MIND MAP

FOR NEET ASPIRANTS

PHYSICAL CHEMISTRY

SOLUTIONS

ONE-SHOT

By – Sudhanshu Sir

Topics *to be covered*

1. Concentration Terms
2. Solubility
   - Solid in liquid
   - Gas in liquid
   - liquid - liquid
3. Colligative Properties
4. Van't hoff factor

① Concenteration Terms

(a) Mole fraction (x) → value '0' to '1'

$$x_A = \frac{n_A}{n_{total}}$$

$$x_B = \frac{n_B}{n_{total}}$$

$$x_A + x_B = 1$$

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

(b) Mass % (w/w) ⇒ mass of that component present in 100 g of solution.

(c) Volume % (V/V) = vol of that component present in 100 ml solution.

(d) mass by volume (w/v) = mass of that component present in 100 ml of solution

Binary solution

Solute (2) (present in less quantity)

Solvent (1) (present in large quantity)

W_1 = Given mass of solvent

W_2 = Given mass of solute

M_1 = Molar mass of solvent

M_2 = Molar mass of solute

n_1 = no. of moles of solvent

n_2 = no. of moles of solute.

(e) volume by mass (V/W) ⇒ vol. of that component in 100 g of solution.

(f) mass fraction ⇒ Ratio of mass of that component to the total mass of solution

(g) volume fraction ⇒ Ratio of vol. of that component to the total volume of solution.
↓ Temp. dependent

(h) Strength of solution (S) = it represents mass of Solute present in 1 ℓ/1000ml solution.

$$S = \frac{W_{solute}(g)}{V_{solution}(\ell)}$$

Temp. dependent

(i) Molarity (M) ⇒ $\frac{n_{solute}\ (mol)}{V_{solution}\ (\ell)}$

unit = mol/ℓ or Molar or M

$$M = \frac{n_2}{V(\ell)} = \frac{n_2 \times 1000}{V(ml)}$$

$$M = \frac{W_2}{M_2} \times \frac{1000}{V(ml)}$$

$n_{solute} = M \times V(\ell)$

mmoles of solute $= M \times V(ml)$

Dilution/concentration ⇒ n_{solute} = constant

$M_1V_1 = M_2V_2$

Mixing

$$M_{mix} = \frac{M_1V_1 + M_2V_2}{V_{mix}}$$

⇒ Temp. dependent quantity

① Molality (m) $= \frac{n_{solute}\,(mol)}{w_{solvent}\,(kg)}$

$m = \frac{n_2}{w_1\,(kg)} = \frac{n_2}{w_1\,(g)} \times 1000 = \frac{w_2}{M_2} \times \frac{1000}{w_1\,(g)}$

unit = mol/kg or molal or (m)

→ temp. independent

Relation of Molality and mole fraction

① $\text{Molality} = \frac{n_2}{n_1} \times \frac{1000}{M_1} = \frac{x_{solute}}{x_{solvent}} \times \frac{1000}{M_1}$

Relation b/w Molarity and strength of solution

Molarity × Molar mass of solute = strength

$M = \frac{\text{Strength}}{M_2}$

Relation b/w Molality (m), Molarity (M) and density of solution

$\text{Molality}\,(m) = \frac{1000\ \text{Molarity}}{1000 \times \text{density} - \text{Molarity} \times \text{Molar mass of solute}}$

$m = \frac{1000\,M}{1000d - MM_2}$

(K) Normality $= \frac{(\text{equivalents})_{\text{solute}}\ (\text{eq.})}{V_{\text{solution}}\ (\ell)} = \frac{(n_{\text{mol}})_{\text{solute}} \times \text{n-factor}}{V_{\text{solution}}\ (\ell)}$

Unit = equiv/litre

Normal or (N)

$N = M \times \text{n-factor}$

$n_{eq} = n_{mol} \times \text{n-factor}$

	n-factor
(1) Atoms	|valency|
(2) Ions	|charge|
(3) Salt	|charge on cation or anion|
(4) Acids	Basicity
(5) Bases	Acidity
(6) Oxidation	no. of $e^{\ominus}$ lost
(7) Reduction	no. of $e^{\ominus}$ gained
(8) Balanced Redox	inc. in O.N (oxn) / Dec in O.N

Dilution/concentration $\Rightarrow N_1V_1 = N_2V_2$

Mixing $\rightarrow \left\{ N_{mix} = \frac{N_1V_1 + N_2V_2}{V_{mix}} \right\}$

Law of equivalence $\Rightarrow$ no. of equivalent of each reactant or product are equal.

