Solution

Solution :- A solution is a homogeneous mixture of two or more substances, in which the solute is uniformly dispersed at the molecular or ionic level within the solvent.

In solution solute(s) can be more than one put solvent must be unique.

Homogeneous mixture :- That mixture which is found as uniform is called homogeneous mixture.

Heterogeneous mixture :- That mixture where throughout the solution the composition is not uniform.

Solute :- The Substance that is dissolved in a solvent to form a solution. It is present in smaller amount.

Solvent :- Substance which decides physical state of solution and containing solute.

Solution

Binary Solution :-

Only one solute is present.

* ## Types of solution on basis of physical state of solvent :-

1) Solid solution is a solution in which the solvent is solid and solid, liquid or gas can be solute.

eg:- Solid in solid → Alloys
Liquid in solid → Amalgam of Hg with Na.
Gas in solid → H_2 in Pd, Cu in Au.

2.) Liquid solution is a solution in which the solvent is liquid and solid, liquid or gas component can be solute.

eg:- Solid in liquid → glucose dissolved in H_2O.
Liquid in Liquid → Ethanal dissolved in H_2O.
Gas in Liquid → Oxygen dissolved in H_2O.

3.) Gaseous solution is solution in which the solvent is gas and solid, liquid or gas can be solute.

Types of solutions

Type of solution	solute	Solvent	Common examples.
Gaseous solutions	Gas	Gas	Mixture of oxygen and nitrogen gases.
	Liquid	Gas	chloroform mixed with nitrogen gas
	Solid	Gas	Camphor in nitrogen gas.
Liquid solutions	Gas	Liquid	oxygen dissolved in water.
	Liquid	Liquid	Ethanol dissolved in water.
	Solid	Liquid	Glucose dissolved in water.
Solid solutions	Gas	Solid	solution of hydrogen in palladium.
	Liquid	Solid	Amalgam of mercury with sodium.
	Solid	Solid	copper dissolved in gold.

* Concentrated Solution :-

That solution in which maximum last amount of solute is dissolve is called concentrated solution.

'or'

That solution in which extra amount of solute can't be dissolve is called concentrated solution.

Concentration of solution :-

Presenting amount of solute in solution is called concentration of solution.

Concentration Terms :-

- Volume related (Temperature dependent)
  - % by volume
  - wt by volume
  - Molarity
  - Normality
- Mass related (T independent)
  - wt/wt %
  - Mole fraction
  - Molality
  - PPM or PPB

(1). wt / wt % :-

Mass percentage of a solution is defined as the percentage by mass of the solute present in the solution.

$$\boxed{wt/wt\ \% = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 100}$$

▷ A solution of NaCl in water 5% (wt/wt).
→ 5g of NaCl present in 100 g solution.

(2) Volume by volume % :-

Volume percentage of a solution is defined as the percentage by Volume of the solute present in the solution.

$$\boxed{V/V\% = \frac{\text{Volume of Solute (ml)}}{\text{volume of solution (ml)}} \times 100}$$

A HCl solution is 7% (V/V%)
7 ml of HCl is present in 100 ml of solution.

(3) wt by volume % :-

Volume percentage of a solution is defined as the percentage by volume of the solute present in the solution.

$$\boxed{wt/V\% = \frac{\text{mass of solute (g)}}{\text{volume of solution (ml)}} \times 100}$$

A sugarsolution is 3% (wt/v)
3g of sugar dissolved in 100 ml water.

(4) Mole fraction :-

The ratio of mole of component and mole of solution is called mole fraction.

$$\boxed{X_A = \frac{n_A}{n_A + n_B}}$$

$A + B \rightarrow$ solution.

$X_A + X_B = 1$

(5) PPM (part per million) :-

According to mass or volume, the amount of solute present in 10^6 parts of the solution is known as PPM.

$$\boxed{\text{No. of PPM} = \frac{\text{Mass of solute (g)}}{\text{Mass of solution (g)}} \times 10^6}$$

Sugar 2 PPM in a solution.
2g sugar in 10^6 g of solution.

