Solution

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SOLUTION

it is a homogeneous mixture of two or more than two substances.

SOLUTE present in less amount

SOLVENT present in large amount.

e.g Sugar Solution

Water + sugar

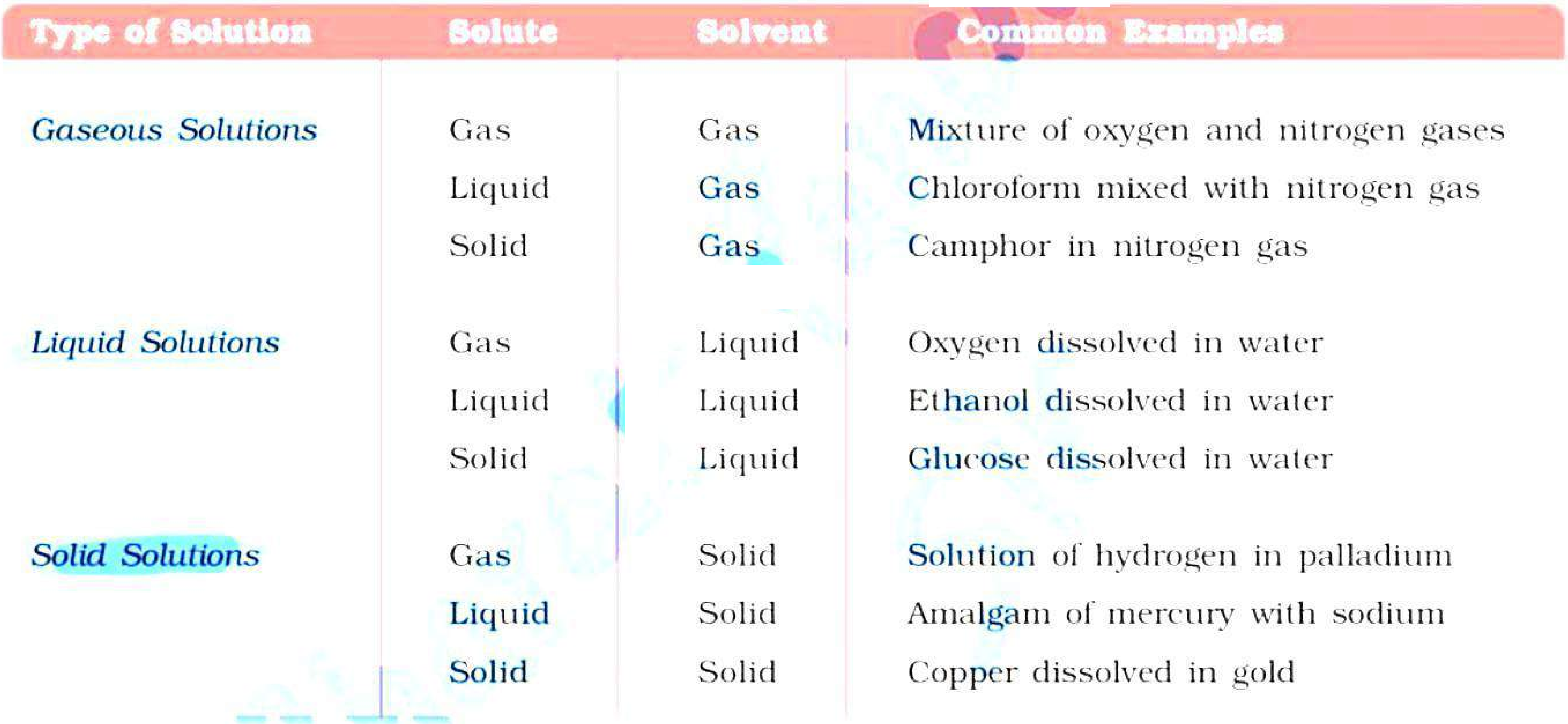
↳ Solvent ↳ solute

BINARY SOLUTION

Prepared by two components.

> Brass → $Cu + Zn$, German Silver → $Cu + Zn + Ni$, Bronze ↓ $Cu + Sn$

Table 2.1: 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

DILUTE SOLUTE ~ very small quantity of solute

CONCENTERATED SOLUTION ~ very large quantity of solute

CONCENTERATION OF SOLUTION

Mass Percentage (w/w)

Mass of a component to the per 100 parts mass of solution.

$$\text{mass \% of A} = \frac{\text{Mass of A}}{\text{Mass of solution}} \times 100$$

Volume Percentage (V/V) :- Volume of a component to the per 100 parts volume of solution.

$$\text{Volume \% of A} = \frac{\text{Vol. of A}}{\text{Vol. of solution}} \times 100$$

Mass by Volume Percentage (w/v) :- mass of a component to the per 100 parts volume of solution.

Parts Per million (ppm) :-

$$\frac{\text{no. of parts of the component}}{\text{Total no. of all components of sol}^n} \times 10^6$$

MOLE FRACTION (X)

no. of moles of a component to the total no. of moles of solution.

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

$$\text{Mole fraction of a component} = \frac{\text{no. of moles of component}}{\text{Total no. of moles of solution}}$$

- mole fraction is a unitless quantity.
- mole fraction of solution is always 1.

MOLARITY :-

number of moles of solute dissolved in one litre (1dm³) of solution.

$$\text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution in litre}}$$

Unit = Moles/litre or M or Molar

$$\boxed{M = \frac{W_B}{M_B} \times \frac{1000}{V(ml)}}$$

W_B → Mass of solute
M_B → Molar Mass of solute
$V(ml)$ → Volume in mL.

- temperature dependent i.e molarity decreases with increase in temp.

Dilution Law , $M_1V_1 = M_2V_2$

Molarity for mixed solution, $M = \frac{M_1V_1 + M_2V_2}{V_1+V_2}$

Molality (m) number of moles of solute per kg of the solvent

Molality = $\frac{\text{no. of moles of solute}}{\text{Mass of solvent in Kilogram}}$

Unit = moles/kg

Molality = $\frac{W_B}{M_B} \times \frac{1000}{W_A(g)}$

W_B → mass of solute
M_B → Molar mass of solute
$W_A(g)$ → Mass of solvent in g

→ Molality is independent of temperature.

eg. When solvent used in water, 1 M solution is more concenterated than 1 molal solution.

SOLUBILITY The maximum amount of solute that can be dissolved in 100 g solvent at a given temperature is termed as its solubility at that temperature.

• FACTORS AFFECTING SOLUBILITY OF G In L

- **Nature of Gas** - The gases which can be easily liquified, are more soluble in common solvents.
- **Nature of the solvent** - The gases which are capable of forming ions in aqueous solutions are much more soluble in water than in other solvent.
- **Temperature** - The solubility of gases in liquid decreases with increase of temperature.
- **Pressure** - The solubility of a gases increase with increase in pressure.

