

Colligative Properties

- depend on number of solute particles **NOT** the nature of the solute particles
- particles are atoms, ions or molecules

i - van't Hoff factor

- show the number of particles a substance produces in solution

| Substance | | Particles in Solution | van't Hoff factor |
|-------------------------------|----------------------|---------------------------------------|-------------------|
| $C_6H_{12}O_6$ (s) glucose | $\xrightarrow{H_2O}$ | $C_6H_{12}O_6$ (aq) nonelectrolyte | $i = 1$ |
| $NaCl$ (s) | $\xrightarrow{H_2O}$ | Na^+ (aq) + Cl^- (aq) | $i = 2$ |
| $Mg(NO_3)_2$ (s) | $\xrightarrow{H_2O}$ | Mg^{2+} (aq) + $2 NO_3^-$ (aq) | $i = 3$ |

Colligative Properties

- | | |
|----------------------------|-----------------------------|
| 1) Vapor Pressure Lowering | $\Delta P = i P_A^0 \chi_B$ |
| 2) Boiling Pt Elevation | $\Delta T_b = i k_b c_m$ |
| 3) Freezing Pt Depression | $\Delta T_f = i k_f c_m$ |
| 4) Osmotic Pressure | $\Pi = i M R T$ |

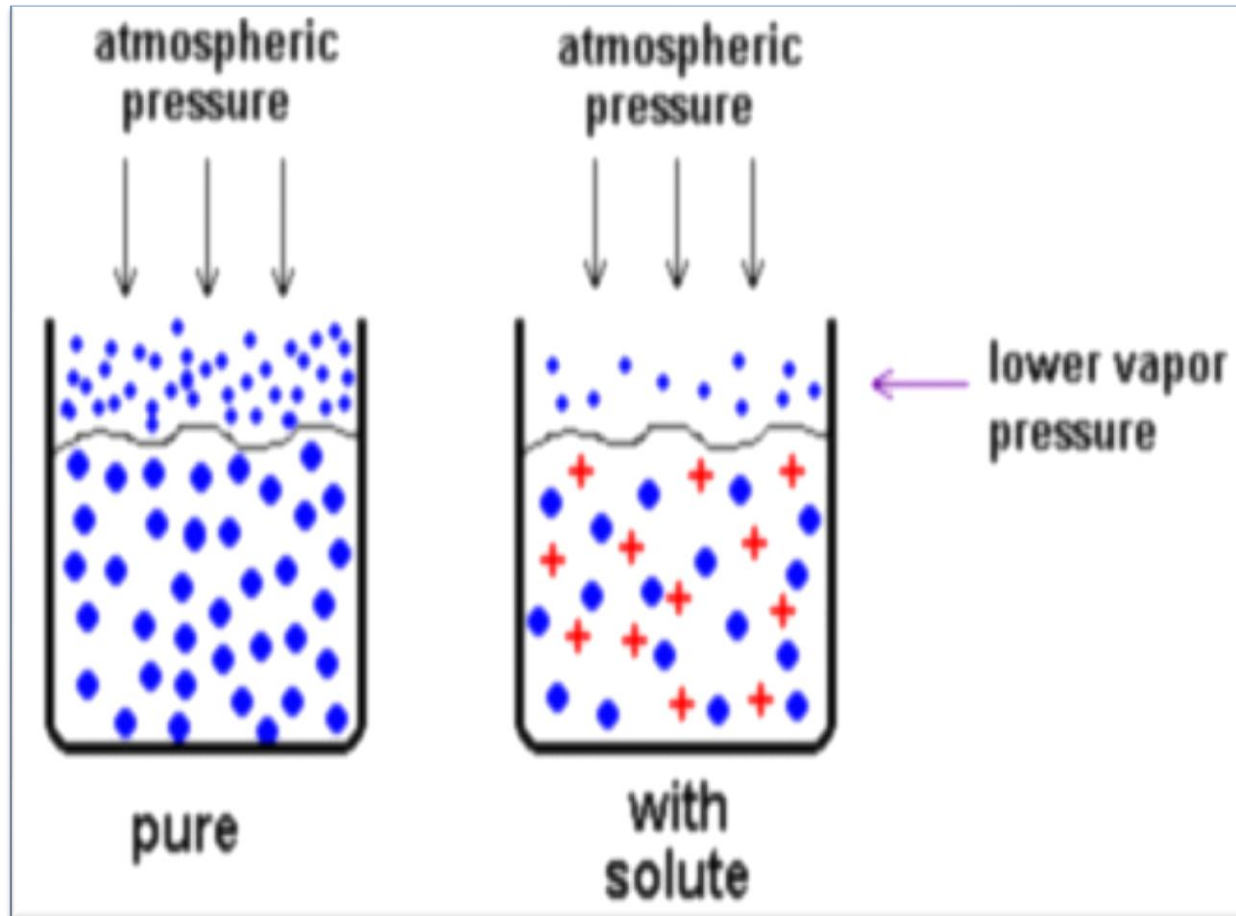
What are Colligative Properties?

