University of Science & Technology

**Faculty of Engineering – First year – Batch 31**

**Semester 1**

## General Chemistry

**Lecture 5**

# Colligative properties of Dilute Solutions

# Solutions

- **Solutions are homogeneous mixture of two or more components. The component that present in a larger quantity is known as solvent.**
- **Solvent determines the physical state in which solution exist. (solid-liquid- gas)**
- **One or more component present in the solution other than solvent are solutes.**

- **Liquid solution - binary solution:**

❖ **For example glucose dissolved in water**

**(solid dissolve in liquid.)**

❖ **Ethylene glycol and water (liquid in liquid).**

# Solubility

- **Solubility of substance is the maximum amount that can be dissolved in a given amount of solvent at specified temperature.**
- **A solution that has not reached its maximum solubility is called an unsaturated solution.**

  **A solution that has reached the maximum solubility is called a saturated solution.**

**Factors affecting solubility:**

- **Polarity of solute and solvent: “Like dissolves like” compound that have similar polarity are soluble in one another.**
- **Temperature : increasing temperature decreases the solubility of a gas in water.**

  **Most solids are more soluble at higher temperatures but important exceptions exist.**

- **Nonvolatile solute is substance that doesn't evaporate into gas at room temperature the one without a measurable vapor pressure. e. g. salt. sugar, urea.**

- **Concentration can be expressed as <u>dilute</u> if relatively very small amount of solute or <u>concentrated</u> if relatively very large amount of solute.**

# Colligative properties of Dilute Solutions

**Colligative properties** of solutions are properties that depend upon the concentration of solute but not upon the identity of the solute.

# Colligative properties

**Colligative properties include 4 physical properties:**

- **freezing point depression**
- **boiling point elevation**
- **vapor pressure lowering**
- **osmotic pressure.**

# Colligative Properties

**Freezing point depression:**

**The addition of nonvolatile solute to a solvent causes the freezing point to go down.**

**The freezing point depression, $T_f$, is directly proportional to the molality of the solute (m).**

$$\Delta T_f = K_f\ m \longrightarrow (1)$$

# Freezing point depression

$\Delta T_f = K_f \, m$

$K_f \equiv$ the proportionality constant depends on the nature of the solvent. (For example $K_f$ for water = 1.86 °C/m )

$\Delta T_f \equiv$ the decrease in freezing point.

$( T_{f\ solvent} - T_{f\ solution})$

# Colligative Properties

**Elevation of boiling point:**

**Addition of nonvolatile solute leads to elevation of the boiling point. Quantitatively the boiling point elevation is directly proportional to the concentration of the solute.**

$$\Delta T_b = K_b\ m \longrightarrow (2)$$

# Elevation of boiling point

**Where:**

**$K_b$ = proportionality constant . Its value depends on nature of solvent.**

*** The boiling point elevation constant($K_b$) for water is 0.512°C/m and its normal boiling point = 100.0°C.**

**$\Delta T_b$ (The change in boiling point)**

$$= T_{\text{b solution}} - T_{\text{b solvent}}$$

**m = molality of the solution(mol/kg solvent)**

# Colligative properties

**Vapor pressure lowering:**

**When nonvolatile solid is dissolved in a liquid, the vapour pressure of the solution becomes lower than the vapour pressure of the pure solvent.**

# Vapor pressure lowering

*** Lowering of vapour pressure of the solvents is governed by Raoults law.**

**Raoult's law states that the vapor pressure of a component of an ideal solution is equal to the mole fraction of the component times its vapor pressure when it is a pure substance.**

$$P_A = P^{\circ}_A \cdot X_A \longrightarrow (3)$$

# Vapor pressure lowering

**Where:**

**$P^{\circ}_{A}$ ≡ vapor pressure of the pure solvent(A).**

**$P_{A}$ ≡ vapor pressure of solvent(A) above the solution**

**$X_{A}$ ≡ the mole fraction of solvent.**

*** The Solution which obeys Raoult's law is called an ideal solution. If a solution does not obey Raoult's law, the solution is non-ideal.**