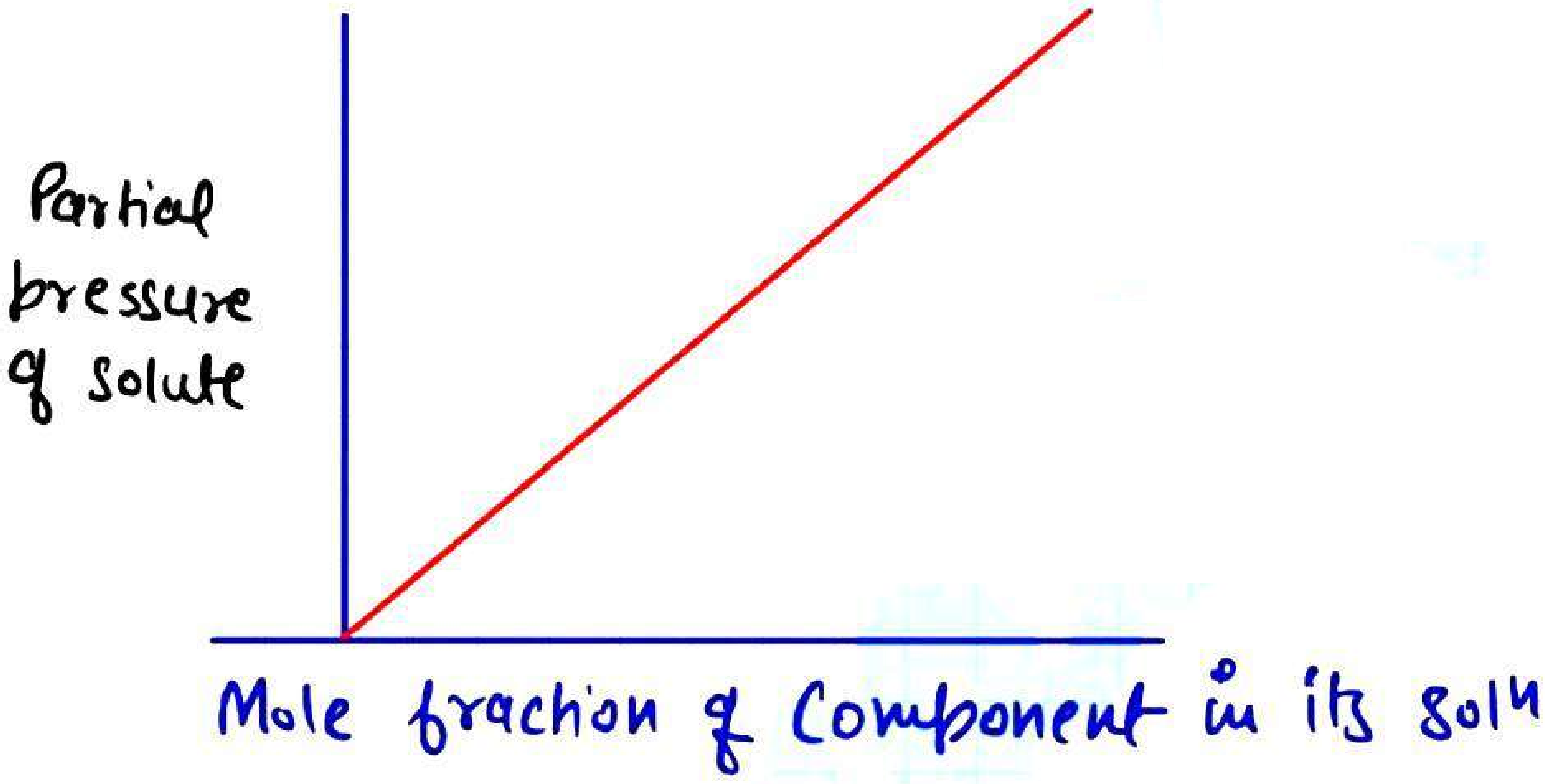
HENRY'S LAW :

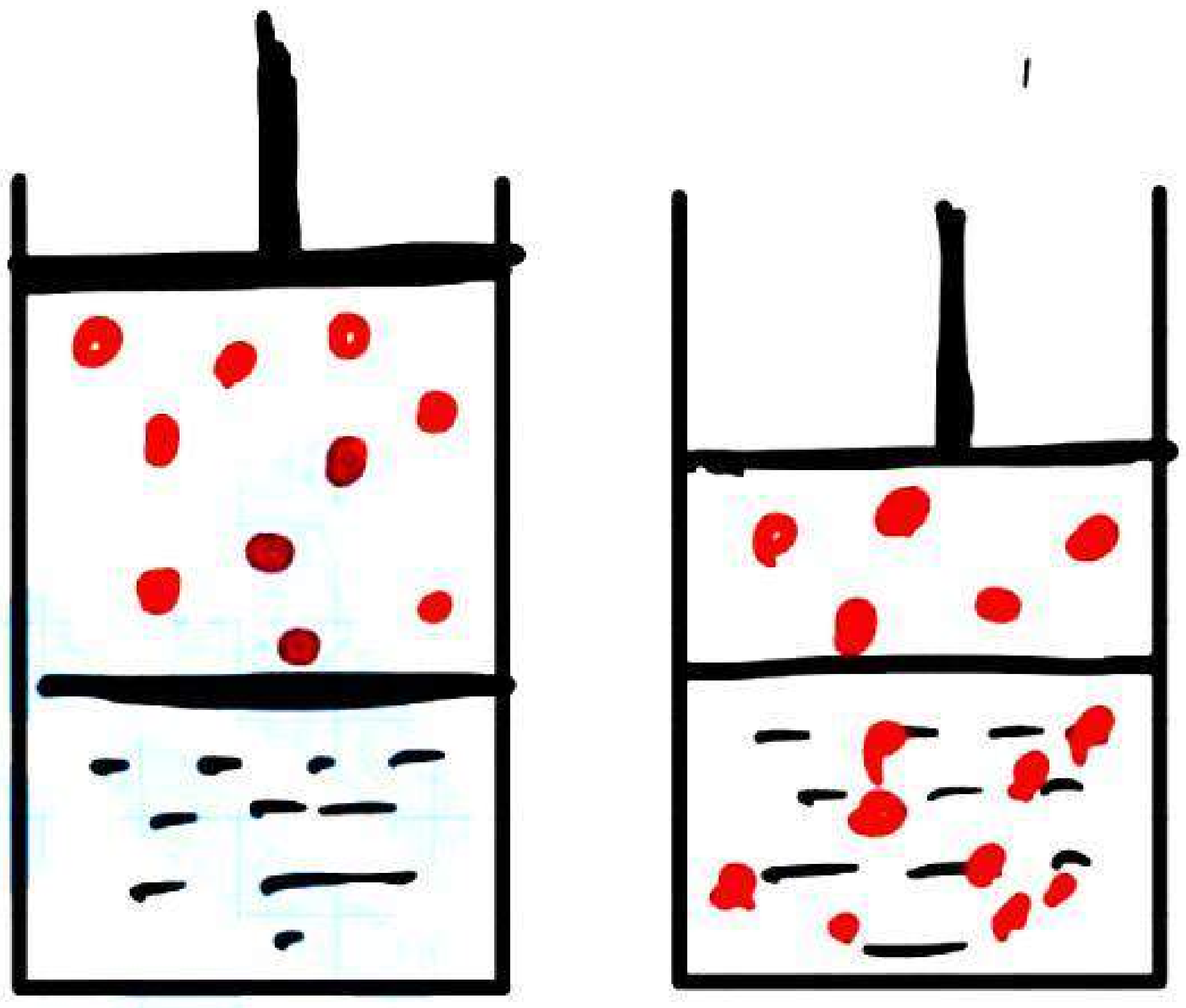
"the partial pressure (p) of the gas in vapour phase is proportional to the mole fraction (χ) of the gas in the solution."

$$p = K_H x$$

- Higher the value of K_H at given pressure, the lower is the solubility of the gas in the liquid

The value of K_H decreases with increase in the temp. Thus, aquatic species are more comfortable in cold water rather than warm water.



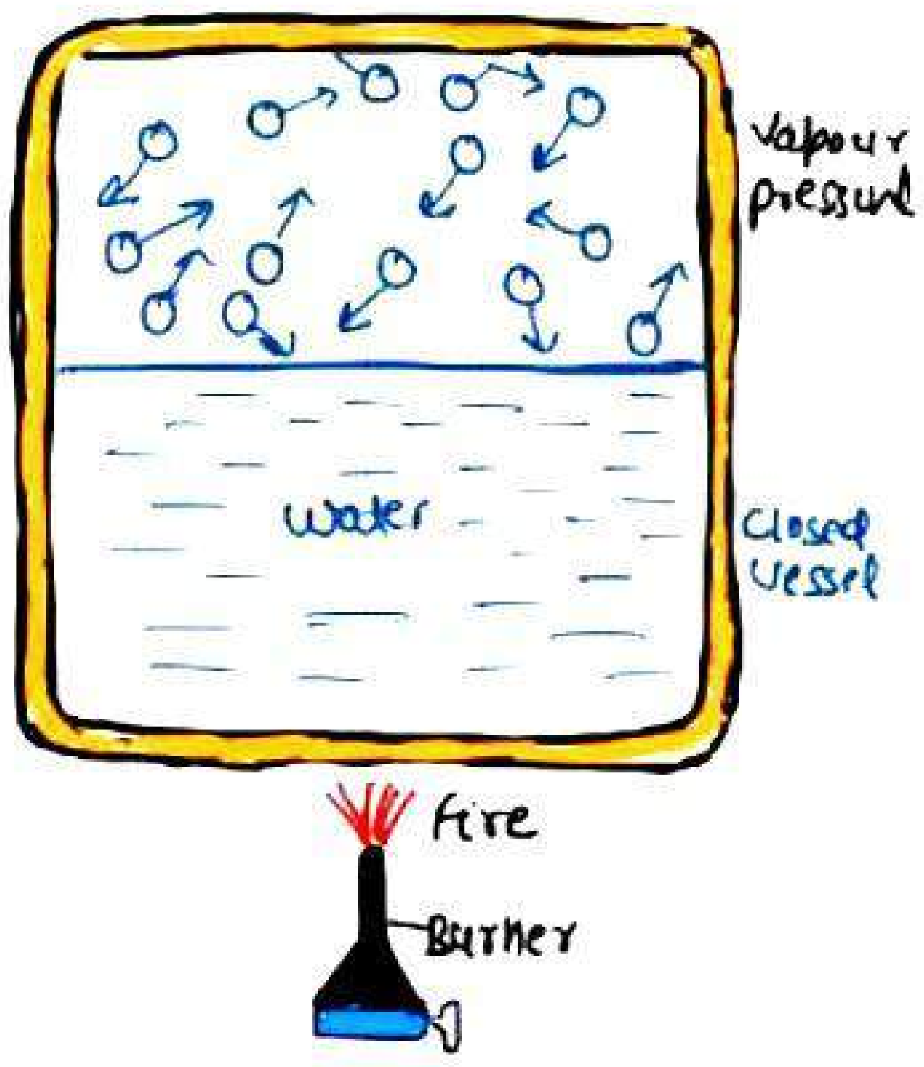


Applications :

in manufacture of soft drinks and soda water, CO_2 is passed at high pressure to increase its solubility.

