Solutions

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Colligative Properties of Solutions

Solution- a homogenous mixture of two or more substances.

Solubility- the maximum amount of a solute that will dissolve in a given quantity of solvent at a specific temperature.

- When solute is introduced into the volume of solvent, the solvent properties change

- Colligative properties are properties of solutions that depend **solely on the number of particles dissolved in the solution**

Four types of colligative properties of solutions:

1. **Vapor-Pressure Lowering**

2. **Boiling-Point Elevation**

3. **Freezing-Point Depression**

4. **Osmotic Pressure**

Vapor-Pressure Lowering

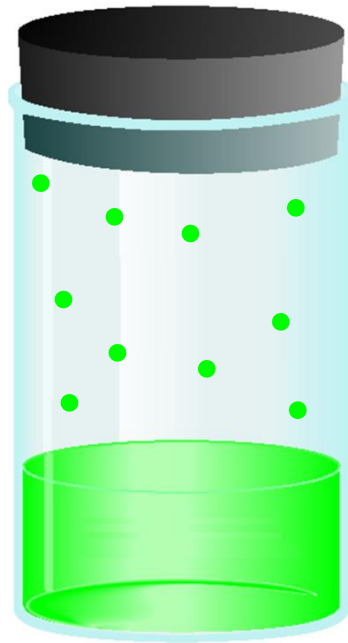Occurs with non-volatile, non-ionizing **solutes** at low solute concentrations.

~0 vapor pressure   does not dissociate

Larger entropy increase
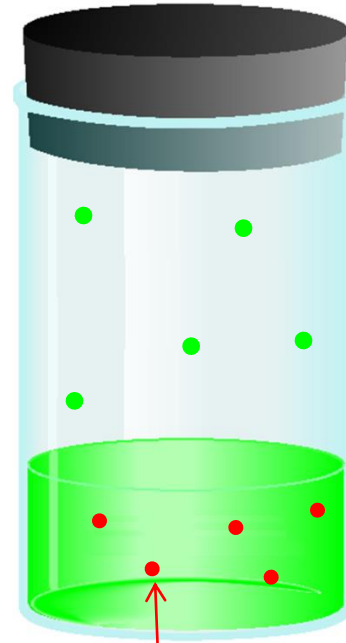
disordered

strong driving force

"Ordered"

Smaller entropy increase

disordered

weaker driving force

less "Ordered"

Gas

Liquid

Solute molecule

The vapor pressure of a pure solvent drops whenever non-volatile solute is added

Raoult's Law (Vapor Pressure Lowering)

- The vapor pressure (P_s) of a solvent is directly proportional to the mole fraction of the solvent in the solution

vapor pressure (P_s) ∝ mole fraction of solvent

- **Raoult's Law:**

$$P_s = \frac{N}{N+n} \times P$$

(P = vapor pressure of the pure solvent)

Where, N = moles of solvent

n = moles of solute

For pure solvent $P_s = P$

moles of solute ↑ X_1 ↓ P ↓

As solute is added, the vapor pressure drops.

4

Raoult's Law (Vapor Pressure Lowering)

- P – the vapor pressure of the pure solvent

  P_s – the vapor pressure of the solution with solute

$$P_s = \frac{N}{N+n} \times P$$

$$\frac{P_s}{P} = \frac{N}{N+n}$$

$$1 - \frac{P_s}{P} = 1 - \frac{N}{N+n}$$

$$\frac{P - P_s}{P} = \frac{n}{n+N}$$

The relative lowering of vapour pressure of a dilute solution is equals to the mole fraction of the solute present in the dilute solution.

Determination of molecular weight from Vapor Pressure Lowering

From Raoult's Law

$$(P - P_s)/P = n/(n+N)$$

Considering
w gms of solute;   Moles of solute (n) = **w/m**
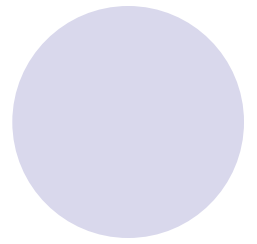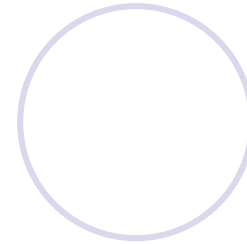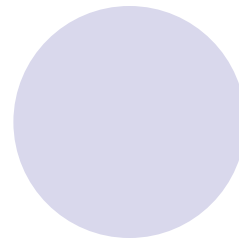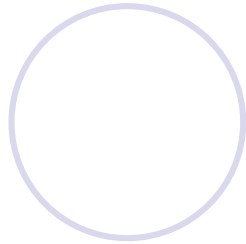**W** gms of solvent; Moles of solvent (N) = **W/M**

