of moles after dissociation / Association

Calculated C.P & no. of moles before dissociation / Ass.

$$i = \frac{\text{obs CP}}{\text{calc CP}}$$

true
↓

obs. C.P

⇒ obs C.P = $i \times$ calculated CP

New Formula

$$\textcircled{1} \quad \frac{P_n^{\circ} - P_A}{P_A^{\circ}} = x_B \times i$$

for electrolytes

$$\textcircled{2} \quad \Delta T_b = k_b \times m \times i$$

as well as
non electrolytes.

$$\textcircled{3} \quad \Delta T_f = k_f \times m \times i$$

$$\textcircled{4} \quad \kappa = MRT \propto i$$

Q. At a given temp., which of the following will have Max. osmotic pressure:

1M NaCl, 1M Na_2SO_4 , 1M $\text{Al}_2(\text{SO}_4)_3$

४

Solution

$$T = MRT \times i$$

M R } Some assumption :- 100%.
T dissociation

$\therefore K$ depends on i .

NaCl

Na_2SO_4

$$\underline{\text{Al}_2(\text{SO}_4)_3}$$

$$\overset{\circ}{i} = 2$$

i = 3

i = 5

\therefore 1M $\text{Al}_2(\text{SO}_4)_3$ have max O.P.

A₂ -



Q. Arrange in the increasing order of O.P. of the following compounds.
Given that

Temperature is same in all cases.

1M NaCl in water

1M Urea in water

1M C_6H_5COON in water

$$\Pi = MRT \times i$$

M = Same

R = Constant

T = Same

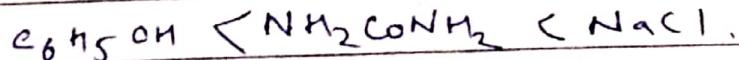
$\therefore \Pi$ depends on i

For NaCl $i = 2$

For NH_2CONH_2 $i = 1$ (do not break)

for C_6H_5COON $i = \frac{1}{2}$

\therefore increasing order of osmotic pressure



Q. 1.1. urea solution, 1.1. NaCl, 1% Na_2SO_4
 (N/V/L)

Arrange in the increasing order
 of osmotic pressure.

Solution

$$\pi = MRT \times i$$

Here π depends on M and i

for urea:

$$i = 1$$

$$\text{Molar } M = \frac{\text{Moles}}{\text{V of solution}} = \frac{1}{60} \text{ mol/L}$$

$$= \frac{1}{60} \times \frac{1000}{1000} \text{ mol/L}$$

$$= \frac{1}{6} \text{ mol/L}$$

$$\pi \propto M \cdot i^2$$

$$\propto \frac{1}{6} \times 1^2 \propto \frac{1}{6}$$

for NaCl ($i=2$)

$$\pi \propto \frac{58.5}{0.1} \times 2^2 \propto \frac{1}{2.92}$$

for Na_2SO_4

$$(i=3)$$

$$\pi \propto \frac{142}{0.1} \times 3^2 \propto \frac{1}{4.7}$$

Increasing order of O.P. = urea < Na_2SO_4 < NaCl.



Q. A 2m NaCl solution in water has elevation in boiling point of 1.88 K. If K_b for water is 0.52 K kg/mol. Calculate i and α (degree of dissociation) for NaCl.

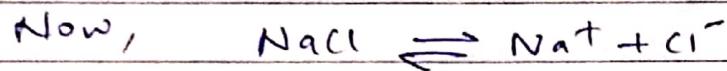
Solution:

$$\Delta T_b = K_b \times m \times i$$

$$\Rightarrow 1.88 = 0.52 \times 2 \times i$$

$$\Rightarrow i = \frac{1.88}{1.04}$$

$$\Rightarrow i = 1.8$$



initial	1	0	0
	$1-\alpha$	α	α

$$i = \frac{1-\alpha + \alpha + \alpha}{1}$$

$$i = 1 + \alpha$$

$$\Rightarrow 1.8 = 1 + \alpha$$

$$\Rightarrow \alpha = \underline{\underline{0.8}}$$

$\therefore 80\%$ dissociation

Ans.



Solubility and Henry's Law

Solubility : The amount of solute (in grams) dissolved in unit volume of a particular solvent to form saturated solution at given temperature and pressure.

unit → g/L or moles/l.

Factor's upon which Solubility depends

(i) Nature of solvent & solute.

Polar - Polar

Non polar - Non polar.

(ii) Temperature

Solute + Solvent → Solution

endothermic Temp ↑ Solubility ↑

Exothermic Temp ↑ Solubility ↓

(iii) Pressure

Solid Solute } already
Liquid Solute } Compressed.

Gaseous Solute } chances for
compression.

Henry's Law

→ The solubility of a gas in liquid is directly proportional to the partial pressure of that gas above liquid surface.

This is known as Henry's law.

If we use the mole fraction of a gas in the solution as a measure of its solubility, then it can be said that the X_g in the solution is \propto to the partial pressure of the gas over the solution.