- To minimise the painful effect (bends) accompanying the decompression of deep sea divers, O_2 diluted with less soluble He gas is used as breathing gas.
- At High altitudes, the partial pressure of O_2 is less than that at the ground level. This leads to low concenteration of O_2 in the blood of climbers which cause "anoxia"

Vapour Pressure



Pressure formed by the vapour of the liquid over the surface of the liquid. Vapour pressure is the pressure caused by the evaporation of liquid

Intermolecular Force

the vapour pressure will be lower when the intermolecular forces are relatively strong since the rate of evaporation is lower.

$$\text{Vapour Pressure} \propto \frac{1}{\text{intermolecular force of Attraction}}$$

Temperature

As the temperature of the liquid increses the kinetic energy associated with the liquid also increases. and due to this increase in kinetic energy the escaping tendency of molecule increases and hence v.p increases.

$$\text{vapour Pressure} \propto \text{Temperature}$$

Concenteration of Solute

The presence of solute in the liquid will decrease the vapour pressure.

Raoult's Law

mole fraction of the solute component in a solution is directly proportional to its partial pressure

$$p \propto x$$

$$p_A \propto x_A$$

$$\Rightarrow p_A = p_A^{\circ} \cdot x_A$$

partial Vapour pressure of a component is equal to the Vapour pressure of that component in pure state multiplied by mole fraction of that component.

$p_A \propto x_A \qquad p_B \propto x_B$

$p_A = p_A^o \times x_A \qquad p_B = p_B^o \times x_B$

Acc. to Dalton's law of partial pressure, the total pressure the solution in a container

$$p_{Total} = p_A + p_B$$
$$= p_A^o \cdot x_A + p_B^o \cdot x_B$$

$\boxed{\because x_A + x_B = 1}$

$$P_{Total} = p_A^o + (p_B^o - p_A^o) x_B$$

Raoult's law for Vapour Pressure of Solid - Liquid Solution

The decrease in V.P of solvent depends on the quantity of non-volatile solute present in the solution irrespective of its nature

$$P_T = P_A + \cancel{P_B}$$
$$P_T = P_A^o \times x_A$$

ROULT'S LAW AS A SPECIAL CASE OF HENRY'S LAW ⇒

Acc. to Raoult's

$P_1 = P_1^o \cdot x_1$

Acc. to Henry

$P = K_H x$

if we compare the eqn for Raoult's law and Henry's law, it can be seen that the partial pressure of the volatile component of gas is directly proportional to its mole fraction in solution. Only the proportionality constant K_H differs from p_1^o. Thus, law becomes a special case of Henry's law in which K_H becomes equal to p_1^o.

IDEAL SOLUTION

- solution must obey Raoult's law

$$p_A = p_A^0 \chi_A$$

$$p_B = p_B^0 \chi_B$$

- Solute - Solvent (A-B) interaction is almost similar to the interaction of A-A and B-B
- $\Delta V_{mix} = 0$ (No expansion or contraction on mixing)
- $\Delta H_{mix} = 0$ (No energy evolved or absorbed

↳ e.g benzene + toluene
n-hexane + n-heptane
chlorobenzene + bromobenzene

NON-IDEAL SOLUTION

- Solution doesn't obey Raoult's law

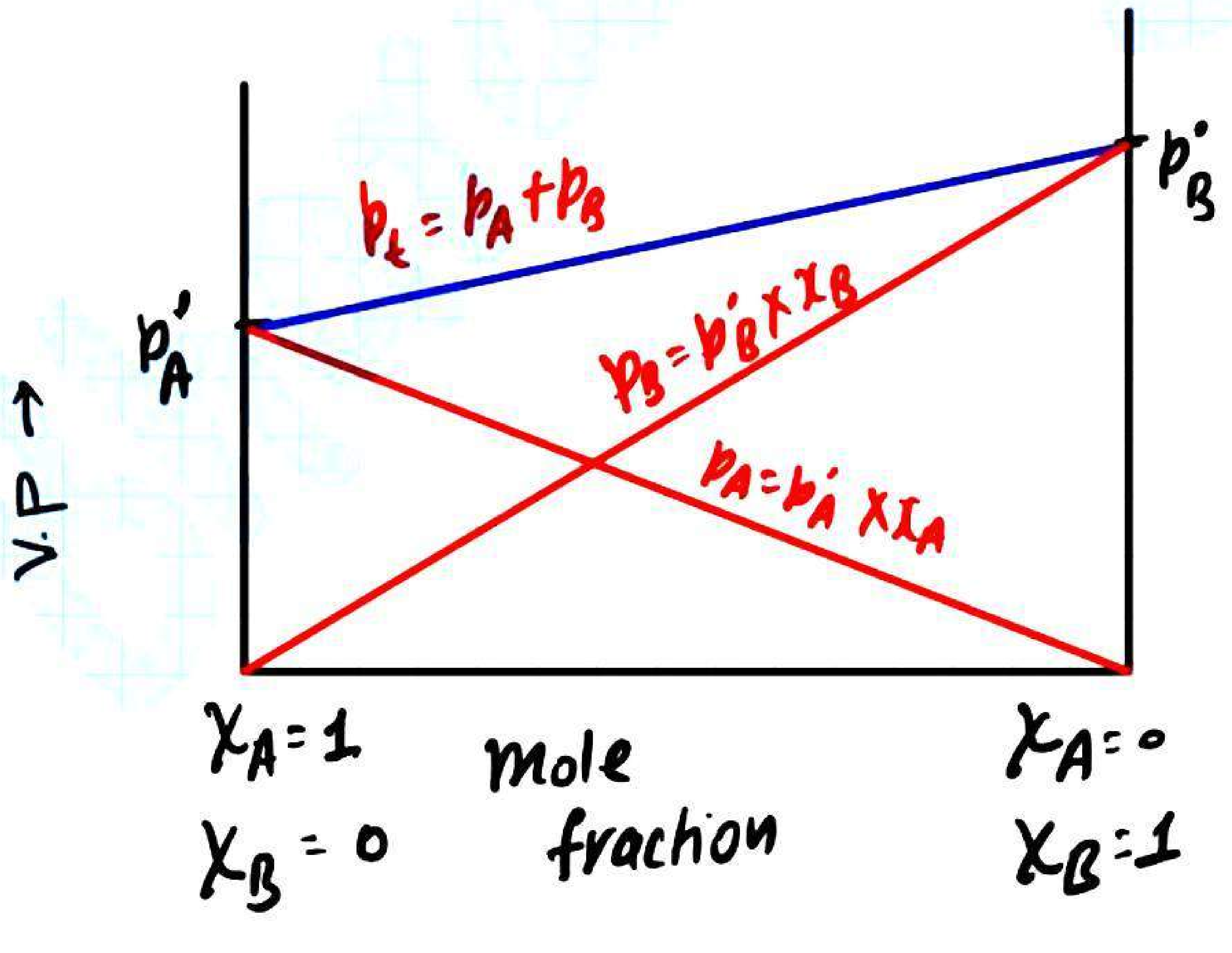
$$p_A \neq p_A^0 \cdot \chi_A$$

$$p_B \neq p_B^0 \chi_B$$

- Solute-Solvent (A-B) interaction is not similar to the interaction of A-A and B-B.
- $\Delta V_{mix} \neq 0$
- $\Delta H_{mix} \neq 0$