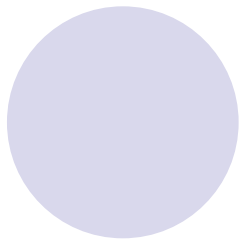Where **m** = molecular weight of solute
And **M** = molecular weight of solvent

$$(P - P_s)/P = n/(n+N)$$

$$P - P_s)/P = (w/m)/ (w/m + W/M)$$

$$P - P_s)/P = wM/mW$$

Limitations of Raoult's Law

1. At higher conc.; solute gain intermolecular forces

2. It does not applies to volatile solutes.

3. Dissociate or associate

Boiling Point Elevation

(Relation between Boiling Point Elevation and Vapor Pressure Lowering)

When a liquid is heated, its vapour pressure rises and when it equals to atmospheric Pressure, the liquid boils.
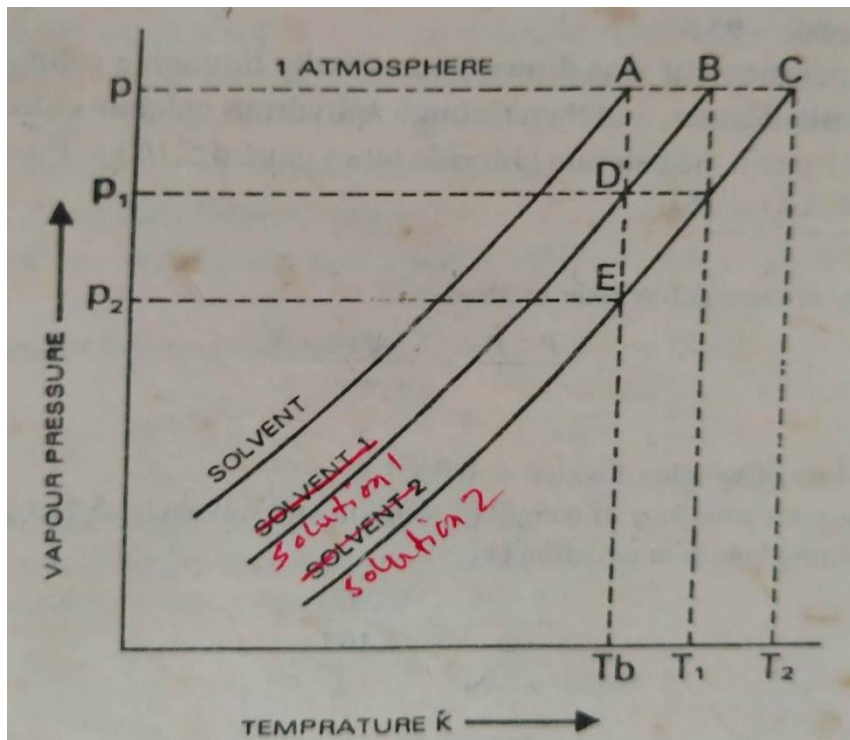
If, T_b = Boiling point of solvent
And T = Boiling point of solution

EVP, $T - T_b = \Delta T$

For dilute solution, the curves BD and CE are parallel and straight lines approximately. Therefore, ACE and ABD are similar triangles
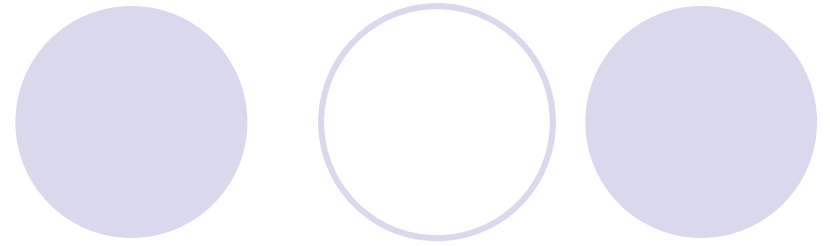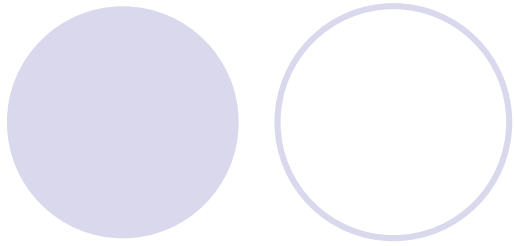
$$\frac{AB}{AC} = \frac{AD}{AE}$$