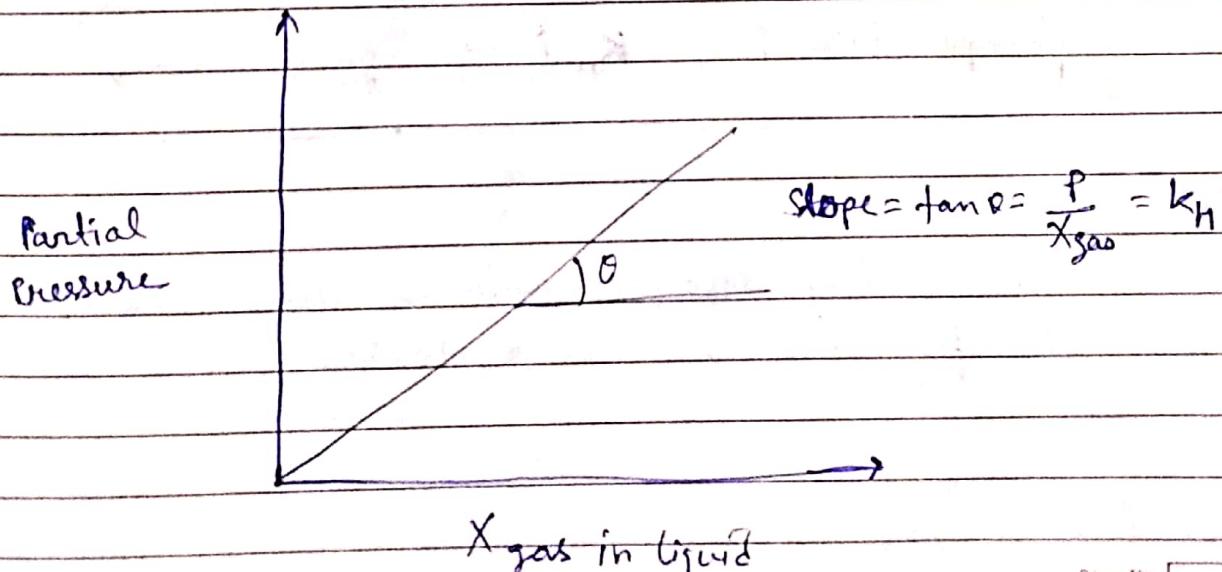
The common forms of Henry's law states that, "the partial pressure of the gas in vapour phase (P) is proportional to the mole fraction of the gas (X) in the solution."

$$P \propto X_g$$

$$\Rightarrow P = k_H \cdot X_g$$

k_H : Henry's law
constant

unit of $k_H \rightarrow$ atm, bar (same unit as Partial pressure)



Date _____

K_H depends on nature of gas and nature of solvent.

⇒ K_H for different gases in water at 20°C

K_H (K bar)	gases
140	He
75	H_2
35	O_2

$$x_{\text{gas in liquid}} = \frac{P}{K_H}$$

Note:-

$$K_H \uparrow \rightarrow x_{\text{gas in liquid}} \downarrow \Rightarrow \text{Solubility} \downarrow$$

$$\text{Temperature} \uparrow \rightarrow K_H \uparrow \rightarrow x_{\text{gas in liquid}} \downarrow \rightarrow \text{Solubility} \downarrow \\ \text{of gas}$$

→ This is why Aquatic animals are more comfortable in cold water.

Date _____

Q. k_h for CO_2 at 298 K is $1.67 \times 10^8 \text{ Pa}$
 Calculate mass of CO_2 dissolved in 500 ml
 soda at 2.5 atm CO_2 pressure at 298 K.

Solution:-

$$P = k_h \times \text{gas in liquid.}$$

$$\Rightarrow 2.5 \times 10^5 \text{ Pa} = 1.67 \times 10^8 \text{ Pa} \times \frac{n_{\text{CO}_2}}{n_{\text{total}}}$$

$$\Rightarrow \frac{n_{\text{CO}_2}}{n_{\text{total}}} = \frac{2.5 \times 10^5}{1.67 \times 10^8}$$

$$\Rightarrow \frac{n_{\text{CO}_2}}{n_{\text{total}}} = \frac{1}{7} \times 10^{-2} \quad (\text{approx})$$

mole fraction is very small.
 i.e. no. of moles of CO_2 in water
 is very low.

$$\therefore \frac{n_{\text{CO}_2}}{n_{\text{water}}} = \frac{1}{7} \times 10^{-2}$$

Let mass of $\text{CO}_2 = x$.

$$\text{Now, } \frac{\frac{x}{44}}{\frac{500 \text{ g}}{18}} = \frac{1}{7} \times 10^{-2}$$

[$500 \text{ ml} \approx 500 \text{ g}$]

$$\Rightarrow \boxed{x = 1.7 \text{ g}} \quad \text{approx}$$



K_H for N_2 is 1×10^5 atm at 298 K

The mole fraction of N_2 in air is 0.8.

Find no. of moles of N_2 from air that dissolves in 10 moles water at 298 K and 5 atm pressure.

Given. $K_H = 1 \times 10^5$ (for N_2)

$$X_{N_2} = 0.8 \\ (\text{in air})$$

$$P_{N_2} = K_H \cdot X_{N_2} \text{ in liquid}$$

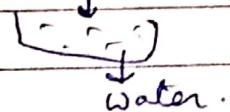
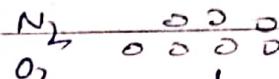
∴ This formula
can't be used
directly

Now,

$$P_{N_2} = P_{\text{Total}} \times X_{N_2} \quad \text{Dalton's law}$$

Total = 5 atm pressure

$$\Rightarrow P_{N_2} = 5 \times 0.8 \\ = 4 \text{ atm.}$$



Now,

$$P_{N_2} = K_H \cdot X_{N_2} \text{ in liquid}$$

$$\Rightarrow 4 = 1 \times 10^5 \times X_{N_2} \text{ in liquid (water)}$$

$$\Rightarrow X_{N_2 \text{ in water}} = 4 \times 10^{-5}$$

$$\Rightarrow \frac{n_{N_2}}{n_{N_2} + n_O + n_{\text{water}}} = 4 \times 10^{-5}$$

$(n_{N_2} + n_O$
very low)

$$\Rightarrow \frac{n_{N_2}}{n_{\text{water}}} = 4 \times 10^{-5}$$

$$\Rightarrow \frac{n_{N_2}}{10} = 4 \times 10^{-5} \Rightarrow n_{N_2} = 4 \times 10^{-4} \text{ moles}$$

Ans.