SOLUTIONS-3
COLLIGATIVE PROPERTIES

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SOLUTIONS: COLLIGATIVE PROPERTIES

- Properties of solutions are not the same as pure solvents.
- Number of solute particles will change vapor pressure (boiling pts) and freezing point.
- There are two kinds of solute: volatile and non volatile solutes – both behave differently.
- Raoult's Law: gives the quantitative expressions on vapor pressure:
  - VP will be lowered if solute is non-volatile: P is new VP, P^0 is original VP and X is mol fraction of solute.

$$P_1 = \chi_1 P_1^0$$

  - VP will the sum of VP solute and solvent if solute is volatile: X_A and X_B are mol fractions of both components.

$$P_T = \chi_A P_A^0 + \chi_B P_B^0$$

EXAMPLE: VAPOR PRESSURE

Calculate the vapor pressure of a solution made by dissolving 115 g of urea, a nonvolatile solute, [$(NH_2)_2CO$; molar mass = 60.06 g/mol] in 485 g of water at 25°C. (At 25°C, P_{H2O} = 23.8 mmHg)

$$P_{H_2O} = \chi_{H_2O} P^0_{H_2O}$$

$$mol_{H_2O} = 485\ g x \frac{mol}{18.02\ g} = 26.91\ mol$$

$$mol_{urea} = 115\ g\ x \frac{mol}{60.06\ g} = 1.915\ mol$$

$$\chi_{H_2O} = \frac{26.91\ mol}{26.91\ mol + 1.915\ mol} = 0.9336$$

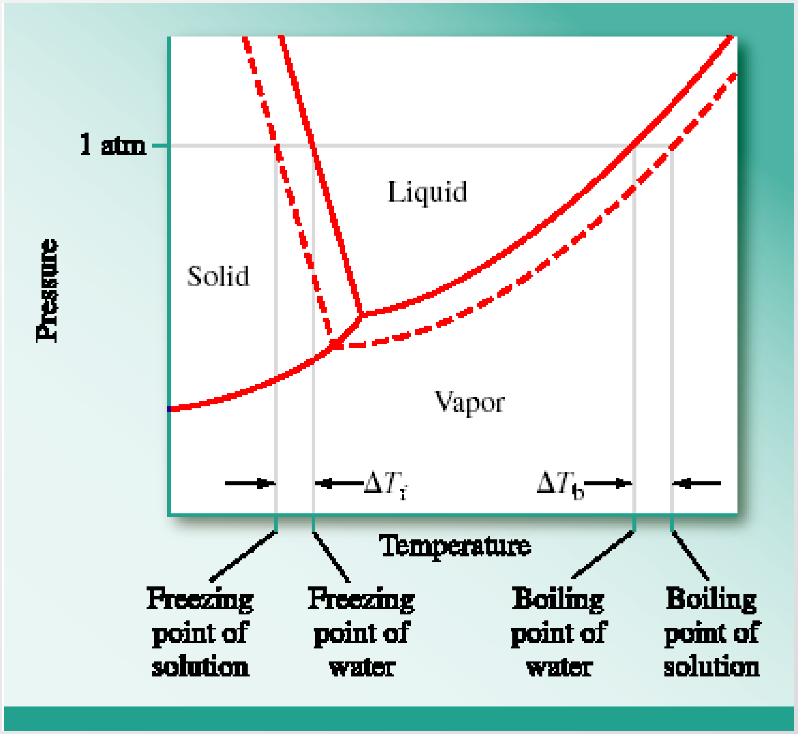
$$P_{H_2O} = 0.9392\ x\ 23.8\ mmHg = 22.2\ mmHg$$

BOILING POINT ELEVATION

- Boiling point of solvent will be raised if a non volatile solute is dissolved in it.
- Bpt. Elevation will be directly proportional to molal concentration.

$$\Delta T_b = K_b m$$

- K_b is molal boiling point elevation constant.