- The colligative means 'tight together'
- ***Colligative properties*** are those that depend only on the concentration of solute particles (number of particles, molecules or ions) but not on their identity (for example molecular structure). The properties are-
 - Lowering of vapor pressure
 - Elevation of boiling point
 - Depression of freezing point
 - Osmotic pressure

Vapor Pressure

- Vapor pressure is the pressure exerted by molecules that have escaped from the liquid phase to the gaseous phase.
- Experiments show that the vapor pressure of a solvent containing a nonvolatile solute is lower than the vapor pressure of the pure solvent at the same temperature.

What is the mechanism of lowering of vapor pressure?

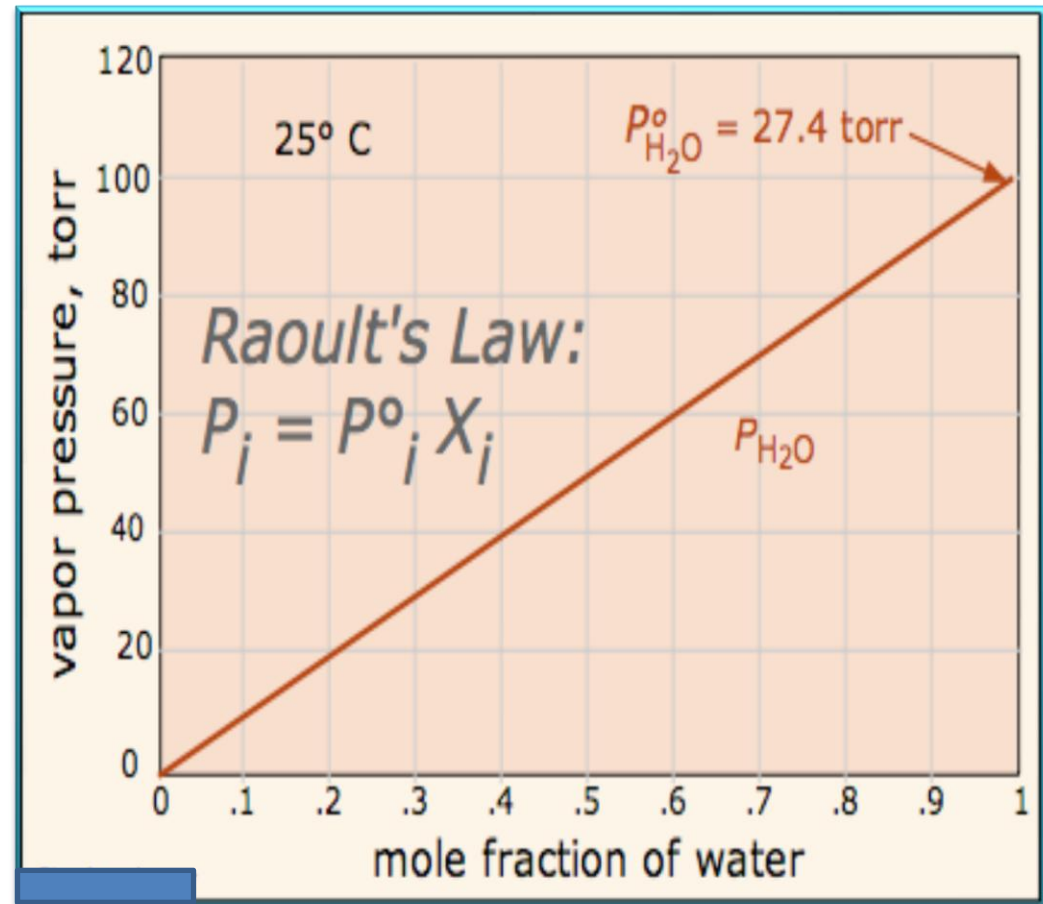


Raoult's Law

The vapor pressure of a solution is *equal* to the vapor pressure of the pure solvent at the same temperature *scaled* by the mole fraction of the solvent present .

$$p = X p^0$$

↑
 vapor pressure of pure solvent
 ↑
 mole fraction of solvent
 ↑
 vapor pressure of solution