$$\frac{T_1}{T_2 - T_b} = \frac{p - p_1}{p - p_2}$$

Where, $p - p_1$ and $p - p_2$ are lowering of vapour pressure for solution 1 and 2.
Hence Elevation of boiling point is directly proportional to the lowering of vapour pressure.
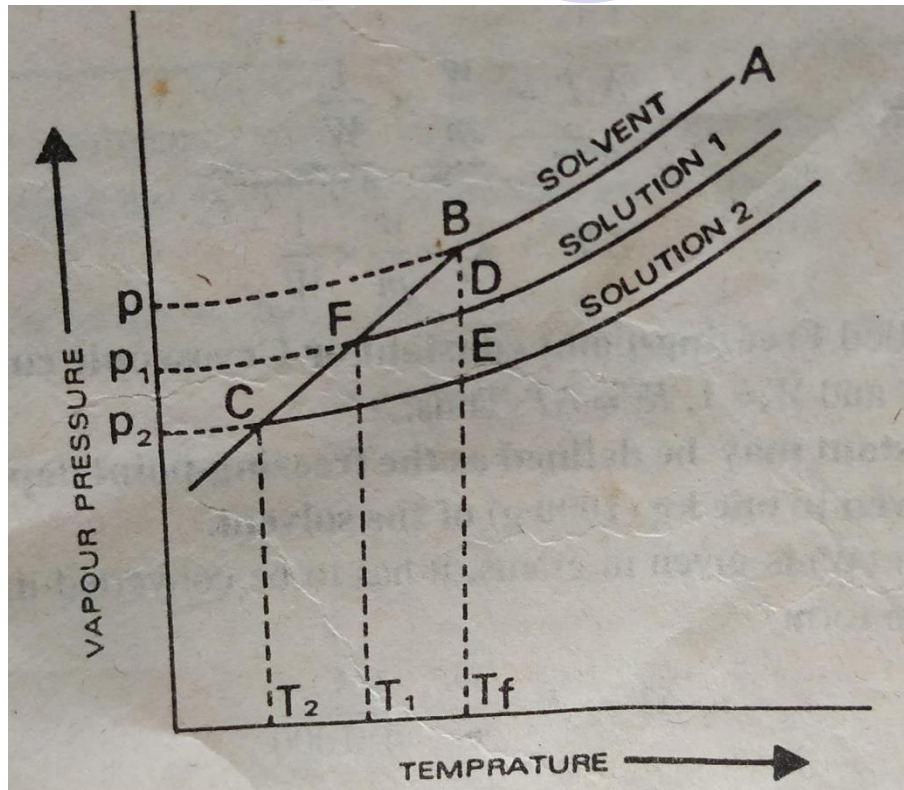
$$\Delta T = p - p_s$$

Determination of molecular weight from Boiling Point Elevation

Freezing-Point Depression

If, T_f = Freezing point of solvent
And T_1 = Freezing point of solution 1

DFP, $T_f - T_1 = \Delta T$

For dilute solution, the curves FD and CE are parallel and straight lines approximately. Therefore, BDF and BEC are similar triangles

