# Properties of Solutions

## Chapter 11

**Solution Composition**
(Review)

Molarity (M) $M = \frac{\text{mol solute}}{\text{Liter of Solution}}$ (Also=mol= M x L)

Mass Percent mass percent $= \frac{\text{g of solute}}{\text{g of solution}} \times 100$

Mole Fraction ($\chi$, chi)

- Ratio number of moles of one component to the total number of moles in a solution.
- For a solution made of only substances A + B.

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

**Molality (m)**

-the number of moles of solute per kilogram of solvent

ex. 11.2
Mass %, m, $\chi$, of $H_2SO_4$ which is 3.75 M and D=1.2309 g/mL

**Solubility**

- the extent to which one substance dissolves in another substance
- the enthalpy change associated with the formation of a solution is the "Heat of Solution" ($\Delta H_{SOLN}$)
- $\Delta H_{SOLN}$ is the sum of the ΔH's involved in forming the solution:

1. Break the solute into individual components ($\Delta H_1$)
   -an endothermic process
2. Overcome molecular attractions between solvent molecules to provide space for the solute particles ($\Delta H_2$)
   -endothermic
3. Attraction between solute and solvent to form the solution ($\Delta H_3$)
   -exothermic

$\Delta H_{soln} = \Delta H_1 = \Delta H_2 = \Delta H_3$

-for $\Delta H_{soln}$:

- A negative $\Delta H_{soln}$ predicts that the solution process should occur
  (Lower level of energy + higher entropy)
- processes with small positive $\Delta H_{soln}$ should also occur
  (Greater Δs more important than + ΔH)

**Factors Affecting Solubility**

1. Structure
   - "Like dissolves like"
   - The closer the solvent and solute are in polarity, the more likely a solution will occur

2. Pressure
   - Does not affect the solubilities of solids and liquids
   - For gases:
     -the solubility of a gas is directly proportional to the partial pressure of that gas above the solution
     -increasing the partial pressure of a gas above a solution increases the solubility of that gas

3. Temperature
   - For solids dissolving in $H_2O$
     -dependence of the solids solubility on temperature must be determined experimentally
     -increasing the temperature increases the solubility of most solids
   - For gases dissolving in $H_2O$:

-increasing the temperature decreases the solubility of gases in $H_2O$
-with greater KE the gas move easily, escapes from the solution

## Colligative Properties

- Properties of a solution that change due to the presence **of solute** particles (**nonvolatile solutes**)
- Amount of change in the property depends on **the number** of solute particles present
- The **identity** of the solute particles is **not important**
- The properties are:
  1. Vapor Pressure
  2. Boiling Point
  3. Freezing Point
  4. Osmotic Pressure

Vapor Pressure

- The pressure of a nonvolatile solute LOWERS the vapor pressure of the solvent
- The surface of the solution is **less than 100%** solvent molecules so less solvent molecules escapes (=less vapor pressure)

## Raoult's Law

- The vapor pressure of a solution is **directly proportional** to the mole fraction of **solvent** in the solution
- $P_{soln} = \chi_{solvent} P_{solvent}$
- $P_{soln}$ = (observed) vapor pressure of the solution
- $\chi_{solvent}$ = mole fraction of the solvent
- $P^0_{solvent}$ = vapor pressure of the pure solvent
  - o

Ex. 11.5 158.0g of sucrose (mol wt = 342.3) is dissolved in 643.5 $cm^3$ of $H_2O$ at 25° C. $D_{H2O}$ = .9971 g/$cm^3$ and the Vapor Pressure = 23.76 torr at 25° C. What is the vapor pressure of the solution?

Ex: 20.0g of Urea is dissolved in 125g $H_2O$ at 25° C (Vapor Pressure $H_2O$ = 23.76 torr at 25° C) $P_{soln}$ is observed to be 22.67 torr. Calculate the molecular weight of urea.

Ex. 11.6

35.0g of solid $Na_2SO_4$ (mol wt = 142) is dissolved in 175g of $H_2O$ at 25 °C. (at 25° C Vapor Pressure of $H_2O$ = 23.76 torr). What is the vapor pressure exerted by the resulting solution?

**<u>Van't Hoff factor</u>**- (Jacobus Van't Hoff) 1901 first Nobel Prize for Chemistry. (Dutch)

-the number of particles that result from dissolving one mole of an electrolyte (Ionic compounds,

Strong Acids, Strong Bases)

- represented in equations by <u>"*i*"</u>
- the actual factor is not a whole number because of "ion pairing" in which some of the ions are connected in the solution at any particular time, thus readuding the total number of particles in the solution.

**<u>Boiling Point Elevation</u>**

-presence of a nonvolatile solute elevates the boiling point of a solution.