Ideal Solution

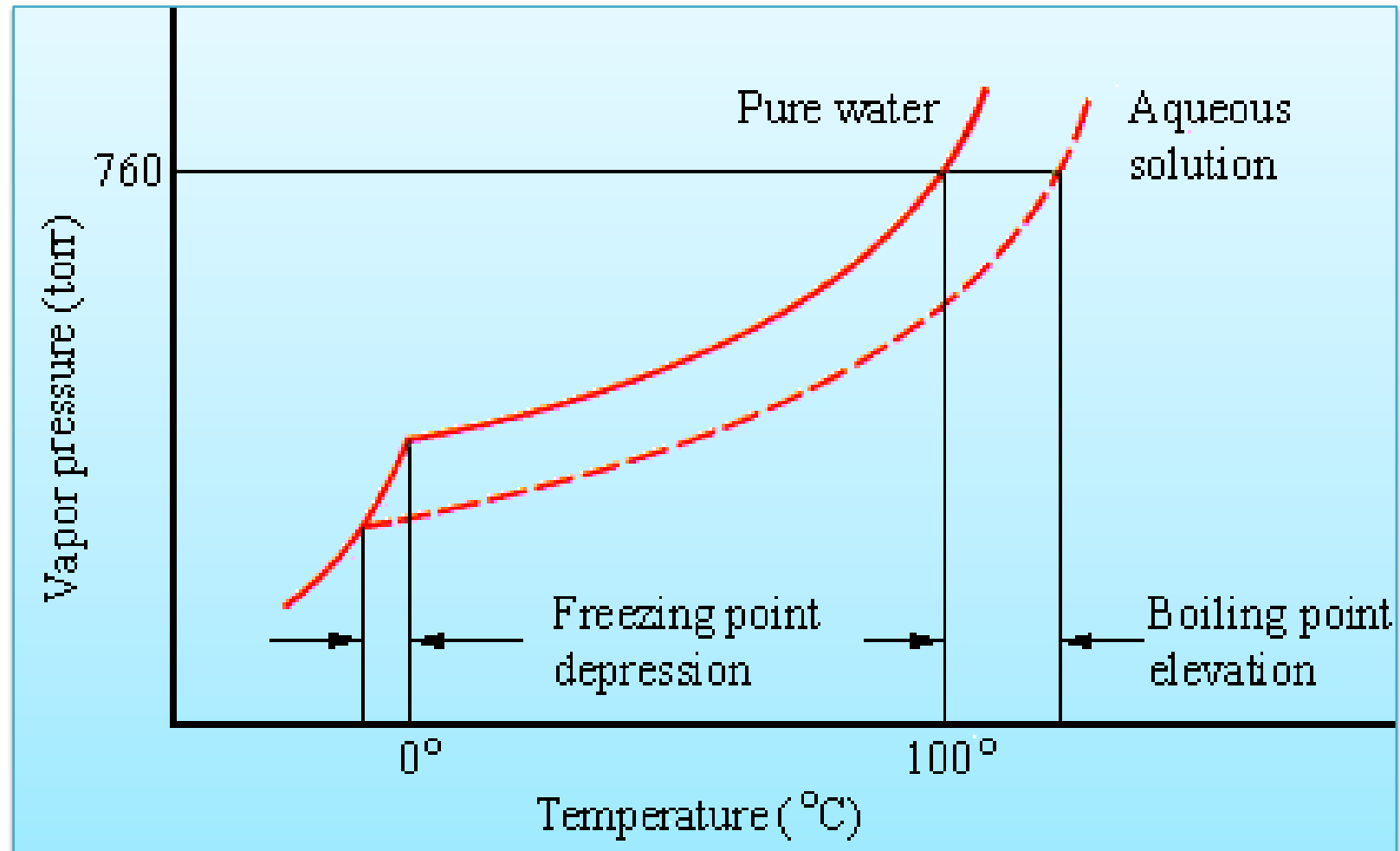
A solution is said to be ideal when it obeys Raoult's Law over all compositions and at all temperature.

A perfect dilute solution obeys Raoult's Law.