(L) Parts per billion (ppb)

$(ppb)_A = \frac{w_A}{w_{\text{mixture}}} \times 10^9$

(M) parts per million (ppm)

$(ppb)_A = \frac{w_A}{w_{\text{mixture}}} \times 10^6$

Solubility ⇒ max. amount of solvent which can be dissolved in a given amount of solvent at a given temp.

- in terms of liquid ⇒ always measured in (mol/l)
- in terms of gases ⇒ always measured in (Molefraction)

Solubility

- Unsaturated soln ⇒ more solute can be added in a given solvent at a given temp.
  - $I.P < K_{sp}$
- Saturated soln ⇒ no more solute can be added in a given solvent at a given temp
  - at equilibrium.
  - $I.P = K_{sp}$
- Supersaturated soln ⇒ More solute can be added in a given solvent at high temp.

Solubility of solid in liquid

Solid solute + liquid solvent $\rightleftharpoons$ Solution

Factors

① Nature of solvent ⇒ "like dissolves like"
- like: polar / non-polar
- dissolves like: polar / non-polar

② Nature of solute
- → Ionic solid → polar in nature.
- → Covalent solid → polar / non-polar

③ Temperature ⇒ if process is endothermic, Solubility of solid in liquid $\propto$ Temp.
if process is exothermic, Solubility of solid in liquid $\propto \frac{1}{\text{Temp.}}$

④ Pressure ⇒ No effect of pressure.

Solubility of Gas in liquid

Gas solute + liquid solvent $\rightleftharpoons$ Solution → always exothermic

Factors

① Temperature : Solubility of Gas in liquid $\propto \frac{1}{\text{Temp.}}$ → examples in daily life

① Soft drinks are preferred at low temp.

② Nature of Gas → IMF ↑ liquefaction of gas easily ↑ solubility ↑

② aquatic species are more comfortable in cold water.

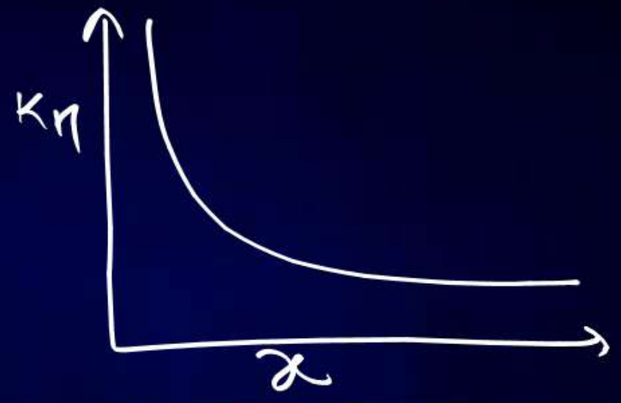
③ Pressure: Solubility of gas in liquid $\propto$ Pressure → Henry's law

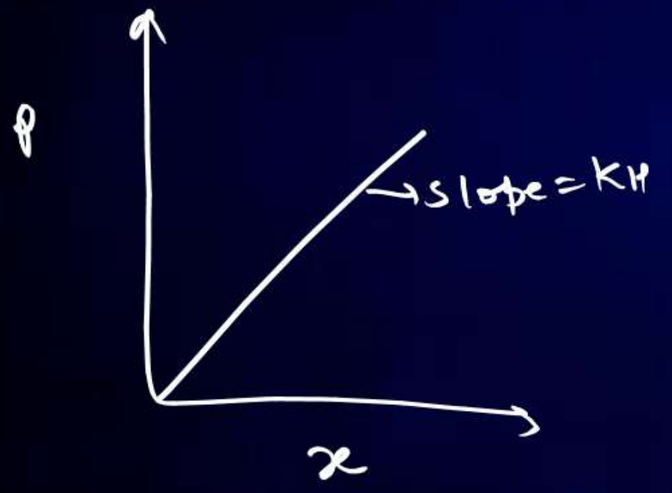
$S \propto P$

in terms of mole fraction $\Rightarrow p \propto x \Rightarrow P = K_H x$ → Henry's constant

$P = K_H x$ → at constant pressure

$K_H \propto \frac{1}{x}$





Temp. ↑ solubility of gas in liquid (x) ↓ K_H ↑

Applications of Henry's law → ① To avoid Bends in Scuba divers, $He_{(g)}$ is added to breathing kit.