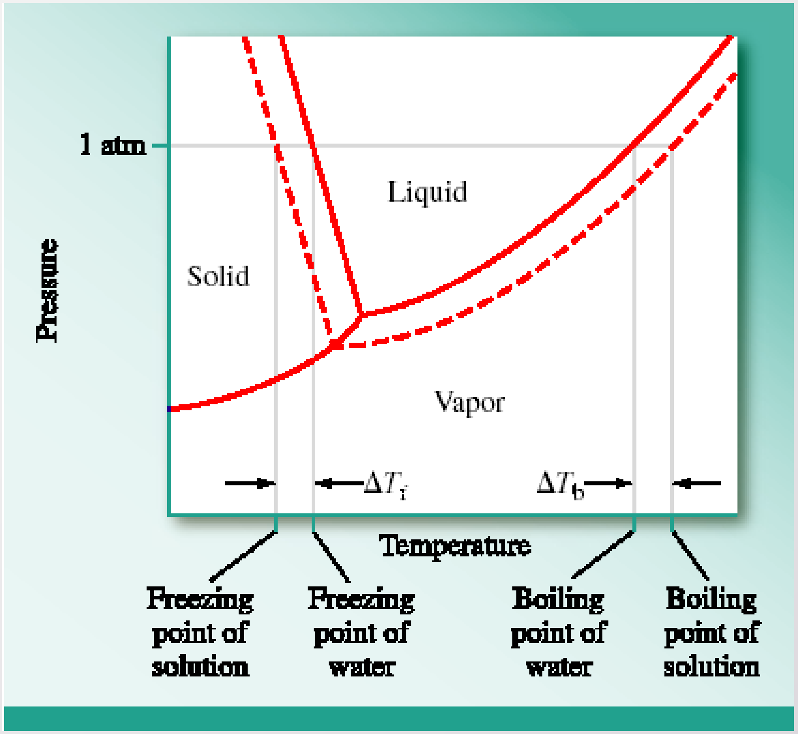


FREEZING POINT DEPRESSION

- The freezing point of a solvent will decrease when a solute is dissolved in it.
- Fpt. Lowering will be directly proportional to molal concentration.

$$\Delta T_f = K_f m$$

- K_f is molal freezing point depression constant.



FREEZING AND BOILING PT. CONSTANTS

Some freezing point depressions and boiling point elevations constants.

Solvent	Normal Boiling Point (°C)	K_b (°C/m)	Normal Freezing Point (°C)	K_f (°C/m)
Water	100.0	0.52	0.0	1.86
Benzene	80.1	2.53	5.5	5.12
Ethanol	78.4	1.22	−117.3	1.99
Acetic acid	117.9	2.93	16.6	3.90
Cyclohexane	80.7	2.79	6.6	20.0

EXAMPLE: FPT. AND BPT. CHANGES

Calculate a) the freezing point and b) the boiling point of a solution containing 268 g of ethylene glycol and 1015 g of water. (The molar mass of ethylene glycol ($C_2H_6O_2$) is 62.07 g/mol. K_b and K_f for water are 0.512°C/*m* and 1.86°C/*m*, respectively.)

Solution: find molality of solution and use the formulas to calculate changes.

$$\text{mol ethylene glycol} = 268\ \text{g} \times \frac{\text{mol}}{62.07\ \text{g}} = 4.318\ \text{mol}$$

$$m = 4.318\ \text{mol} \times \frac{1}{1015\ \text{g}} \times \frac{10^3\ \text{g}}{\text{kg}} = 4.254\ m$$

$$\Delta T_\text{f} = \frac{1.86^\circ\text{C}}{m}\ x\ 4.254\ m = 7.91^\circ\text{C}$$

$$7.91^\circ\text{C} = 0.00^\circ\text{C} - T_\text{f}$$

$$T_\text{f} = -7.91^\circ\text{C}$$

$$\Delta T_\text{b} = \frac{0.512^\circ\text{C}}{m}\ x\ 4.254\ m = 2.18^\circ\text{C}$$

$$2.18^\circ\text{C} = T_\text{b} - 100.00^\circ\text{C}$$

$$T_\text{b} = 102.18^\circ\text{C}$$

EXAMPLE: CALCULATION OF MOLAR MASS USING FPT. DEPRESSION

In a freezing-point depression experiment, the molality of a solution of 58.1 mg anethole in 5.00 g benzene was determined to be 0.0784 *m*. What is the molar mass of anethole?