**Example 1**

**What is the freezing point of a 0.05 molal solution of non-electrolyte in water($K_f$ = 1.86 °C/m )?**

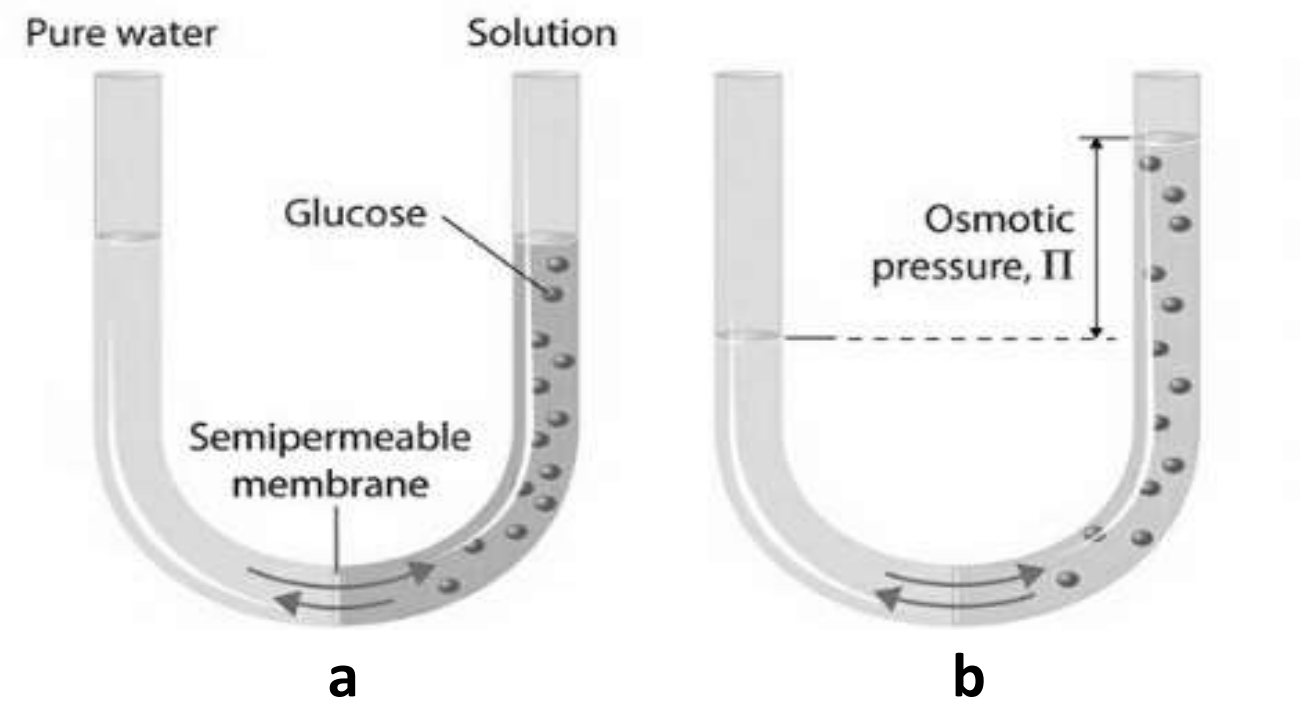
**Solution**

$\Delta T_f = K_f\ m$, **m = 0.05molal,** $K_f = 1.86°C\ m^{-1}$

$\Delta T_f = 1.86 \times 0.05 = 0.093°C$

$T_f = 0 - 0.093 = -0.093°C$

# Osmosis and Osmotic pressure



# Colligative properties

**Osmotic pressure:**

* **Osmosis**: refers to the movement of solvent molecules through a semipermeable membrane from a dilute to a concentrated solution.

* **Osmotic pressure**: is the pressure that is needed to stop osmosis.

# Osmotic pressure

* **Experimental measurements on dilute solutions have shown that osmotic pressure of a solution is directly proportional to the concentration of the solution and to its absolute temperature.**

# Osmotic pressure

$$\pi = \frac{nRT}{V} = MRT \longrightarrow (4)$$

$\pi \equiv$ osmotic pressure

M $\equiv$ molar concentration

R $\equiv$ gas constant

T $\equiv$ temperature of solution (K)

# Osmotic pressure

* **Osmosis** is important in biological system.

  Blood serum has an osmotic pressure of

  7.7 atm.

# Colligative Properties

**<u>The effect of electrolytes on colligative properties</u>:**

The effect of electrolytic solution on the colligative properties depends on the number of ions provided when the solute is completely ionized.

$NaCl \longrightarrow Na^{+} + Cl^{-}$ (2 ions)

$BaCl_2 \longrightarrow Ba^{+2} + 2Cl^{-}$ (3 ions)

* Although strong electrolytes are completely ionized in aqueous solution, the ions are not completely independent of each other.

Example 2 :

Calculate the osmotic pressure of a 0.300M solution of glucose, $C_6H_{12}O_6$ , in water that is used for intravenous infusion at body temperature 37°C (R = 0.082 atm. L. $mol^{-1}$ $K^{-1}$).

## Solution

Given: M= 0.300M; R= 0.082 atm. L. $mol^{-1}$ $K^{-1}$

T= 37°C +273= 310K ; substitute in equation:

$\pi$ = MRT ; the osmotic pressure of a 0.300M solution of glucose = 7.626atm

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