$He = 11.2\%$
$N_2 = 56.7\%$
$O_2 = 32.1\%$

② At high altitudes, Anoxia → low O_2 in blood as atmospheric pressure is low.

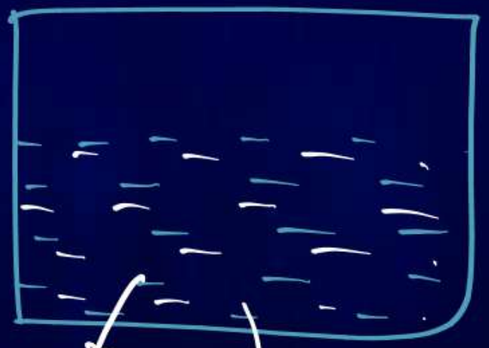
Limitations of Henry's law → ① P = not very high
② T = not very low
③ Gas should not react / ionise / dissociate in liquid.

Solubility of liquid - liquid solution

liquid

x_A = mole fraction of A in liquid phase

x_B = mole fraction of B in liquid phase



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

Raoult's law

for a volatile liquid, V.P of the liquid in solution is directly proportional to its mole fraction in liquid phase

$P_A \propto x_A \Rightarrow \boxed{P_A = P_A^\circ x_A}$ $\quad P_A^\circ$ = V.P of pure liquid A

$P_B \propto x_B \Rightarrow \boxed{P_B = P_B^\circ x_B}$ $\quad P_B^\circ$ = V.P of pure liquid B

$\boxed{P_{total} = P_A + P_B = P_A^\circ x_A + P_B^\circ x_B}$

liquid

- volatile
  - forms vapours
  - → V.P
- non-volatile
  - donot form vapours.
  - → no V.P.

Vapour pressure (V.P) → Pressure exerted by vapours of liquid.

⇒ V.P of any liquid $\propto \frac{1}{B.pt} \propto \frac{1}{I.M.F} \propto$ Temp.

$\Rightarrow \boxed{\log \frac{P_2}{P_1} = \frac{\Delta H_{vap}}{2.303R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)}$