Solution:

Strategy: Use molality to find moles of solute -> use mass of solute to find mm.

Solute mass = 58.1 mg = 0.0581 g

Solvent mass = 5.00 g = 0.005 Kg

m=0.0784mol/Kg;

mol of solute = 0.0784 mol/Kg x 0.005 Kg = 3.92 x 10^{-4} mol

Molar mass = g/mol

$$\text{Molar mass} = \frac{58.1 \times 10^{-3}\ \text{g}}{3.92 \times 10^{-4}\ \text{mol}} = 148\ \text{g/mol}$$

EXAMPLE: CALCULATION OF MOLAR MASS USING BOILING POINT ELEVATION

An 11.2-g sample of sulfur was dissolved in 40.0 g of carbon disulfide. The boiling-point elevation of carbon disulfide was found to be 2.63°C. What is the molar mass of the sulfur in the solution? What is the formula of molecular sulfur? (K_b, for carbon disulfide is 2.40°C/*m*.)

Solution:

Strategy: calculate molality -> calculate moles of solute -> find mm using g solute.

$$\Delta T_b = K_b m$$

$$m = \frac{\Delta T_b}{K_b} = \frac{2.63°C}{2.40 \frac{°C}{m}} = 1.096\ m$$

$$m = \frac{\text{mol solute}}{\text{kg solvent}}$$

$$\text{mol solute} = m \times \text{kg solvent}$$

$$= 1.096\ m \times 0.0400\ \text{kg}$$

$$= 0.04383\ \text{mol}$$

$$\text{Molar mass} = \frac{11.2\ \text{g}}{0.04383\ \text{mol}} = 255.5\ \text{g/mol}$$