-Since vapor pressure decreases because of the solute, the temperature required to get a vapor pressure equal to the external pressure increases.

$K_b$ = boiling point elevation constant

-the number °C each mole of particles present per kilogram of solvent (m) raises the boiling point of the solution.

- For $H_2O$, $K_b$ = 0.51 °C/M (table 11.5 p528)

Therefore:

$\Delta T = K_b m$

18.00g of glucose is dissolved in 150.0g of $H_2O$. The boiling point of the solution is 100.34 C. What is the molecular weight of glucose? $K_b$=0.51 C/m

-for strong electrolytes

$\Delta T = iK_b m$

i= the number of moles of particles produced by the dissociation of the solute

ex. $NaCl_{(s)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)}$     i=2

**Freezing Point Depression**

-the presence of a solute *DECREASES* the freezing point of a solution

$K_f$ = the freezing point depression constant

-the number of C° each mole solute particles present per kilogram of solvent (m) lowers the freezing point of the solution

-for $H_2O$: $K_f$ = 1.86 C/m

$\Delta T = K_f m$

-for electrolytes

$\Delta T = iK_f m$

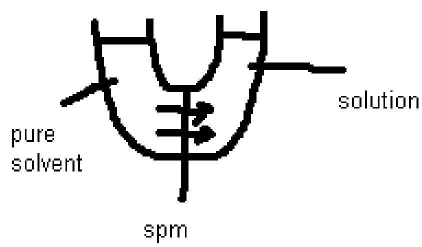
Ex. 11.9

What mass of ethylene glycol ($C_2H_6O_2$, 62.1 g/mol) must be added to 10.0L of $H_2O$ to produce a solution that freezes at -23.3 C?    (assume $D_{H20}$=1 g/mol)

11.10
0.546g of Thyroxine (a hormone that controls metabolism) is dissolved in 15.0g of benzene ($C_6H_6$). The solutions freezing point lowered by 0.240 C by the thyroxine. What is the molecular weight of thyroxine? (for $C_6H_6$, $K_f$ = 5.12 C/m, Table 11.5 p 454)

**<u>Osmotic Pressure</u>**

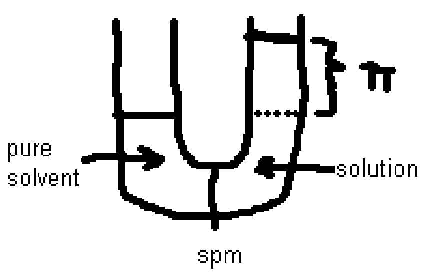
Osmosis- the flow of a solvent into a solution through a semi-permeable membrane (allows solvent but not solute particles to pass through it.)




-Solute particles cannot penetrate the semi-

permeable membrane

-Solute particles block solvent molecules form




-Theme is a net increase in the volume of the solution until the extra pressure is enough to stop the flow of solvent through the semi-permeable membrane.

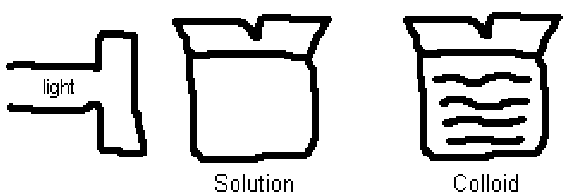
-This pressure is the "Osmotic pressure" (π)

$$\pi = MRT$$

π = osmotic pressure in atm
M = molarity of the solution
R = gas constant, .0821 L atm · $(\text{mol K})^{-1}$
T = Temperature in Kelvin

Ex. 11.11
$1.00 \times 10^{-3}$g of a protein are dissolved in enough $H_2O$ to make 1.00mL of solution. The osmotic pressure is measured to be 1.12 torr at 25.0 C. What is the molecular weight of the protein?

**<u>Colloids (also called colloidal dispersions)</u>**
-particles larger than particles in a solution are suspended in some medium.
-exhibit the "Tyndall Effect" (John Tyndall, British Physicist 1820-1893)
-the particles are large enough to scatter light as it passes through the colloid.




-the light is visible in the colloid

Ex. Headlights in fog.

**<u>Types of colloids</u>**

| | | |
|---|---|---|
| 1) Aerosol | - liquid in a gas | Ex. Fog |
| | - Solid in a gas | Ex. Smoke |
| 2) Foam | - gas in a liquid | Ex. Whipped Cream |
| | | Ex. Shaving Cream |
| 3) Emulsion | - liquid in a liquid | Ex. Milk |
| | | Ex. Mayonnaise |
| 4) Sol | - solid in a liquid | Ex. Jello |
| | | Ex. Paint |