(6) PPB (Part per Billion) :-

According to mass or volume, the amount of solute present in 10^9 parts of the solution is known as PPB.

$$\boxed{\text{No. of PPB} = \frac{\text{mass of solute (g)}}{\text{mass of solution (g)}} \times 10^9}$$

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(7) Molarity :-

The number of moles of solute dissolved in one liter of solution is called molarity.

$$\boxed{\text{Molarity} = \frac{\text{no. of moles of solute}}{\text{volume of solution (L)}}}$$

On dilution ;

[$n = MV$] $\boxed{M_1V_1 = M_2V_2}$

Molarity of Mixture ;

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

(8) Molality or molal concentration :-

The number of moles of solute dissolved in 1 kilogram of solvent.

It is denoted by m.

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

(9) Mass Fraction :-

The ratio of the mass of a component to the total mass of the mixture is called mass fraction.

$$\boxed{X_A = \frac{m_A}{m_A + m_B}}$$

(10) Normality :-

Number of gram equivalent of Solute which are present in 1 L solution.

It is denoted by N.

$$\boxed{N = \frac{\text{no. of gram equivalent of Salute}}{\text{Volume of solution}}}$$

(11) Equivalent Mass :-

The mass of a substance that reacts with or replaces 1 mole of hydrogen atoms (or 1 mole of electrons) in a chemical reaction.

$$\boxed{\text{Equivalent mass} = \frac{\text{Molecular mass}}{\text{Valency factor } X}}$$

Valency factor for -
Acid → basicity
Base → acidity
Salt → total +ve charge on cation.

ote :-

$$\boxed{\text{Number of gram equivalent} = \frac{\text{mass}}{\text{Equivalent mass}}}$$

also,

$$\boxed{\text{Number of gram equivalent} = \text{no. of moles} \times X}$$

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* Solubility :-

At constant temperature, the amount of solid solute that dissolves in 100 g of solvent to form a saturated solution is called solubility.

$$\boxed{S = \frac{\text{Mass of solute}}{\text{Mass of solvent}} \times 100}$$

* Dissolution :-

When solute is added continuosly in solvent (liquid); the concentration of solution keeps on increasing. This process is known as dissolution.

* Crystallization :-

Crystallization is the process through which a pure solid forms from its solution by cooling or evaporation in the form of crystals.

* Saturated Solution :-

A saturated solution is a solution in which no more solute can be dissolved at a given temperature and pressure.

* Unsaturated solution :-

An unsaturated solution is a solution that contains less solute than the maximum amount it can dissolve at a given temperature and pressure.

* Solubility of a solid in a liquid :-

The solubility of a solid in a liquid at any temperature is defined as the maximum amount of the solid (solute) in grams which can dissolve in 100 g of liquid (solvent) to form saturated solution at a specific temperature.

Factors affecting solubility :-

(i) Nature of solute and solvent.
(ii) Temperature.

Note:- Pressure has very little effecton solubility of solid in a liquid solid and liquids are highly incompressible.

(i) Nature of solute and solvent :-

'Like dissolves like' this implies that solid solute dissolves in solvent which is chemically similar. Polar (ionic) solute dissolve in polar solvent and Non-polar solute dissolve in non-polar solvent.

(ii) Effect of temperature on solubility :-

The substance in which the process of dissolution is exothermic ; the solubility decreases with increase in temperature.

The substance in which process of dissolution is endothermic, the solubility increases with increase in temperature.

* Solubility of Gas in a liquid :-

The solubility of any gas in a particular liquid is the volume of gas that can be dissolved in unit volume of liquid to form saturated at particular temperature and pressure of 1 atm.

Factors affecting solubility :-

(i) Nature of gas and solvent
(ii) Effect of temperature
(iii) Effect of pressure.

(i) Nature of gas and solvent :-

The greater solubility of gases in solvent is due to their chemical similarity with solvent.

Gases like N_2, H_2, O_2 etc. dissolve in water only to a small extent and CO_2, HCl, NH_3 are highly soluble.

(ii) Effect of temperature :-

The solubility of gases decreases with increase in temperature. Temperature ↑ : Solubility ↓ Because on heating kinetic energy cause more motion in gas molecules which break intermolecular bonds and escape from solution.

(iii) Effect Of Pressure (Henry's Law) :-

The solubility of gases increases with increase in pressure.