$$P_{total} = P_A^\circ x_A + P_B^\circ x_B$$

$$x_A + x_B = 1$$

$$x_A = 1 - x_B$$

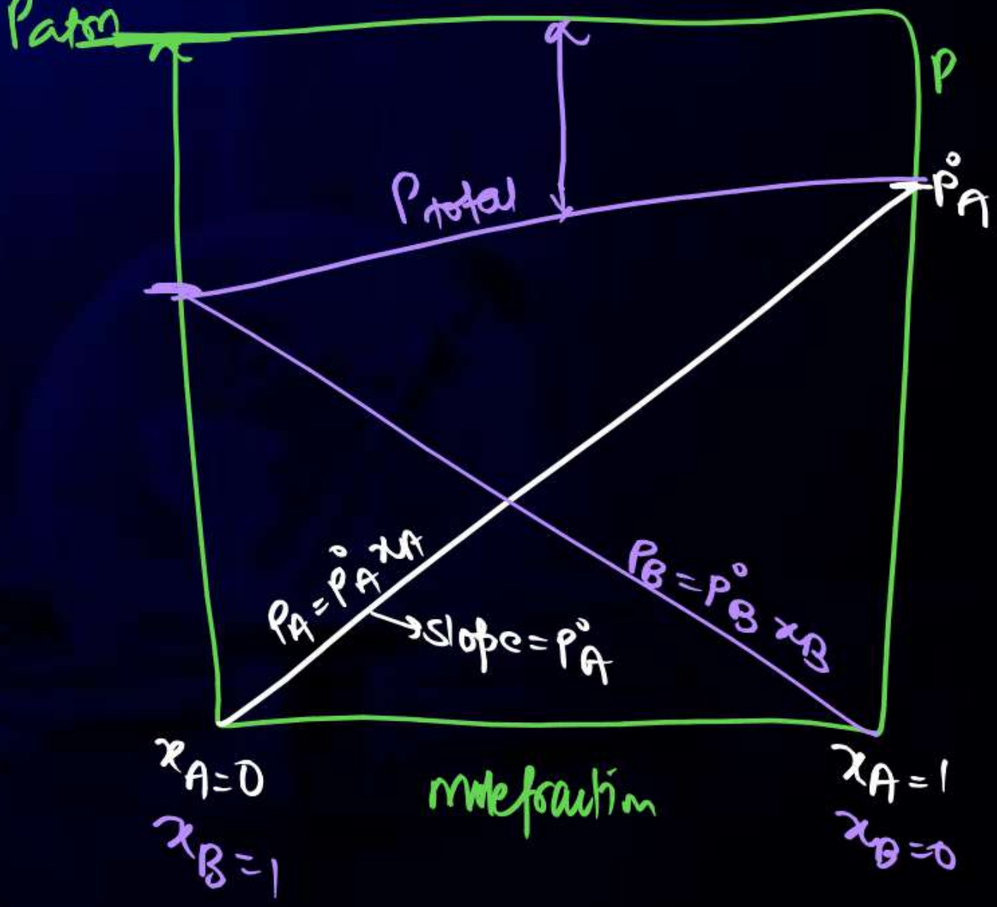
$$x_B = 1 - x_A$$

$$P_{total} = P_A^\circ + x_B (P_B^\circ - P_A^\circ)$$

$$= P_B^\circ + x_A (P_A^\circ - P_B^\circ)$$

if $x_A = 0$, $x_B = 1$ $\Rightarrow P_{total} = P_B^\circ$

if $x_A = 1$, $x_B = 0$ $\Rightarrow P_{total} = P_A^\circ$



Composition in vapour phase

y_A = mole fraction of A in vapour phase $= \dfrac{P_A}{P_{total}} = \dfrac{P_A^\circ x_A}{P_A^\circ x_A + P_B^\circ x_B}$

y_B = mole fraction of B in vapour phase $= \dfrac{P_B}{P_{total}} = \dfrac{P_B^\circ x_B}{P_A^\circ x_A + P_B^\circ x_B}$

$$y_A + y_B = 1$$

Solutions ($\Delta G < 0, \Delta S > 0$)

Ideal Solution → $\Delta H_{mix} = 0$, $\Delta V_{mix} = 0$

Which obeys Raoult's law Completely.

$P_A = P_A^\circ x_A$

$P_B = P_B^\circ x_B$

$P_{total} = P_A + P_B$

$A\text{-}A + B\text{-}B \rightleftharpoons 2A\text{-}B$

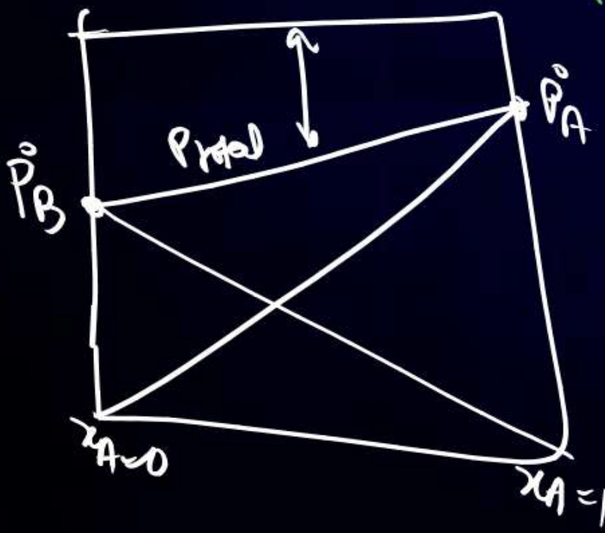
Reason

IMF $A\text{-}A \simeq B\text{-}B \simeq A\text{-}B$

Benzene + toluene

methane + ethane

$CCl_4 + SiCl_4$



Non-ideal solution → $\Delta H_{mix} \neq 0$, $\Delta V_{mix} \neq 0$

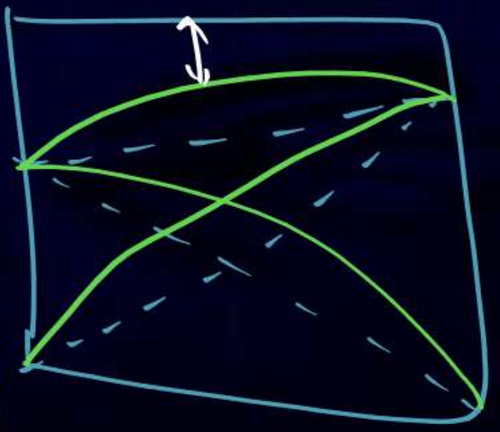
Which do not obey Raoult's law completely.