$$\frac{DF}{EC} = \frac{BD}{BE}$$

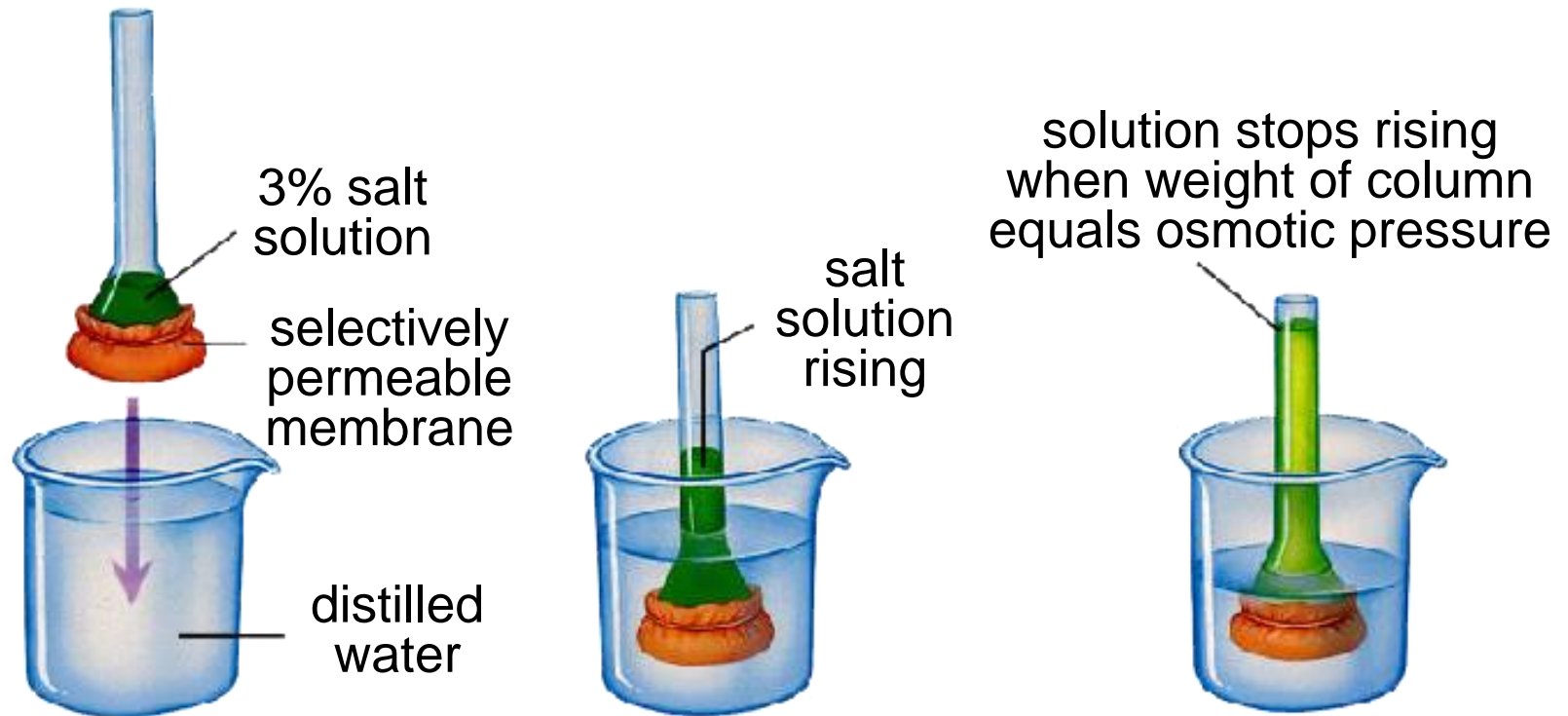$$\frac{T_f - T_1}{T_f - T_2} = \frac{p - p_1}{p - p_2}$$

Where, $p - p_1$ and $p - p_2$ are lowering of vapour pressure for solution 1 and 2.
ence depression of freezing point is directly proportional to the lowering of vapour pressure

$$\Delta T = p - p_s$$

Osmosis

Osmosis is the selective passage of solvent molecules through a porous membrane from a dilute solution to a more concentrated one.

A **semipermeable membrane** allows the passage of solvent molecules but blocks the passage of solute molecules.