↳ eg ethanol + water
CS_2 + acetone
$CHCl_3 + CH_3COCH_3$
$CHCl_3 + C_6H_6$

GRAPH OF IDEAL SOLUTION



POSITIVE DEVIATION

- A-B interaction is weaker than interaction of A-A and B-B
- observed vapour pressure are greater than V.P calculated by Raoult's law

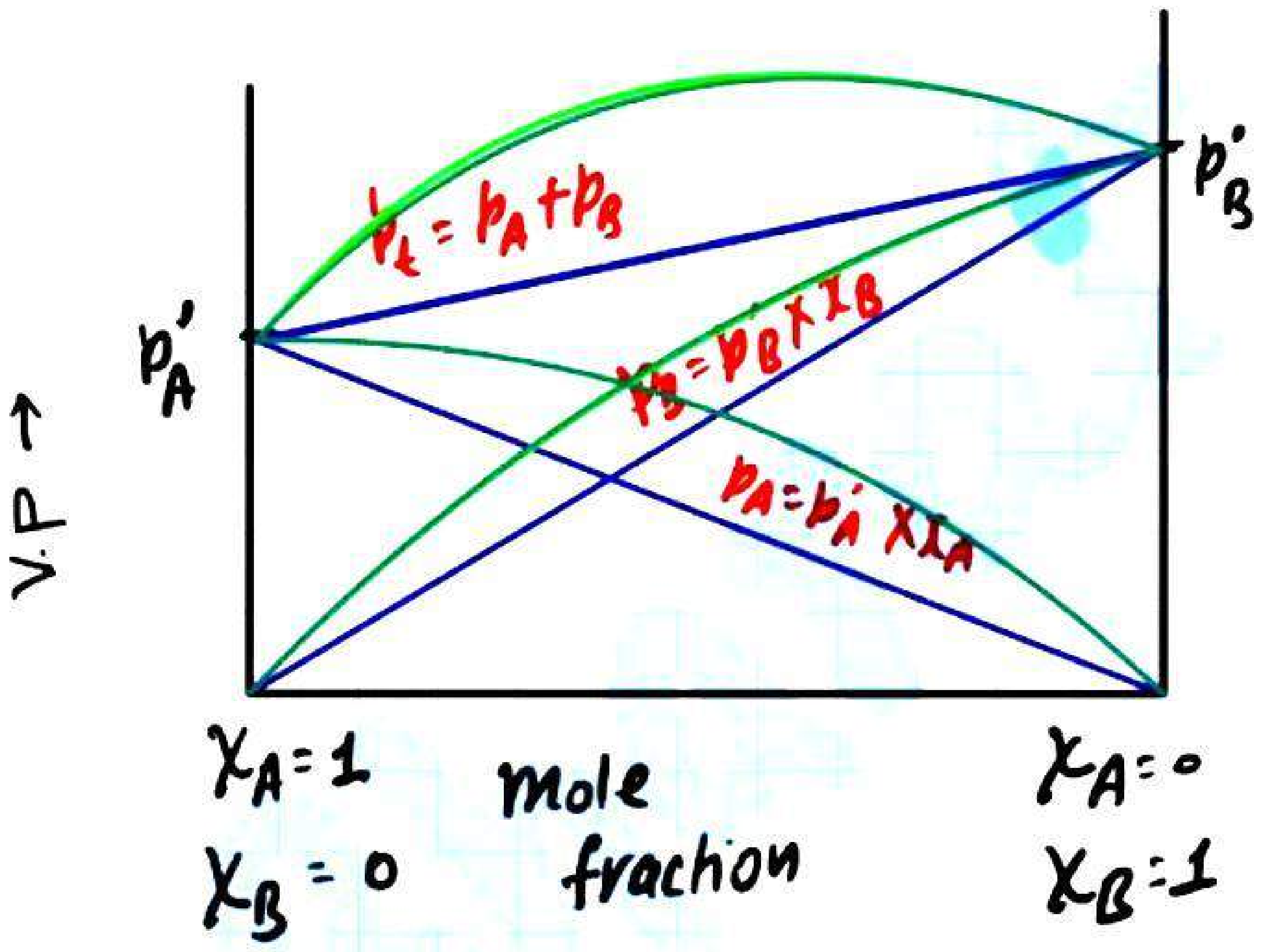
$p_A > p_A^\circ \cdot \chi_A$

$p_B > p_B^\circ \cdot \chi_B$

$\Delta H_{mix} > 0$

$\Delta V_{mix} > 0$

- Form minimum boiling azeotropes



● +ve deviation

Ethanol + Water

CS_2 + Acetone

$CCl_4 + C_6H_6$

CCl_4 + Toluene

ethanol + Cyclohexane

$CCl_4 + CHCl_3$

NEGATIVE DEVIATION

- A-B interaction is stronger than interaction of A-A and B-B
- observed vapour pressure are lower than V.P calculated by Raoult's law

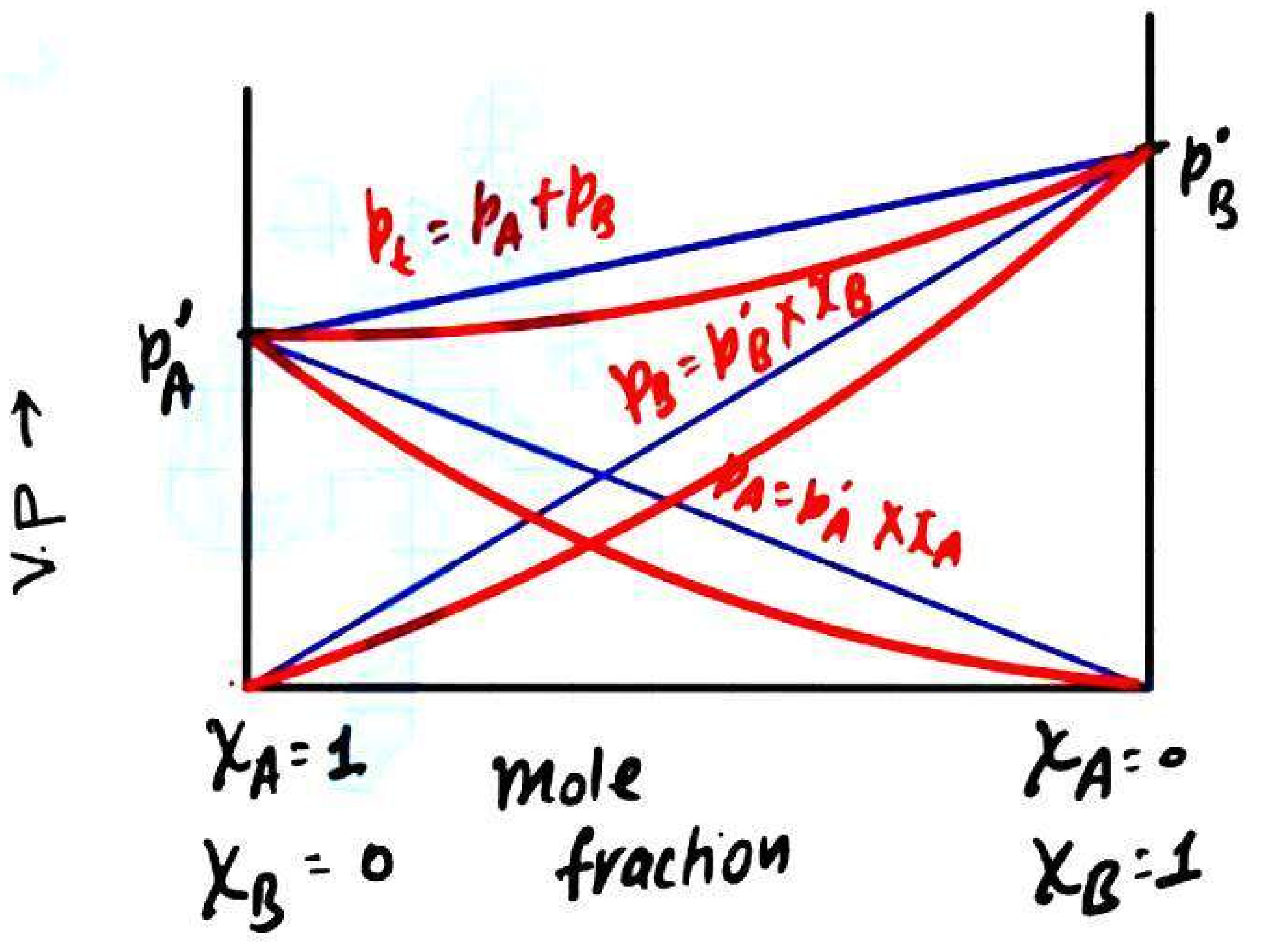
$p_A < p_A^\circ \cdot \chi_A$

$p_B < p_B^\circ \cdot \chi_B$

$\Delta H_{mix} < 0$

$\Delta V_{mix} < 0$

- Form maximum boiling azeotropes



● -ve deviation.