Positive deviation

$P_A > P_A^\circ x_A$

$P_B > P_B^\circ x_B$

$P_{total} > P_A^\circ x_A + P_B^\circ x_B$

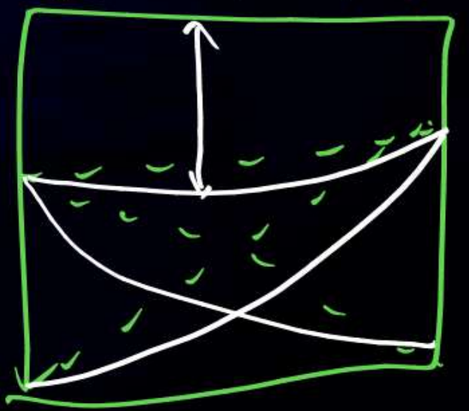


Negative deviation

$P_A < P_A^\circ x_A$

$P_B < P_B^\circ x_B$

$P_{total} < P_A^\circ x_A + P_B^\circ x_B$



positive Deviation

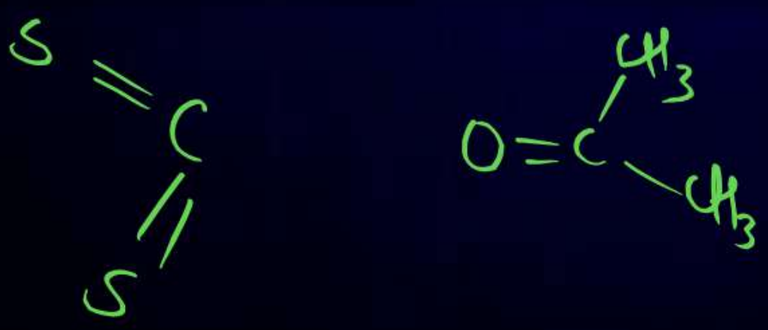
$$A-A + B-B \rightleftharpoons 2A-B$$

Reason

IMF $(A-A)$ or $(B-B) > (A-B)$

$$\left\{\begin{array}{l} \Delta H_{mix} > 0 \\ \Delta V_{mix} > 0 \end{array}\right\}$$

e.g → $(H_2O + alcohol)$



Negative deviation

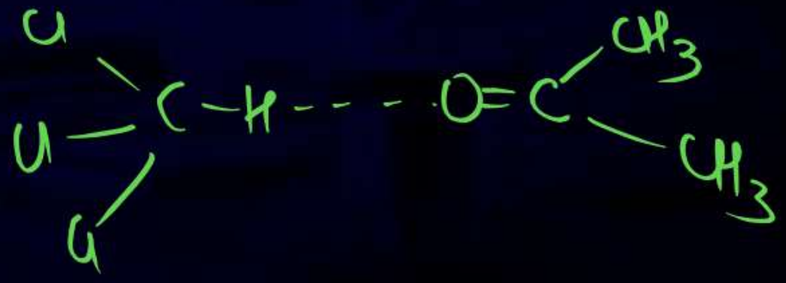
$$A-A + B-B \rightleftharpoons 2A-B$$

Reason

IMF $A-A$ or $B-B < (A-B)$

$$\left\{\begin{array}{l} \Delta H_{mix} < 0 \\ \Delta V_{mix} < 0 \end{array}\right\}$$

e.g → $(H_2O + acid)$



Azeotropes ⇒ mixtures having same composition in liquid and vapour phase and Constant boiling point of mixture.

→ Components of Azeotropes cannot be separated by distillation.

$x_A = y_A$

$x_B = y_B$

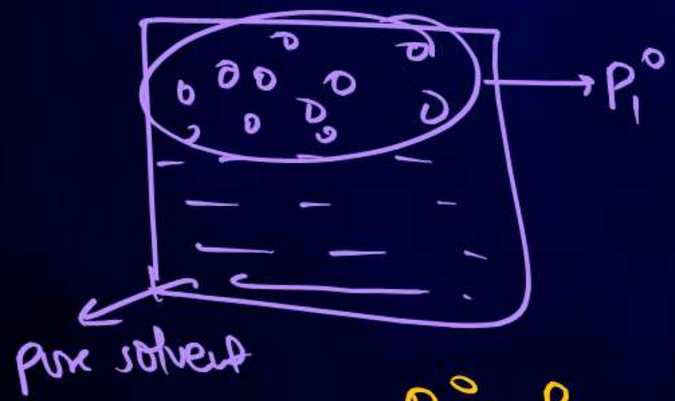
Max. B.pt Azeotropes ⇒ solutions which shows (-ve) deviation from Raoult's law.