empirical formula of sulfur = S

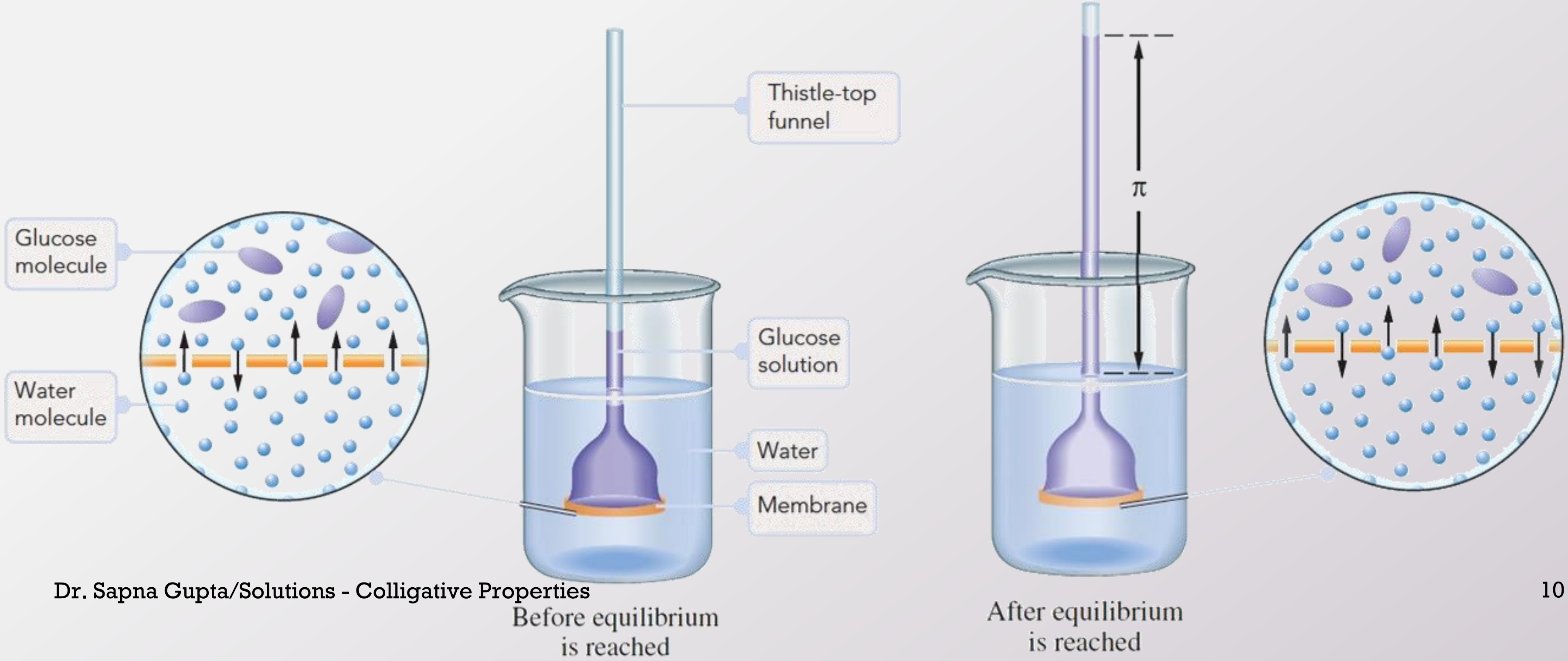
and atomic mass is 32.065 g/mol

$$n = \frac{255.5}{32.065} \approx 8$$

Sulfur = S_8

OSMOSIS

- Osmosis is the movement of solvent molecules through a semipermeable membrane.
- Osmotic pressure, π, is the pressure that just stops osmosis. Osmotic pressure is a colligative property of a solution.
- $\pi = MRT$ (R = gas const.; M = molarity and T = temp in Kelvin)



OSMOSIS – SOLUTIONS OF ELECTROLYTES

- Dissociation of strong and weak electrolytes affects the number of particles in a solution.
- van't Hoft factor (i) – accounts for the effect of dissociation

$$i = \frac{\text{actual number of particles in solution after dissociation}}{\text{number of formula units initially dissolved in solution}}$$

- The modified equations for colligative properties are:

$$\Delta T_{\mathrm{f}} = iK_{\mathrm{f}}m$$
$$\Delta T_{\mathrm{b}} = iK_{\mathrm{b}}m$$
$$\pi = iRTM$$

EXAMPLE: VAN'T HOFF FACTOR

The freezing-point depression of a 0.100 *m* $MgSO_4$ solution is 0.225°C. Determine the experimental van't Hoff factor of $MgSO_4$ at this concentration.

Solution:

One way:

Calculate for i directly

$$\Delta T_f = iK_f m$$

$$0.225^oC = i\,\frac{1.86^oC}{m}\ x\ 0.100\ m$$

$$i = 1.21$$

Second way:

Compare the freezing points

$$\Delta T_f = \frac{1.86^oC}{m}\,x\,0.100\ m = 0.186^oC$$

$$i = \frac{0.225^oC}{0.186^oC} = 1.21$$

EXAMPLE: CALCULATION OF MOLAR MASS USING OSMOTIC PRESSURE

A solution made by dissolving 25.0 mg of insulin in 5.00 mL of water has an osmotic pressure of 15.5 mmHg at 25°C. Calculate the molar mass of insulin. (Assume that there is no change in volume when the insulin is added to the water and that insulin is a nondissociating solute.)

Solution:

Strategy: calculate Molarity -> calculate moles -> calculate molar mass

$$\pi = 15.5 \text{ mmHg x } \frac{\text{atm}}{760 \text{ mmHg}} = 2.039\text{x}10^{-2}\text{atm} \qquad \text{T} = 25+273 = 298\text{K}$$

$\pi = MRT$

$$M = \frac{\pi}{RT} = 2.039\text{x}10^{-2}\text{atm x } \frac{\text{mol}\cdot\text{K}}{0.08206 \text{ L}\cdot\text{atm}} x \frac{1}{298 \text{ K}}$$