* Henry's law :-

Henry's Law states that the solubility of a gas in a liquid increases with the increase in pressure of that gas over the liquid, at constant temperature.

$$P \propto x$$

$$\boxed{P = K_H x}$$

K_H is Henry's constant.
Different gases have different values of K_H at same temperature and in same solvent.

- K_H is function of nature of gases.

- Greater value of K_H ; lower the solubility.

$$\uparrow \frac{P}{K_H} = x \downarrow \; ; \; \text{solubility} \downarrow \; ; \; x \downarrow$$

Value of K_H increases with increase of temperature implying that the solubility decreases with increase in temperature.

K_H ↑ ; temperature ↑
X ↓ ; solubility ↓
∵ temperature ↑ : salubility ↓

That's why aquatic life prefer cold water.

↳ Applications of Henry's law :-

1.) In production of carbonated beverges.
To increase the solubility of CO_2, the bottles are sealed under high pressure.
when sealed open CO_2 bubbles come out because partial pressure of CO_2 decreases.

2.) Scuba divers depends on compressed air for their O_2 supply.
At depth, pressure ↑, solubility ↑
As come upper side of sea, O_2 dissolved in to blood will used up in metabolic process, but N_2 form bubbles as divers comes to atm pressure. This cause Bends or decampression sickness. To avoid this, cylinders are filled with air diluted with Helium.

For Mountain climbers :-

At high altitude, the partial pressure of

O_2 is less than ground level. Thus, low O_2 concentration in blood and tissue, resulting anoxia, in which they feel weak and unable to think properly.

* Vapour pressure :-

Vapour pressure is the pressure exerted by the vapour of a liquid when it is in dynamic equilibrium with its liquid at a given temperature in a closed container.

Factor affecting vapour pressure :-

(i) Nature of liquid.
weaker the intermolecular forces, greater the amount of vapour pressure.

$$\boxed{\text{Vapour pressure} = \frac{1}{\text{forces of attraction between molecule.}}}$$

(ii) Temperature
Higher the temperature, greater the vapour pressure.

Vapour pressure of Liquid-Liquid solutions :-

for a solution of liquid-liquid, as both the component of solution are volatile, each component farm vapour pressure above the liquid.

This is governed by Raoult's law :-

In a solution of volatile liquids the partial vapour pressure of each component of the solution is directly proportional to its mole fraction present in solution.

According to Raoult's law,

$P_A \propto X_A$

$P_A = P^\circ_A X_A$, where P_i° is vapour pressure of pure component one, at same temperature.

Similary, for other

$$P_B = P^\circ_B X_B$$

By Dalton's law of partial pressure,

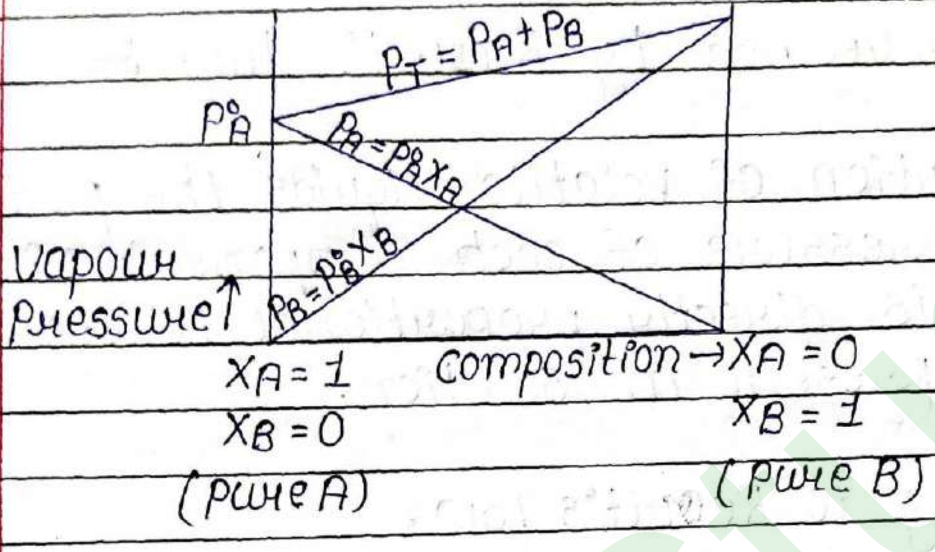
$$\begin{aligned} P_{Total} &= P_A + P_B \\ &= P^\circ_A X_A + P^\circ_B X_B \\ &= P^\circ_A (1 - X_B) + P^\circ_B X_B \\ &= P^\circ_A - P^\circ_A X_B + P^\circ_B X_B \end{aligned}$$