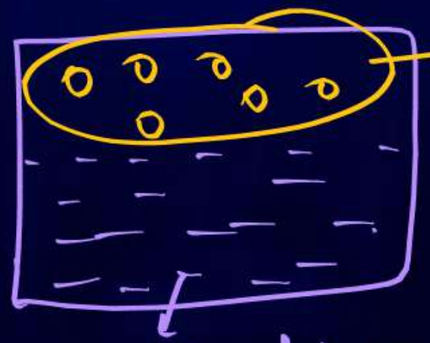
Min B.pt azeotropes ⇒ solutions which shows (+ve) deviation from Raoult's law.

Colligative Properties ∝ only on number of solute particles

↳ independent of size, reactivity, physical state of solute particles.

① Relative lowering of Vapor Pressure (RLVP)





P_1 = V.P of solvent in solution
= V.P of solution

solvent + non-volatile solute = solution

$P_1^\circ > P_1$

$P_1 = P_1^\circ x_1$ (Raoult's law)

ΔP = lowering in v.p = $P_1^\circ - P_1 = P_1^\circ - P_1^\circ x_1 = P_1^\circ(1-x_1) = P_1^\circ x_2$

Relative lowering in v.p = $\frac{\Delta P}{P_1^\circ} = x_2 = \frac{P_1^\circ - P_1}{P_1^\circ}$

$$RLVP = \frac{P_1^\circ - P_1}{P_1^\circ} = x_2 = \frac{n_2}{n_1 + n_2}$$

for very dilute solution $(n_2 + n_1 \simeq n_1)$

1. $n_2 <<< n_1$
2. ΔP = very low
3. x_2 = very low

$$\frac{\Delta P}{P_1^\circ} = RLVP = \frac{P_1^\circ - P_1}{P_1^\circ} = \frac{n_2}{n_1} = \frac{w_2}{M_2} \times \frac{M_1}{w_1}$$

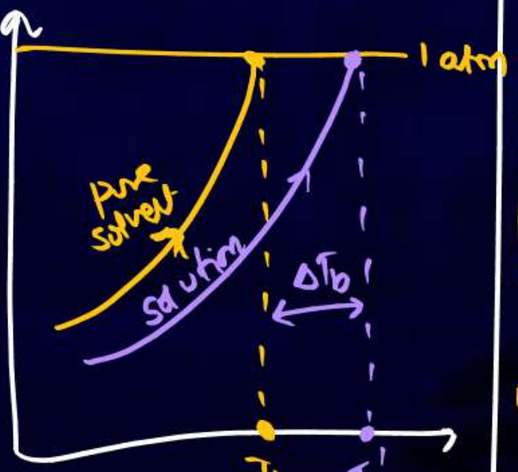
② Elevation in boiling point (ΔT_b)

$\Delta T_b \propto$ molality

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

$$\Delta T_b = K_b \times \frac{w_2}{M_2} \times \frac{1000}{w_1}$$

K_b → molal b.pt elevation constant or ebullioscopic constant



$$K_b = \frac{RT_b^2 M}{1000 \Delta H_{vap}}$$

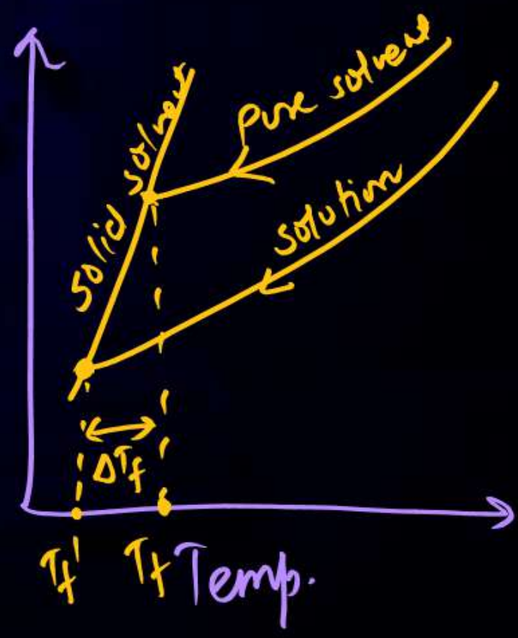
③ Depression in freezing point (ΔT_f)

$\Delta T_f \propto$ molality

$$\Delta T_f = K_f m$$

$$\Delta T_f = K_f \times \frac{w_2}{M_2} \times \frac{1000}{w_1}$$

K_f → molal f.pt depression constant or cryoscopic constant



$$K_f = \frac{RT_f^2 M}{1000 \Delta H_{fus.}}$$

NOTE → order of molality, ΔT_b, ΔT_f, B.pt of solution are always same But order of freezing point are opposite to them.