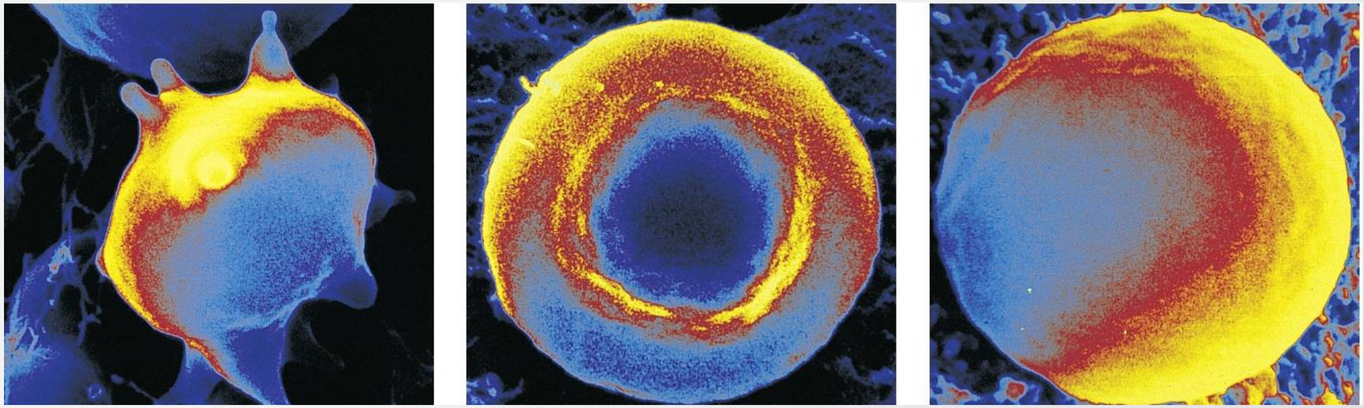
$$M = 8.338 \text{ x } 10^{-4} M = \frac{8.338 \text{ x } 10^{-4}\text{mol}}{\text{L}}$$

$$\text{mol} = \frac{8.340 \text{ x } 10^{-4}\text{mol}}{\text{L}} \text{ x } 5.00 \text{ mL x } \frac{10^{-3}\text{L}}{\text{mL}} = 4.169 \text{x}10^{-6}\text{mol}$$

$$\mathcal{M} = 25.0 \text{ mg x } \frac{10^{-3}\text{g}}{\text{mg}} \text{ x } \frac{1}{4.169 \text{x}10^{-6}\text{mol}} = \frac{6.00 \text{ x } 10^{3}\text{g}}{\text{mol}}$$

OSMOSIS - APPLICATION

- Osmosis is key in water transport in blood and in water transport in plant.



A

Hypertonic solution

Water flows out of cell.

Crenation

B

Isotonic solution

C

Hypotonic solution

Water flows into cell.

Hemolysis

COLLOID

- There are two kinds of solutions: true solution (homogeneous solution) and colloids: which is a dispersion of particles in a solvent.
- It is an interemediate between homo and heterogeneous mixture.
- Particle size – 10^3-10^6 pm
- Examples are: aerosols, foam, emuslions, sols, gels etc.

Dispersing Medium	Dispersed Phase	Name	Example
Gas	Liquid	Aerosol	Fog, mist
Gas	Solid	Aerosol	Smoke
Liquid	Gas	Foam	Whipped cream, meringue
Liquid	Liquid	Emulsion	Mayonnaise
Liquid	Solid	Sol	Milk of magnesia
Solid	Gas	Foam	Styrofoam
Solid	Liquid	Gel	Jelly, butter
Solid	Solid	Solid sol	Alloys such as steel, gemstones (glass with dispersed metal)

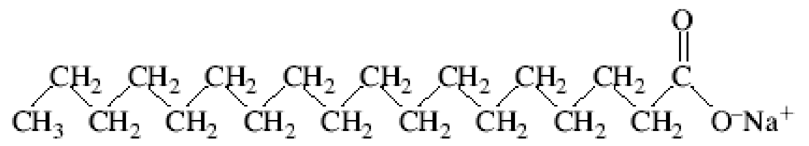
TYNDALL EFFECT

- One can tell there is a true solution or colloid by shining light through the solution.
- A true solution will not show light scattering.