$$\boxed{P_{Total} = P^\circ_A + X_B (P^\circ_A - P^\circ_B)}$$

If Y_A and Y_B represent the mole fraction of the component A and B respectively in vapour phase, then

$$\boxed{Y_A = \frac{P_A}{P_{total}}} , \quad \boxed{Y_B = \frac{P_B}{P_{total}}}$$

Graph :-



Raoult's Law as a special case of Henry law :-

According to Raoults law,

$$P_1 = P_1^\circ X_1$$

and, Henry's law

$$p = K_H X$$

On comparing both equation we can say that Raoult's law becomes a special case of Henry's law in which K_H becomes equal to P_1°. only constant differs.

→ Vapour pressure of solution of solid in Liquid :-

On adding non-volatile solute in a solution. It is observed that presence of non-volatile solute reduces the escaping tendency of solvent molecule into vapour phase and thus lower the vapour pressure of the solvent.

According to Raoult's law,
vapour pressure of solvent in solution (P_s)
= Mole fraction of solvent in solution (X_1) x Vapour pressure of pure solvent (P°).

Non volatile solute do not contribute in total vapour pressure of the solution.

So, vapour pressure of solution = vapour pressure of the solvent in solution.

$$\because \frac{P_s}{P^\circ} = X_1 \text{ —— eq ① } (P_s \propto X_1)$$

Mole fraction of solvent $= X_1 = \frac{n_1}{n_1+n_2}$

Substituting value of X_1 in equation 1.

$$\frac{P_s}{P^\circ} = \frac{n_1}{n_1+n_2}$$

$$\boxed{\frac{P^\circ - P_s}{P^\circ} = \frac{n_2}{n+n_2}}$$

$P^\circ - P_s$ express lowering of vapour pressure. and $\frac{P^\circ - P_s}{P^\circ}$ is called relative lowering of vapour pressure.

Hence, we can define that,
"The relative lowering of vapour pressure of a solution containing a non-volatile solute is equal to mole fraction of solute in the solution.

* Ideal and Non-Ideal Solutions :-

(1) Ideal Solution :-

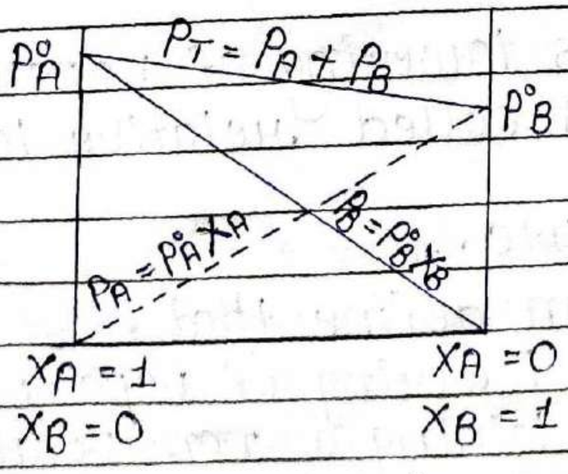
An ideal solution is that solution that follows raoult's law under all standard temperature and concentration.

- no change in volume on mixing. $\Delta V_{mix} = 0$
- no change in ethalpy. $\Delta H_{mix} = 0$
  [no heat absorbed or evolved]

- Intermolecular interaction between the components are of same magnitude as the pure component.

Example :-

(i) Benzene + Toluene
(ii) n-Hexane + n-Heptane
(iii) Ethyl bromide + Ethyl chloride
(iv) chlorobenzene + Bromobenzene.