(4) Osmotic Pressure (π) ⇒ Pressure applied to stop Osmosis.

$\pi \propto$ Temp

$\propto$ Concentration

$$\pi = CRT$$

$$\pi = \frac{n}{V(\ell)} \times R \times T$$

$$\pi = \frac{w_2}{M_2} \times \frac{1000}{V(ml)} \times RT$$

Osmosis → flow of solvent molecules only through SPM

from (1) pure solvent to Solution.

or

(2) High conc^n of solvent to low conc^n of solvent

or

(3) low conc^n of solute to High conc^n of solute

or

(4) low Osmotic Pressure to high Osmotic Pressure

$\pi_1 = \pi_2$ → isotonic solution

Advantage to use Osmotic Pressure

1. its magnitude is large even for small changes.
2. Molarity is used.
3. Absolute value.

Reverse Osmosis (R.O) ⇒ flow of

solvent molecules only through SPM opposite to Osmosis when applied Pressure is greater than Osmotic pressure.

Examples of Osmosis
1. Raw mango
2. Carrot
3. Wilted flowers

Van't hoff factor (i) → for non-electrolytes ⇒ $i = 1$

→ for electrolytes → $i > 1$, $i < 1$

$$i = \frac{\text{no. of particles after diss/ass}}{\text{no. of particles before diss/ass}}$$

Association
(no. of particles decreases)
$i < 1$

Dissociation
(no. of particles increase)
$i > 1$

Electrolytes

→ **Strong electrolytes** ⇒ $\alpha = 1$ (100% diss/association)

Dissociation	association
$i = n$	$i = \frac{1}{n}$
n = no. of particles after dissociation	when n = no. of particles after association

→ **Weak electrolyte** ⇒ $\alpha < 1$ (less than 100% diss/association)

Dissociation	association
$i = 1 + (n-1)\alpha$	$i = 1 + \left(\frac{1}{n} - 1\right)\alpha$
α → fraction	α → fraction

$i = \frac{\text{Normal / Formula Molar mass}}{\text{Abnormal / calculated Molar mass}}$

Abnormal / calculated → obtained from colligative property formulas.

$i > 1$ (dissociation)

$\frac{M_{normal}}{M_{abnormal}} > 1$

$M_{normal} > M_{abnormal}$

$i < 1$ → association

$\frac{M_{normal}}{M_{abnormal}} < 1$

$M_{normal} < M_{abnormal}$

$i = \frac{\text{observed / experimental colligative property value}}{\text{calculated / expected colligative property value}}$

for non-electrolyte ($i=1$)

$$\frac{\Delta P}{P_1^\circ} = x_2 = \frac{n_2}{n_1+n_2}$$

$$\Delta T_b = K_b \times m = K_b \times \frac{w_2}{M_2} \times \frac{1000}{w_1}$$

$$\Delta T_f = K_f \times m = K_f \times \frac{w_2}{M_2} \times \frac{1000}{w_1}$$

$$\pi = CRT = \frac{w_2}{M_2} \times \frac{1000}{V(ml)} \times RT$$

For electrolytes ($i \neq 1$)

$$\frac{\Delta P}{P_1^\circ} = i x_2$$

$$\Delta T_b = i K_b m$$

$$\Delta T_f = i K_f m$$

$$\pi = iCRT$$

← Modified colligative property formulae

C_6H_5COOH

- in water → dissociation

$C_6H_5COOH \rightleftharpoons C_6H_5COO^{\ominus} + H^{\oplus}$

$i = 1 + (2-1)\alpha$

$i = 1 + \alpha$

- in Benzene → (association)

$2(C_6H_5COOH) \rightleftharpoons (C_6H_5COOH)_2$

$i = 1 + \left(\frac{1}{2} - 1\right)\alpha$

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

Homework

- PYQs → NEET
  - Jee-mains (last 5 years)
- NCERT & NCERT examplar


Thank you