$CHCl_3 + CH_3COCH_3$

$CHCl_3 + C_6H_6$

$H_2O + HCl$

$H_2O + HNO_3$

methanol + acetic acid.

AZEOTROPIC MIXTURE

A mixture of two liquids which boils at a particular temperature like a pure liquid and distils over in the same composition, formed by non-ideal solution.

MAX. BOILING AZEOTROPES

formed by those liquid pairs which show negative deviation

- B.Pt higher than either of the components.

e.g $H_2O_{(20.22\%)} + HCl_{(79.78\%)}$

MIN. BOILING AZEOTROPES

formed by those liquid pairs which show positive deviation.

- B.Pt lower than either of the components

e.g $C_2H_5OH_{(95.57\%)} + H_2O$ (4.43%

COLLIGATIVE PROPERTY

Those property which depends upon no. of moles of solute or amount of solute, doesn't depends upon nature of solute or solvent

→ Relative lowering of Vapour pressure

→ Elevation in boiling point

→ Depression in freezing point

→ Osmotic Pressure

RELATIVE LOWERING IN VAPOUR PRESSURE

when a non volatile solute is added to solvent, vapour pressure of solvent decreases.

$$\underbrace{\frac{p'_A - p_s}{p'_A}}_{\text{relative lowering in V.P}} = \chi_B \rightarrow \text{mole fraction of solute}$$

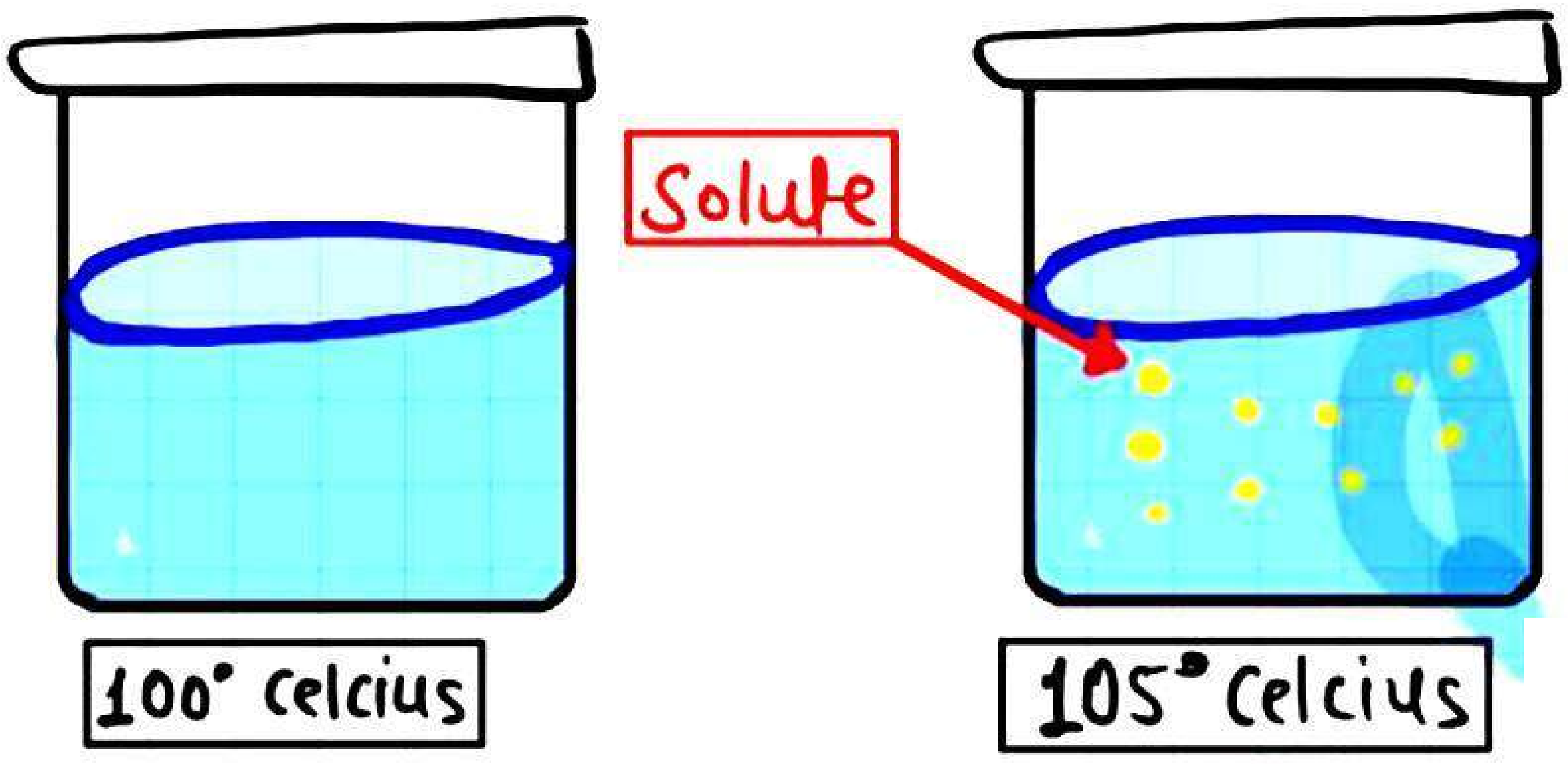
for dilute solution $n_B <<< n_A$

$$\frac{p_A^\circ - p_s}{p_A^\circ} = \frac{n_B}{n_A}$$

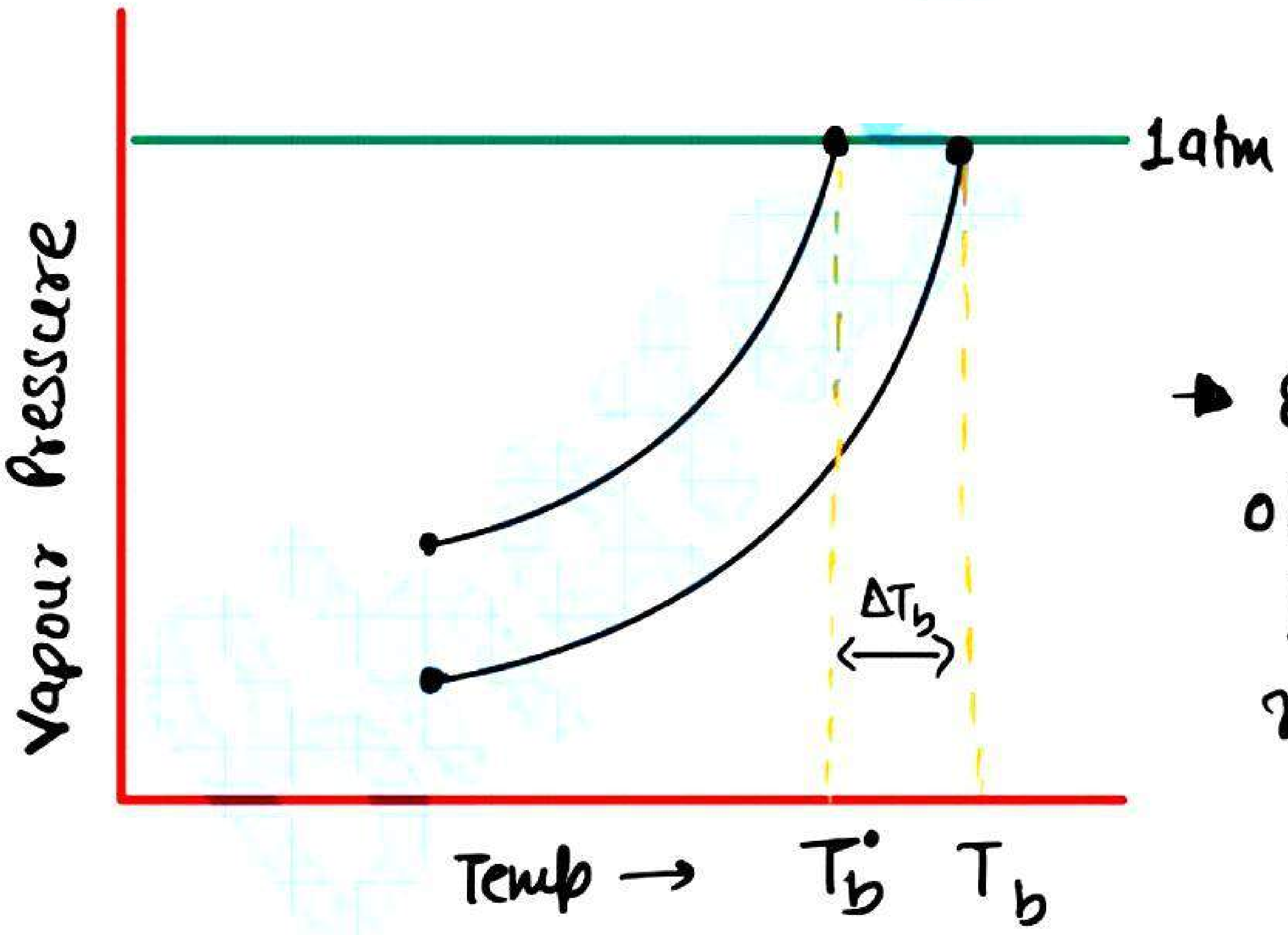
$$\frac{p_A^\circ - p_s}{p_A^\circ} = \frac{w_B}{M_B} \times \frac{M_A}{w_A} \Rightarrow M_B = \frac{w_B}{w_A} \times M_A \times \frac{p_A^\circ}{p_A^\circ - p_s}$$