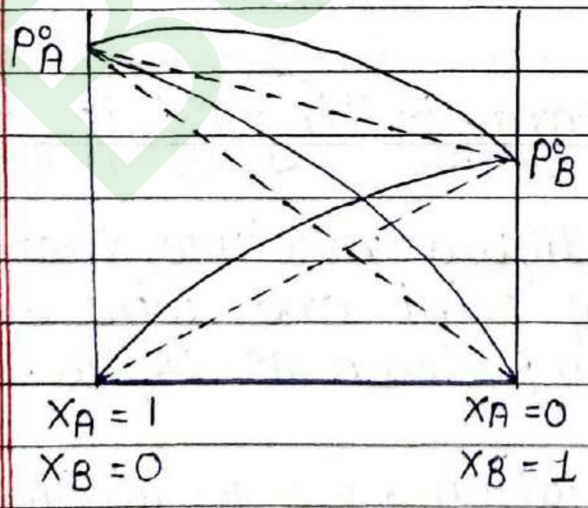


(2) Non-Ideal Solution (do not obeys Raoult's law):-

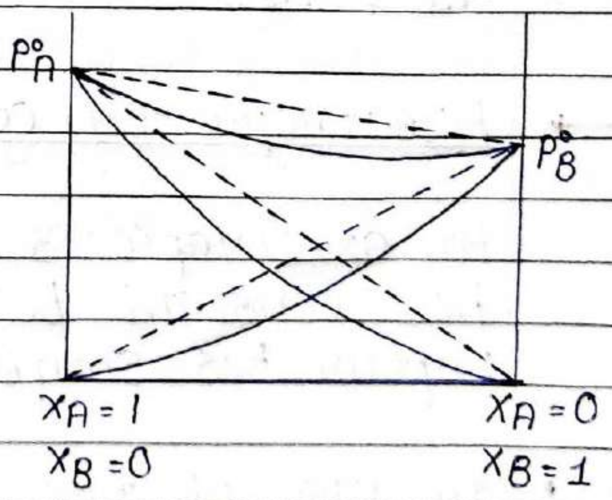
Showing positive Deviation	Showing negative Deviation
• The interaction between the components are less than in the pure component.	• The interaction between the components are greater than the pure component.
• $\Delta V_{mix} = +ve$	• $\Delta V_{mix} = -ve$
• $\Delta H_{mix} = +ve$	• $\Delta H_{mix} = -ve$
• $P_A > X_A P_A^\circ$ $P_B > X_B P_B^\circ$	• $P_A < X_A P_A^\circ$ $P_B < X_B P_B^\circ$
• Form minimum boiling azeotropes.	• form maximum boiling azeotropes.

Graphs :-

→ +ve deviation



→ negative deviation



Non-Ideal Solution examples –

(i) Positive Deviation–

- → Acetone + carbon disulphide
- → Methyl alcohol + H_2O
- → Aceton + Ethyl alcohol.
- → Aceton + Benzene
- → Ethyl alcohol + H_2O
- → carbon tetrachloride + chloroform
- → CCl_4 + Benzene
- → CCl_4 + Toulene.

(ii) Negative Deviation –

- → $CHCl_3$ + Benzene
- → $CHCl_3$ + Diethyl ether
- → Acetone + Aniline
- → $HCl + H_2O$
- → $HNO_3 + H_2O$
- → Acetic acid + Pyridine
- → $HI + H_2O$

↳ Azeotropic or constant Boiling Mixture –

An azeotropic is a liquid mixture that has constant boiling point and whose vapour has same composition as liquid.

⤳ In case of +ve deviation, we get minimum azeotropes and in case of negative deviation we get maximum boiling azeotropes (eg. Nitric acid + water, ethanol+ water)

* Colligative properties of solution :-

That property of solution which depends on number of particles of solute but it does not depend on nature of solute is known as colligative property of solution.

These are —

(i) Relative lowering of vapour pressure
(2) Elevation in boiling point.
(3) Depression in freezing point.
(4) Osmotic pressure of solution.

(1) Relative lowering of vapour pressure :-

When non-volatiles solute is present in liquid solvent then vapour pressure of pure solution decreases than vapour pressure of pure solvent is known as lowering of vapour pressure.

Let vapour pressure of solvent is P_0 and vapour pressure of solution is P_S.