For an ideal solution-

- solute-solute
 - solvent-solvent &
 - solute-solvent interactions
- should be negligible.*

Colligative properties



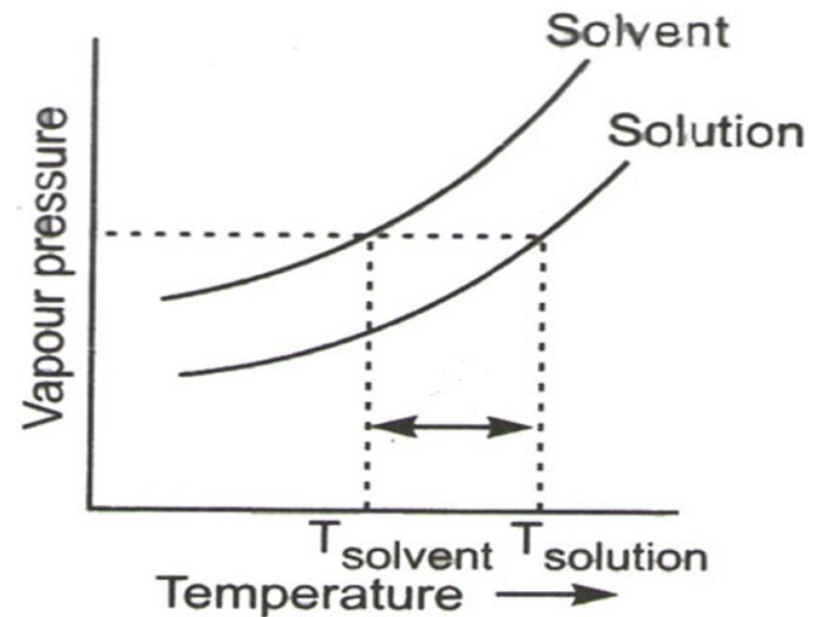
WHAT IS FREEZING POINT?

Freezing point of a liquid is defined as the temperature at which the liquid and solid forms are in equilibrium and the freezing point of a solution is the temperature at which the solution is in equilibrium with the pure crystalline solvent.

The depression of freezing point of a liquid by the addition of a non-volatile solute.

- The curve for the solid solvent is steeper than those for the pure solvent and solution.

- The curve for the solutions lies below that for the pure solvent.



Freezing Point Depression

- The freezing point of a 1-molal solution of a non electrolyte solute in water is found by experiment to be 1.86°C lower than the freezing point of water.
- When the solution is 2-molal the freezing point is lowered by 3.72°C .
- In fact, for any concentration of a non electrolyte solute in water, the decrease in freezing point can be determined using the value of $-1.86^{\circ}\text{C}/\text{m}$.
- This value is called the **molal freezing-point constant**.
- Freezing-point depression can be calculated by using the following equation.
- $\Delta T_f = K_f m$
- K_f is the freezing-point depression constant. m is the molality
- Each solvent has its own characteristic molal freezing-point constant.

ELEVATION OF BOILING POINT

- ➔ The addition of a non volatile solute lowers the vapour pressure and consequently elevates the boiling point.
- ➔ The vapour pressure of the solution will become equal to the atmospheric pressure at a higher temperature.
- ➔ In others word the boiling point of the solution will be higher than that of the solvent.
- ➔ The vapour pressure-temperature diagram(figure) of pure solvent and solution clearly explain the elevation of boiling point.

Osmotic Pressure

- **Semipermeable Membranes**
 - Allow the movement of some particles while blocking the movement of others
- **Osmosis**
 - The movement of solvent through a semipermeable membrane from the side of lower solute concentration to the side of higher solute concentration
- **Osmotic Pressure**
 - External pressure that must be applied to stop osmosis
- **Life Processes**
 - Cell membranes are semipermeable
 - Shrink when placed in solution of higher concentration

Applications??

Application of Colligative Properties (Molar Mass of solute from lowering of vapor pressure)

For a solution,

$$\frac{P^o - P}{P^o} = \frac{n}{n + N}$$

For a dilute solution,

$$\frac{P^o - P}{P^o} = \frac{n}{N}$$

$$\therefore \frac{P^o - P}{P^o} = \frac{w_2 / M_2}{w_1 / M_1} \quad w \text{ and } M \text{ are mass and molar mass}$$

Here, P^o and P are the vapor pressures of solvent and solution, respectively.

Suffix 1, 2 represent solvent and solute, respectively.

Application of Colligative Properties (Molar Mass of solute from depression of freezing point)

For a solution,

$$\Delta T_f = K_f m$$

Here, ΔT_f = Depression of freezing point; K_f = Depression of Freezing point constant or Cryoscopic constant; m = molality = mol/kg of the solvent

$$\therefore \Delta T_f = K_f \times \frac{(\text{mol})\text{solute}}{(1000\text{g})\text{solvent}}$$

$$\therefore \Delta T_f = K_f \times \frac{m_2 / M_2}{1000 \times m_1 / M_1}$$

Here, m and M stand for mass and molar mass

Suffix 1, 2 represent solvent and solute, respectively.