ELEVATION IN BOILING POINT

Boiling point of a liquid is the temp. at which its vapour pressure becomes equal to the atmospheric pressure



Boiling point elevation is the increase in the boiling point of a solvent due to the presence of non-volatile Solute.



B.Pt of Solution

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

B.Pt of pure solvent

↳ elevation in B.Pt

- Experimentally it has been observed that elevation in b.pt is proportional to molal conc.

$\Delta T_b \propto m$

$\Delta T_b = K_b m$

ebullioscopic constant

molal elevation constant.

Unit of K_b $= K\ kg\ mol^{-1}$

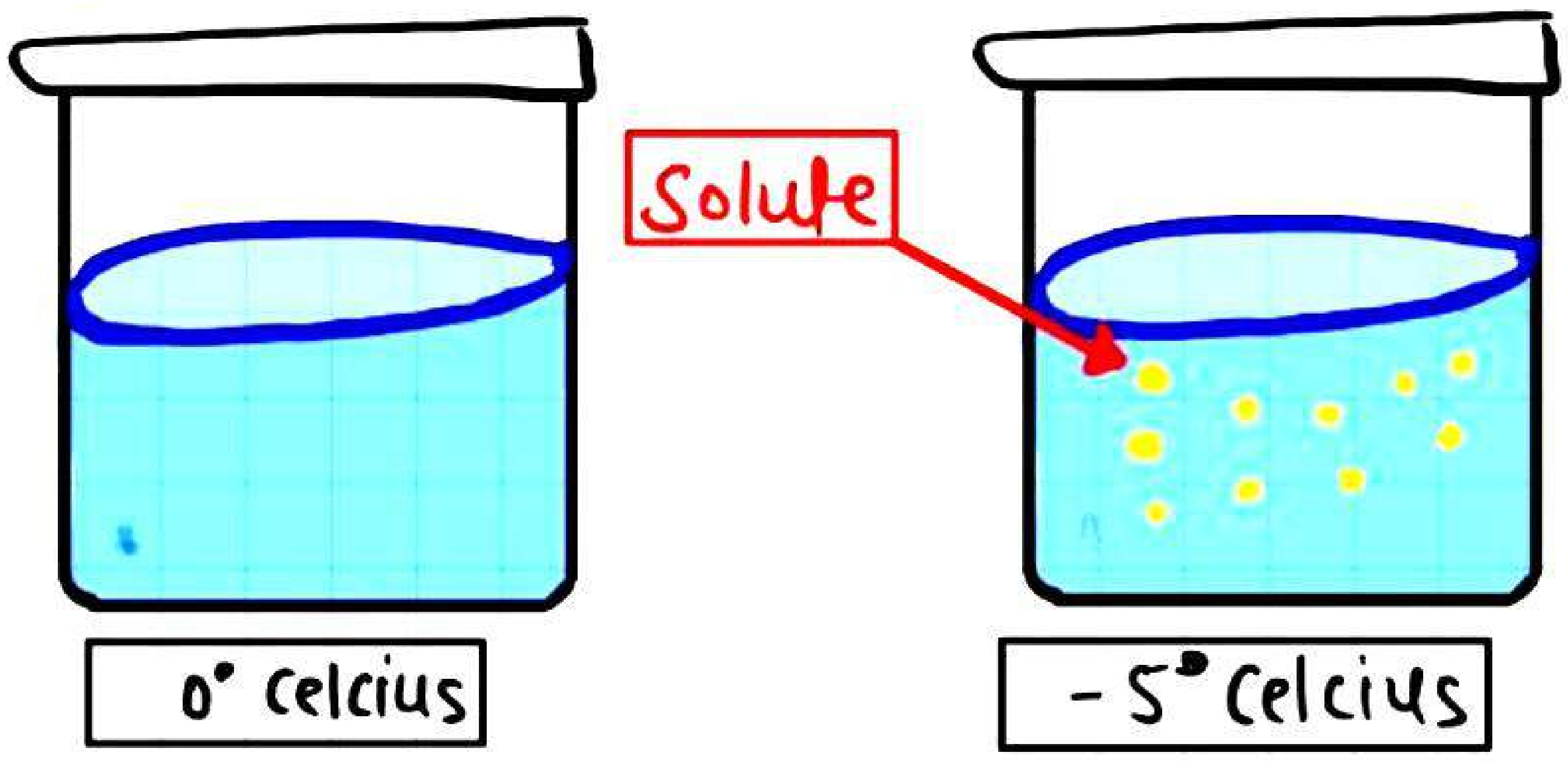
$$\Delta T_b = K_b m$$
$$= K_b \times \frac{w_B}{M_B} \times \frac{1000}{w_A(g)}$$

$$\boxed{M_B = \frac{K_b \times w_B \times 1000}{\Delta T_b \times w_A(g)}}$$

where
M_B → Molar mass of solute
$w_A(g)$ → Mass of Solvent in g
w_B → Mass of Solute

DEPRESSION IN FREEZING POINT

Freezing point of a liquid is the temp at which vapour pressure of of the solvent in its liquid and solid phase becomes equal.