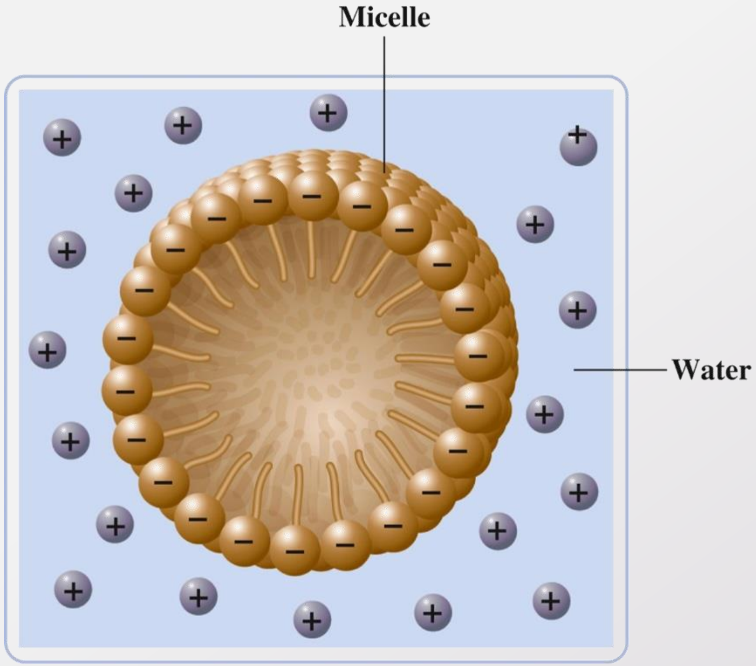
- A good example of Tyndall effect is fog.
- Protiens also form colloids in water.
- Coagulation is a process when a colloid is aggregated (precipitated) e.g. curdled milk.

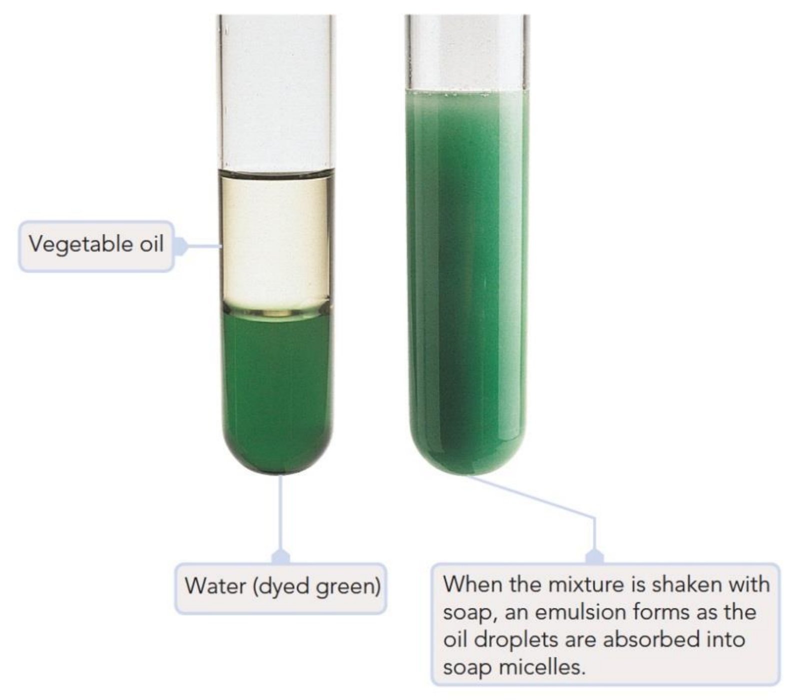
MICELLES

- These are formed when a molecule has both hydrophilic (water loving) and hydrophobic (water fearing) components.
- Classic e.g. is soap.



Sodium stearate ($C_{17}H_{35}COO^-Na^+$)





KEY CONCEPTS

- Solutions
- Raoult's Law
- Freezing point depression
- Boiling point elevation
- Osmosis
- Colloids