It was derived earlier ;

$$\boxed{\frac{P^{\circ}-P_S}{P^{\circ}} = \frac{n_2}{n_1+n_2}} \quad \text{or} \quad \boxed{\frac{P_1^{\circ}-P_1}{P_1^{\circ}} = X_2}$$

Or

$$\boxed{\frac{P^{\circ} - P_s}{P_s} = \frac{n_2}{n_1}}$$

↳ This formula can be used for dilute as well as concentrated solutions.

(2) Elevation in boiling point :-

When a non-volatile solid solute is dissolved in a liquid solvent, the boiling point of the resulting solution increases compared to the boiling point of the pure solvent. This increase is called elevation in boiling point.

→ **Boiling point :-** The temperature at which liquid vapour pressure equals atmospheric pressure.

It is denoted by T_b.

The increase in B.P $\Delta T_b = T_b - T_b^{\circ}$ is known as elevation in boiling point.

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

From experiments,

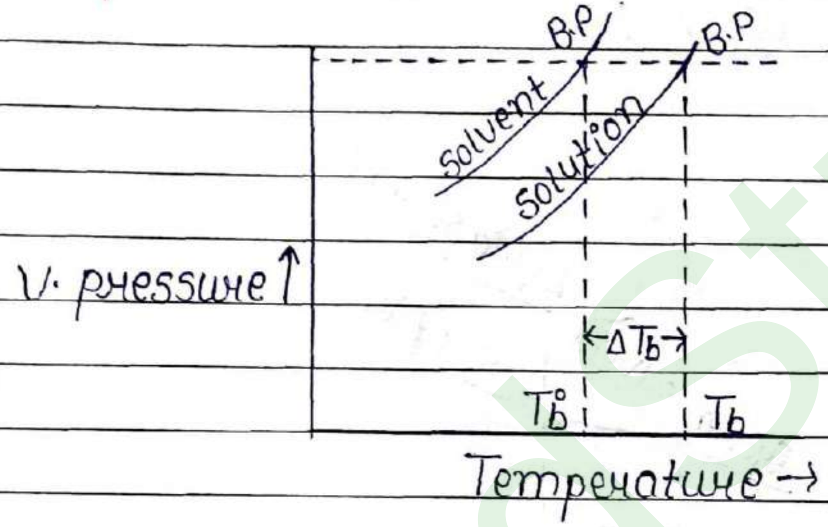
$$\Delta T_b \propto m \text{ (molal conc. of sol}^n\text{)}.$$

$$\boxed{\Delta T_b = K_b m}$$

where K_b is molal elevation constant and depends upon nature of solvent.

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

Graph :-



(3) Depression in freezing point :-

When solid solute is dissolved in liquid solvent then, freezing point of complete solution decrease than, freezing point of pure solvent is known as depression in freezing point.

Freezing point is the temperature at which vapour pressure of liquid state becomes equal to vapour pressure of solid state.

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

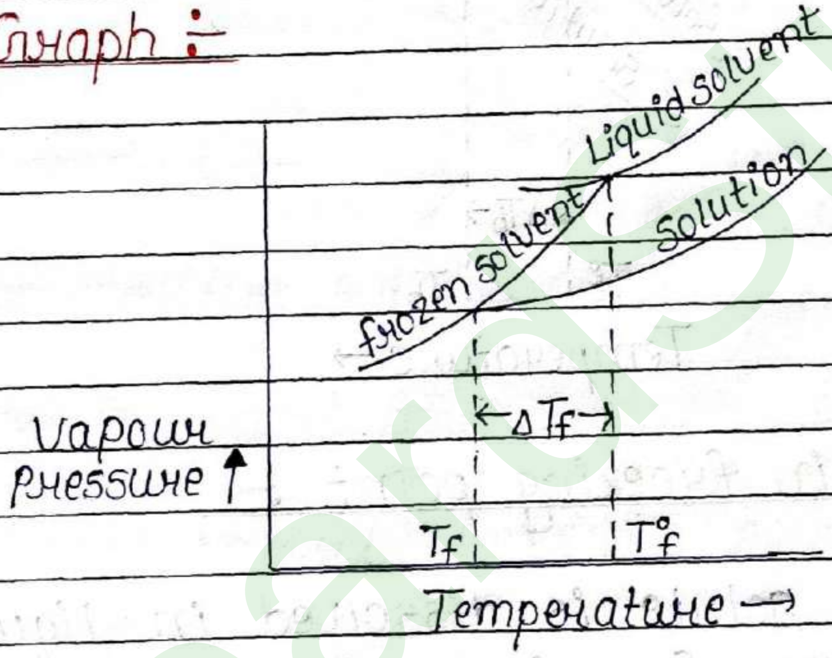
$\Delta T_f \propto m$

$\boxed{\Delta T_f = K_f m}$

where K_f is molal depression constant and depends on solvent.