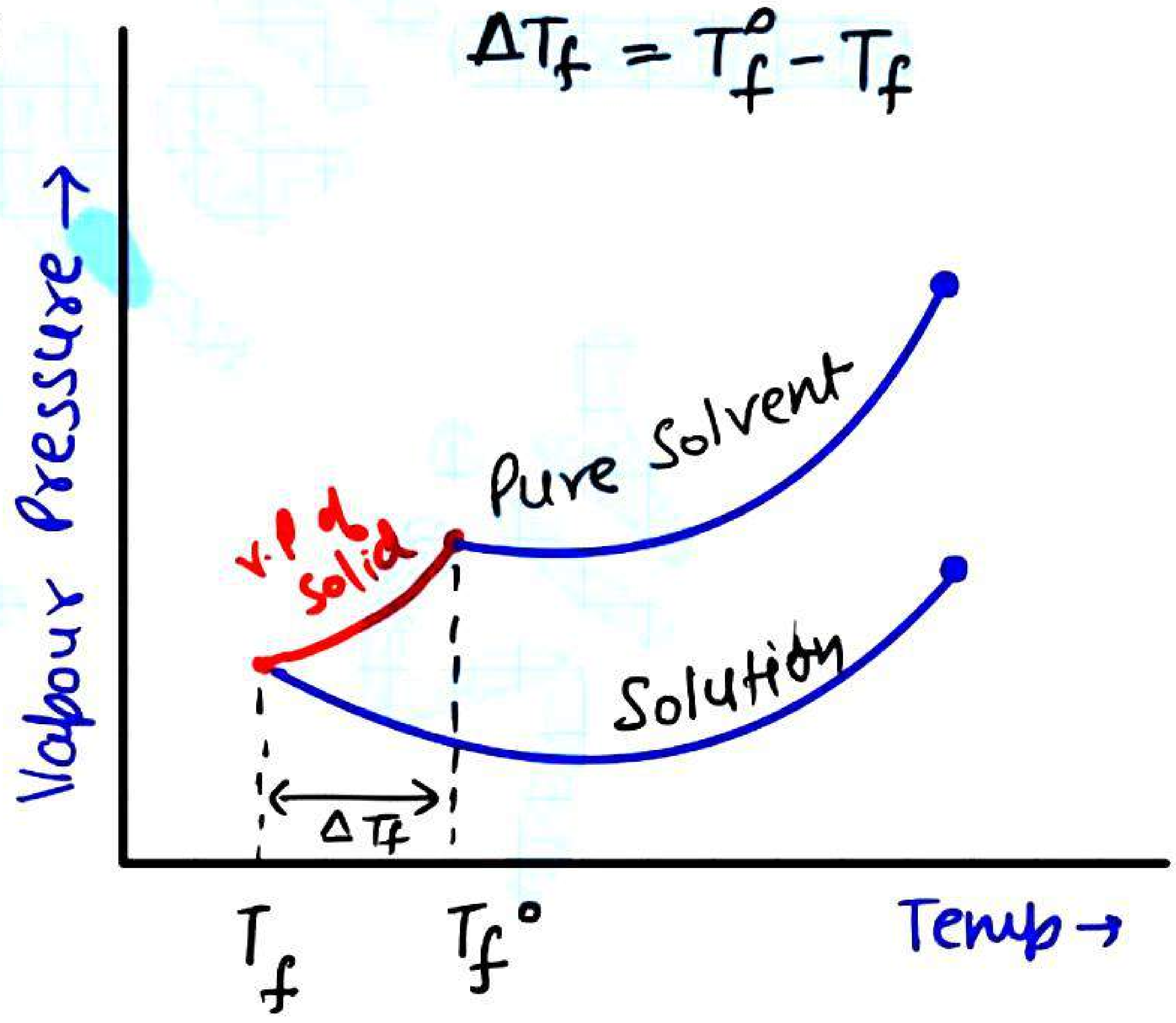
Freezing point depression is the decrease in the freezing point of a solvent due to the presence of non-volatile solute particles.

Experimentally it has been observed depression in f pt is directly proportional to molal conc.

$\Delta T_f \propto m$

$$\Delta T_f = \overset{\text{cryoscopic constant}}{K_f}\, m$$

↓ molal depression constant



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

$$\Delta T_f = K_f \times \frac{w_B}{M_B} \times \frac{1000}{w_A(g)}$$

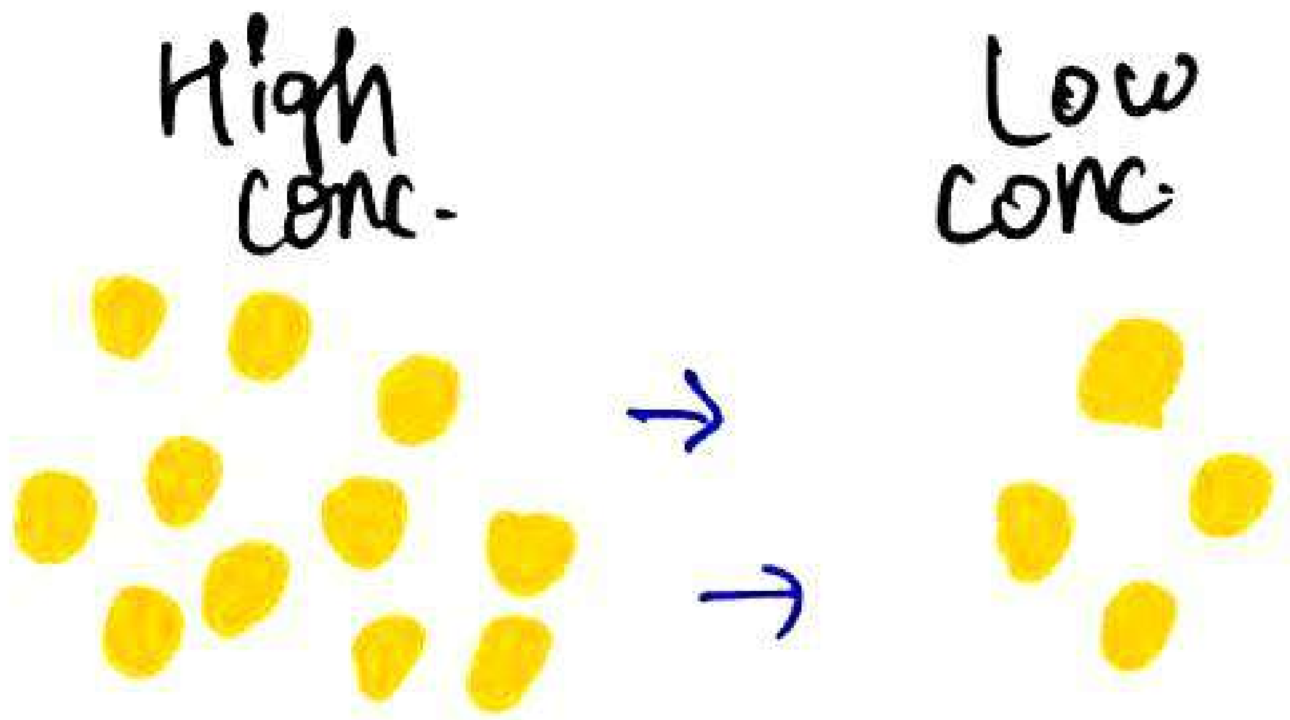
$$M_B = \frac{K_f \times w_B \times 1000}{\Delta T_f \times w_A(g)}$$

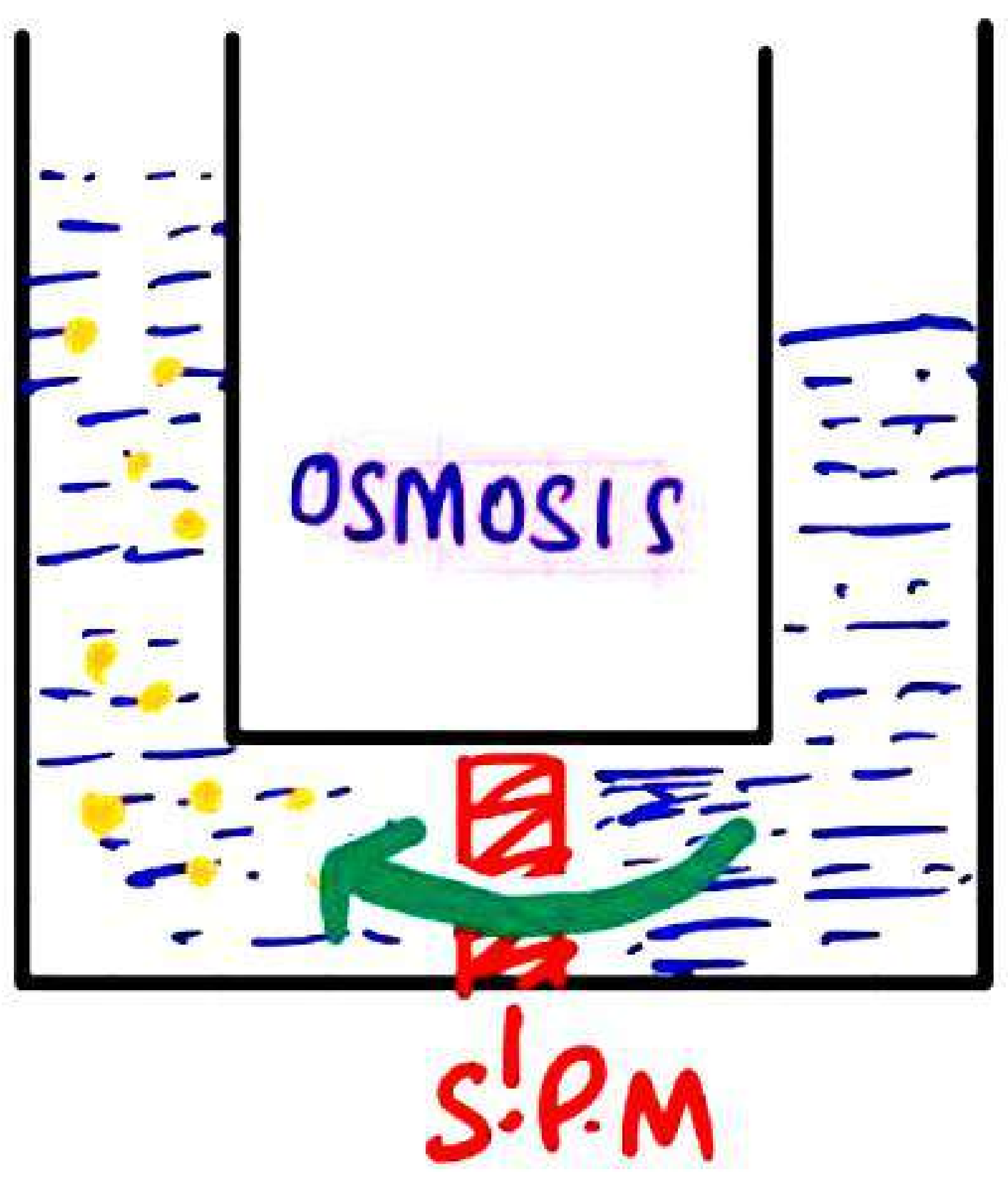
eg ethylene glycol is usually added to water in radiator to lower its freezing point. It is called antifreeze solution.