3% salt solution

selectively permeable membrane

distilled water

salt solution rising

solution stops rising when weight of column equals osmotic pressure

Osmosis

Osmosis is the selective passage of solvent molecules through a porous membrane from a dilute solution to a more concentrated one.
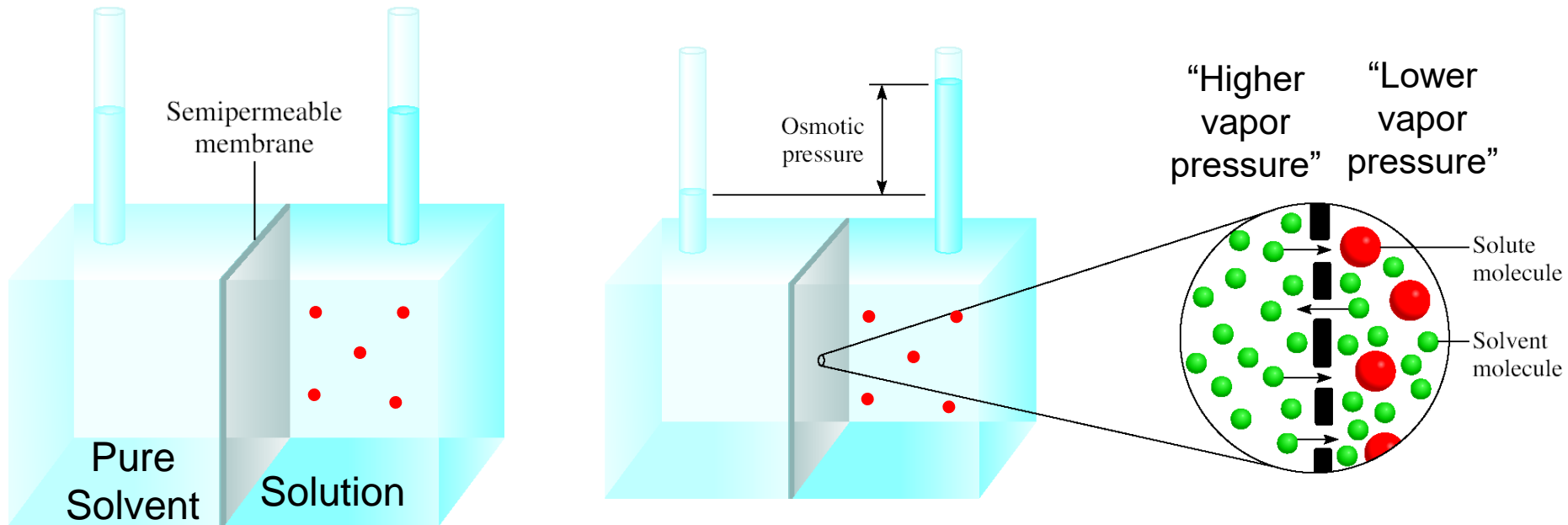
A **semipermeable membrane** allows the passage of solvent molecules but blocks the passage of solute molecules.

Osmotic pressure (π) is the pressure required to stop osmosis.
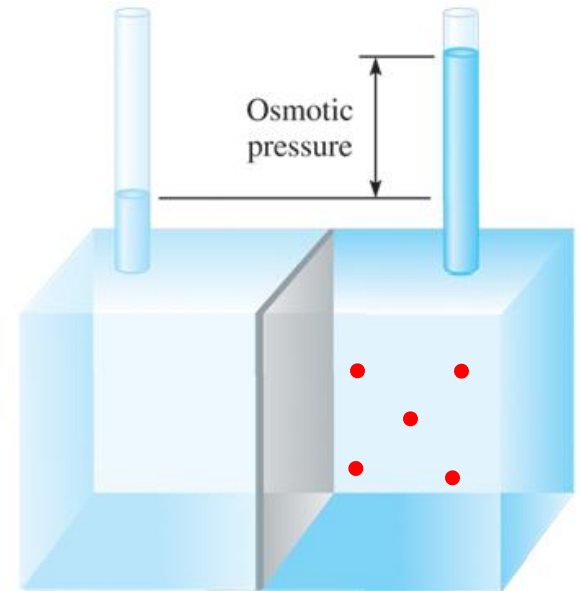
Osmotic Pressure

- Osmosis is a rate controlled phenomenon.
  - The solvent is passing from the dilute solution into the concentrated solution at a faster rate than in opposite direction, i.e. establishing an equilibrium.

- The osmotic pressure
$$\pi = MRT$$

$\pi = \text{osmotic pressure (atm)}$

$M = \text{molar concentration of solution (mol/L)}$

$R = 0.0821 \dfrac{\text{L atm}}{\text{mol K}}$

$T = \text{absolute temperature (K)}$

Abnormal Colligative Properties of Solutions