Application of Colligative Properties (Molar Mass of solute from elevation of boiling point)

For a solution,

$$\Delta T_b = K_b m$$

Here, ΔT_b = Elevation of boiling point; K_b = Elevation of boiling point constant or ebullioscopic constant; m = molality = mol/kg of the solvent

$$\therefore \Delta T_b = K_b \times \frac{\text{mole of solute}}{1000 \text{ g of solvent}}$$

$$\therefore \Delta T_b = K_b \times \frac{m_2 / M_2}{1000 \times m_1 / M_1}$$

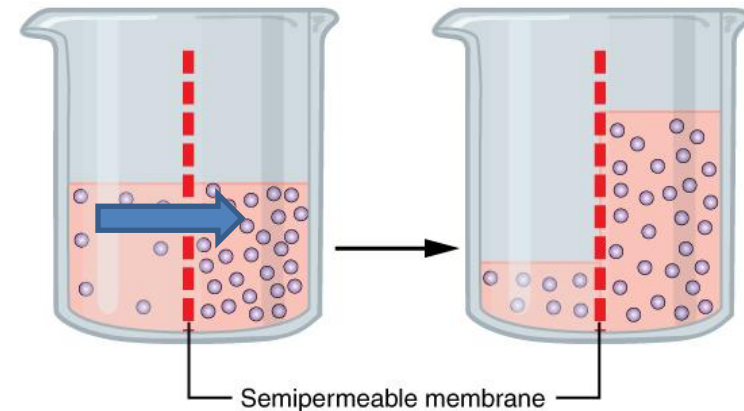
Here, m and M stand for mass and molar mass

Suffix 1, 2 represent solvent and solute, respectively.

Osmosis

Osmosis is the spontaneous net movement of solvent molecules through a semi-permeable membrane into a region of higher solute concentration, in the direction that tends to equalize the solute concentrations on the two sides.

The osmotic pressure is defined to be the minimum pressure required to maintain an equilibrium, with no net movement of solvent. Osmotic pressure is a colligative properties, meaning that the osmotic pressure depends on the molar concentration of the solute but not on its identity.



$$\Pi = mRT$$

Here, π = Osmotic pressure;
 M = mol/L; R = gas constant, and
 T = absolute temperature

What are the applications of osmosis and reverse osmosis?

Osmosis

- an important biological process

A cell is an aqueous solution surrounded by semipermeable membrane and outside the membrane is an aqueous solution

- If a solution has the same osmotic pressure as then cell, the solution is **isotonic**
- If the solution has a greater osmotic pressure than the cell, the solution is **hypertonic**
- If the solution has a smaller osmotic pressure than the cell, the solution is **hypotonic**

If a cell is place in a

- hypertonic solution, the solvent flows out of cell and the cell shrinks → **crenation**
- hypotonic solution, the solvent flows into the cell and the cell swells and burst → **hemolysis**

Colloids

- Dispersion of particle of one substance throughout another substance
- Dividing line between solutions and heterogeneous mixtures
- Dispersed particles are larger than molecules in a solution but not so large that the compounds of the mixture separate under the influence of gravity
- Examples: Fog, smoke, whipped cream, milk, paint, marshmallow, butter, ruby glass
- Particle size: 10\AA to 2000\AA (can not see without microscope)
- Particles are large enough to scatter light

Tyndall effect - scattering of light by colloidal particles

Types of Colloids

aerosols - liquid droplets (fog) or solid particles dispersed throughout a gas

emulsion - liquid droplets dispersed throughout another liquid (milk)

sol - solid particles dispersed in a liquid (biological fluids)

foam - gas in a liquid or solid (whipping cream)

Two major classes of colloids

1) hydrophilic colloid

- water-loving
- strong attraction between dispersed phase and water

2) hydrophobic colloid

- water-hating
- lack of attraction between dispersed phase and water
- unstable, aggregates into larger particles

Coagulation - process by which dispersed phase of a colloid is made to aggregate and separate from the continuous phase

examples of coagulation

curdling of milk - lactose ferments to lactic acid

delta formation - soil in river water meets concentrated ionic solution in the ocean

Colloids can have both major classes present in one substance

- one end is hydrophilic and the other end is hydrophobic
- in water the hydrophobic ends associate together while the hydrophilic ends associate with water molecules.

This process is known as forming micelles

micelles - a colloidal-sized particle formed in water by the association of molecules or ions that have a hydrophobic end and a hydrophilic end.

Soaps are colloids which form micelles