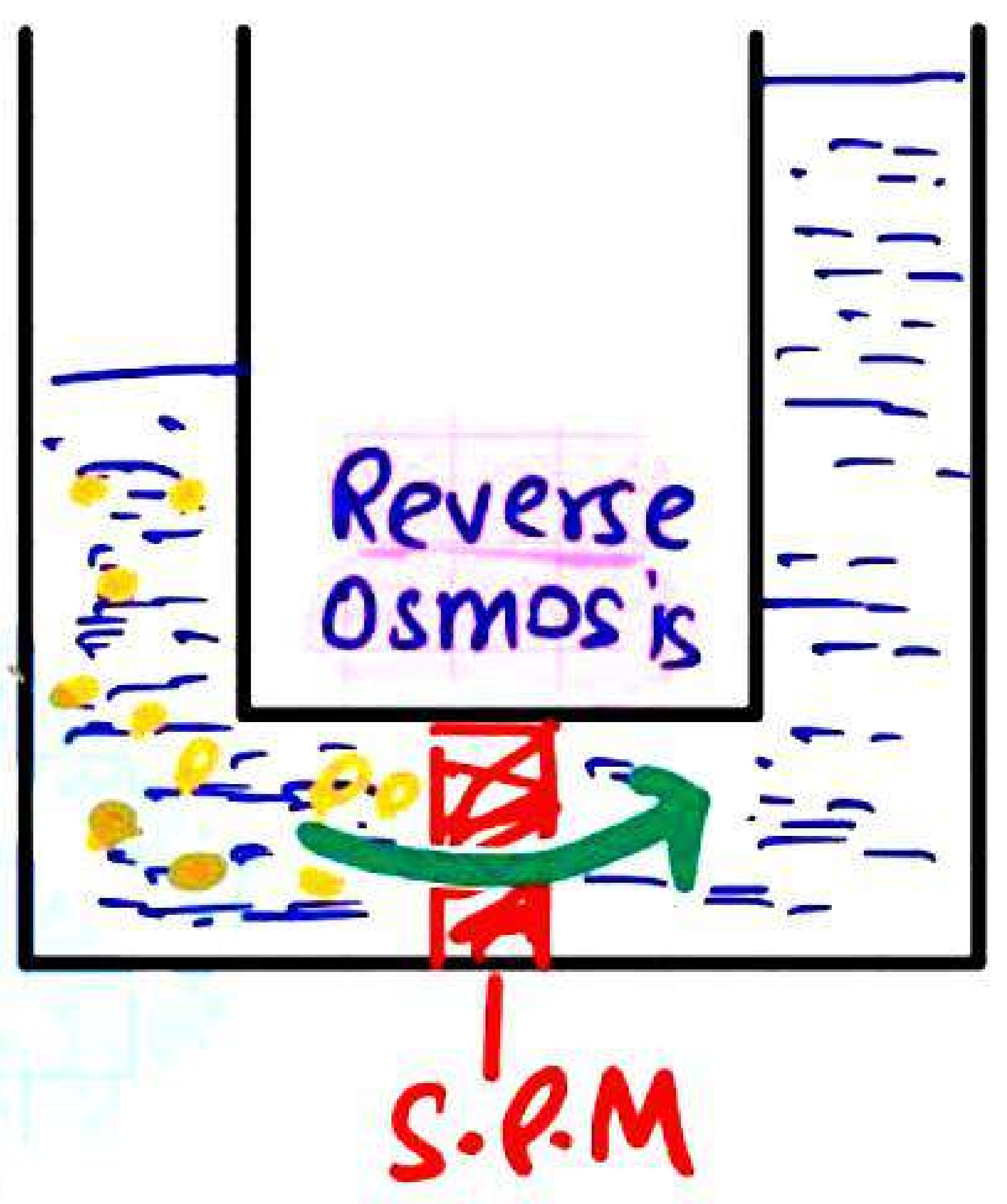
eg common salt (NaCl) and anhydrous $CaCl_2$ are used to clear snow on the roads because they depress the f.pt of water

OSMOSIS and OSMOTIC PRESSURE

Diffusion







OSMOSIS

it is the phenomenon of spontaneous flow of solvent molecules through a semi permeable membrane from pure solvent solution to concenterated solution.

SEMI PERMEABLE MEMBRANE

membrane, which allow only solvent molecules to pass through.

NATURAL

animal bladder, cell membrane

ARTIFICIAL

$Cu_2[Fe(CN)_6]$, which doesn't work in non-aqueous solution as it dissolves in them.

OSMOTIC PRESSURE:

Pressure applied on solution to stop osmosis, is called osmotic pressure. It is denoted by P or π.

Osmotic Pressure (π) $\propto T$ —①

$\pi \propto C$ —②

From ① & ②

$\pi = R \times C \times T$

Ⓡ → Gas Constant

$$\pi = R \times T \times \frac{W_B}{M_B} \times \frac{1000}{V(ml)}$$

$$M_B = \frac{R \times T \times W_B \times 1000}{\pi \times V(ml)}$$

$$\boxed{\pi = \frac{R \times T \times d}{M_B}}$$

ISOTONIC SOL^N^ Two solutions having same osmotic pressure
eg 0.91% solution of pure NaCl is isotonic with human RBC's
They have same molar concenteration

HYPERTONIC
Having high osmotic pressure $\boxed{\pi_A > \pi_B}$

HYPOTONIC
Having low Osmotic pressure

EXOSMOSIS
It is outward flow of water or solvent from a cell through semi-permeable membrane

ENDOSMOSIS
It is inward flow of water or solvent from a cell through semi permeable membrane.

ABNORMAL MOLECULAR MASS

In some cases, observed colligative properties deviate from their normal calculated values due to association or dissociation of molecules.

$$\text{Colligative Property} \propto \frac{1}{M_B}$$

Higher values observed in case of association e.g benzene
Lower values observed in case of dissociation e.g KCl

VAN'T HOFF FACTOR (i)

ratio of observed value of colligative property to the calculated value of colligative property.

$$i = \frac{\text{Observed Colligative Property}}{\text{Calculated colligative Property}}$$

or $$i = \frac{\text{normal molecular mass}}{\text{observed molecular mass}}$$

or $$i = \frac{\text{no. of particles after association or dissociation}}{\text{number of particles initially}}$$

Colligative Property and Van't Hoff factor

$$\Delta T_b = i K_b m$$

$$\Delta T_f = i K_f m$$

$$\pi = i\, CRT$$

$$\frac{P_A^\circ - P_s}{P_A^\circ} = i\, x_B$$

i for strong electrolyte like

$KCl = 2$, $NaCl = 2$, $MgSO_4 = 2$

$K_2SO_4 = 3$, $Al_2(SO_4)_3 = 5$

Degree of Dissociation (α) and Van't Hoff factor (i)

if one molecule of a substance gets dissociated into n particles and α is the degree of dissociation then

$$A \longrightarrow np$$

initially	1 mol	0
At eq.	$1-\alpha$	$n\alpha$

Total no. of moles at equilibrium = $1-\alpha+n\alpha$

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

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

Degree of Association (α) and Van't Hoff factor (i)

If n molecules of a substance A associate to form A_n and α is the degree of association, then

$$nA \longrightarrow A_n$$

initially	1 mol	0
At equilibrium	$1-\alpha$	$\frac{\alpha}{n}$

Total no. of moles at equili

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

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

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

$\boxed{i=1}$ no association or dissociation

$\boxed{i>1}$ particles undergoes dissociation

$\boxed{i<1}$ particles undergoes association