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

Graph :



Constant K_f and K_b
The values of K_f and K_b can be ascertained from the following relations,

$$K_f = \frac{R \times M_1 \times T_f^2}{1000 \times \Delta_{fus} H}$$

$$K_b = \frac{R \times M_1 \times T_b^2}{1000 \times \Delta_{vap} H}$$

R is gas constant.
M_1 is Molar mass of solvent.
T_f is freezing point of pure solvent in K.
T_b is boiling point of pure solvent in K.
$\Delta_{fus}H$ represent enthalpy for fusion of solvent.
$\Delta_{Vap}H$ represent enthalpy vapourisation of solvent.

(4) Osmotic Pressure :-

Osmotic pressure is the minimum pressure that must be applied to a solution to stop the flow of pure solvent into the solution through a semipermeable membrane.

It is denoted by π.

SPM → Do not permit solute particle.
eg:- Animal membrane, cellophane, copper ferrocyanide.

Osmotic Pressure : (π)

The net movement of solvent molecule from solvent to solution can be stopped by applying some extra pressure over solution and that extra pressure over solution side which stops osmosis is called osmotic pressure.

$\pi \propto C / M$ (Molarity of solution)
$\pi \propto T$ (Temperature in K).
$\pi = MRT$ or CRT

$\boxed{\pi = CRT}$ where, R is solution constant.

$R = 0.082\ atm\ L\ mol^{-1} K^{-1}$

⇝ Diffusion :-

Diffusion is the process by which molecules move from a region of higher concentration to a region of lower concentration, untill they are evenly distributed.

▶ Isotonic :-

Solution with equal osmotic pressures are called isotonic.

▶ Hypotonic :-

Solution have lower osmotic pressure than normal solution.

▶ Hypertonic :-

Solution have higher osmotic pressure than normal solution.

* Reverse Osmosis :- RO

(Reverse osmosis) is a water purification process that uses a semipermeable membrane to remove ions, unwanted molecules, and large particles (like bacteria and salts) from water.

Applied pressure should be more than osmotic pressure.

→ Abnormal molar mass :-

The molar mass calculated through the colligative properties is sometimes different from that of experimentally determined molar mass is known as abnormal molar mass.

* Vant hoff factor :-

Vant hoff developed a factor for that solution which indicates abnormal behaviour then that factor is called vant-hoff factor.

$$i = \frac{\text{total number of moles of solute after dissociate}}{\text{total number of moles of solute before dissociate}}$$
or Associate

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

$$i = \frac{\text{normal molar mass}}{\text{observed molar mass}}$$

For example :

→ $K_4[Fe(CN)_6] \longrightarrow 4K^{+} + [Fe(CN)_6]^{4-}$

initial 1 $\quad 0 \quad 0$

equilibrium $1-\alpha$ $\quad 4\alpha \quad \alpha$

$$i = \frac{1-\alpha+4\alpha+\alpha}{1}$$

$$i = \frac{1+4\alpha}{1}$$

in case of dissociation i is greater than 1.

if dissociation 100%

$$i = \frac{1+4\times 1}{1} = 5$$

$i=5$

→ $2\ CH_3COOH \rightleftharpoons (CH_3COOH)_2$

initial	1	0
equilibrium	$1-\alpha$	$\alpha/2$

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

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

$i=\frac{1}{2}$ incase of association value of i is less than unity.

1. $\boxed{\frac{P_1^\circ - P_1}{P_1^\circ} = i \times \frac{n_2}{n_1}}$
2. $\Delta T_b = i K_b m$
3. $\Delta T_f = i K_f m$
4. $\pi = i CRT$