Chapter 11 – Properties of Solutions

11.1 Solution Composition
    A. Molarity

        1. $Molarity(M) = \dfrac{moles\ \ solute}{liters\ \ of\ \ solution}$

    B. Mass Percent

        1. $Mass\ \ percent = \left(\dfrac{mass\ \ of\ \ solute}{mass\ \ of\ \ solution} \right) \times 100$

    C. Mole Fraction

        1. $Mole\ \ fraction\ \ of\ \ componentA = x_A = \dfrac{n_A}{n_A + n_B}$

    D. Molality

        1. $Molality = \dfrac{moles\ \ of\ \ solute}{ki\log ram\ \ of\ \ solvent}$

    E. Normality

        1. $Normality = \dfrac{equivalents}{liter\ \ of\ \ solution}$
        2. Equivalents of acids and bases
            a. Mass that donates or accepts a mole of protons
        3. Equivalents of oxidizing and reducing agents
            a. Mass that provides or accepts a mole of electrons

11.2 The Energies of Solution Formation
    A. "Like Dissolves Like"
        1. Polar molecules and ionic compounds tend to dissolve in polar solvents
        2. Nonpolar molecules dissolve in nonpolar compounds
    B. Steps of Solution Formation
        1. Breaking up the solute into individual components (expanding the solute)
            a. Endothermic
        2. Overcoming intermolecular forces in the solvent to make room for the solute (expanding the solvent)
            a. Endothermic
        3. Allowing the solute and solvent to interact to form the solution
            a. Often exothermic
    C. Enthalpy (Heat) of Solution
        1. $\Delta H_{sol'n} = \Delta H_{step1} + \Delta H_{step2} + \Delta H_{step3}$
        1. $\Delta H_{sol'n}$ may have a positive sign or a negative sign
        3. Enthalpy (Heat) of Hydration, ΔH_{hyd}
            a. Include ΔH of step 2 and step 3

D. Factors Favoring the Solution Process
    1. Negative value for $\Delta H_{sol'n}$
    2. Increase in entropy
    3. For positive values of $\Delta H_{sol'n}$ it is the increase in entropy that outweighs the increase in energy and causes the solution process of occur

11.3 Factors Affecting Solubility
  A. Structure Effects
    1. Polar (hydrophilic) dissolves in polar
      a. Water soluble vitamins
    2. Nonpolar (hydrophobic) in nonpolar
      a. Fat soluble vitamins
  B. Pressure Effects
    1. Henry's Law
      a. The amount of a gas dissolved in a solution is directly proportional to the pressure of the gas above the solution
      b. $P = kC$
        (1) P = partial pressure of the gaseous solute above the solution
        (2) C = concentration of the dissolved gas
        (3) k = constant characteristic of a particular solution
      c. Henry's Law works best for dilute solutions of gases that do not dissociate or react with the solvent
  C. Temperature Effects
    1. Solids
      a. Increases in temperature <u>always</u> cause dissolving to occur more rapidly
      b. Increases in temperature <u>usually</u> increases solubility (the amount that can be dissolved)
    2. Gases
      a. Solubility of gases <u>always</u> decreases with increasing temperature

11.4 The Vapor Pressure of Solutions
  A. Nonvolatile Solutes
    1. Nonvolatile electrolytes lower the vapor pressure of a solute
      a. Nonvolatile molecules do not enter the vapor phase
      b. Fewer molecules are available to enter the vapor phase
  B. Raoult's Law
    1. $P_{so\ln} = X_{solvent}P^0_{solvent}$ where $X_{solvent}$ is the mole fraction of the solvent in the solution
      a. a linear equation (y = mx)
    2. Molar mass of a solute can be calculated from experimental results for vapor pressure lowering
  C. Ionic solutes
    1. Dissociation of ionic compounds has nearly two, three or more times the vapor pressure lowering of nonionic (nonelectrolyte) solutes.

D. Non-ideal Solutions
    1. Liquid-liquid solutions in which both components are volatile
    2. Modified Raoult's Law:
$$P_{TOTAL} = P_A + P_B = X_A P_A^0 + X_B P_B^0$$
        a. P^0 is the vapor pressure of the pure solvent
        b. P_A and P_B are the partial pressures
E. Ideal Solutions
    1. Liquid-liquid solution that obeys Raoult's law
        a. No solution is perfectly ideal, though some are close
    2. Negative deviations from Raoult's law (lower than predicted vapor pressure for the solution)
        a. Solute and solvent are similar, with strong forces of attraction
        b. $\Delta H_{sol'n}$ is large and negative
    3. Positive deviations from Raoult's law (higher than predicted vapor pressure for the solution)
        a. Solute and solvent are dissimiliar, with only weak forces of attraction
        b. Particles easily escape attractions in solution to enter the vapor phase

11.5 Boiling Point Elevation and Freezing-Point Depression
A. Colligative Properties
    1. Properties dependent on the <u>number</u> of solute particles but not on their <u>identity</u>
        a. Boiling-Point elevation
        b. Freezing-Point depression
        c. Osmotic Pressure
B. Boiling-Point Elevation
    1. Nonvolatile solutes elevate the boiling point of the solvent
$$\Delta T = K_b m_{solute}$$
        a. ΔT is the boiling point elevation
        b. K_b is the molal boiling point elevation constant of the solvent
        c. m_{solute} is the molality of the solute in the solution
C. Freezing-Point Depression
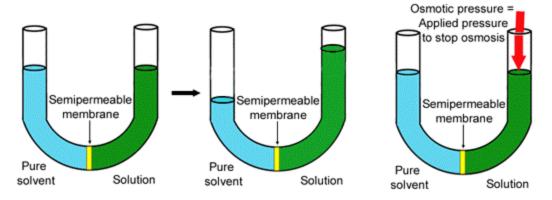   1. Solutes depress the freezing point of the solvent
$$\Delta T = K_f m_{solute}$$
        a. ΔT is the freezing point depression
        b. K_f is the molal freezing point depression constant of the solvent
        c. m_{solute} is the molality of the solute in the solution

11.6 Osmotic Pressure
   A. Osmosis
      1. The flow of solvent molecules into a solution through a semipermeable membrane

   B. Osmotic Pressure
      1. The pressure necessary to keep water from flowing across a semipermeable membrane
      2. Osmotic pressure can be used to characterize solutions and determine molar masses

$$\pi = MRT$$

         a. π is osmotic pressure in atmospheres
         b. M is the molarity of the solution
         c. R is the gas law constant
         d. T is the Kelvin temperature
   C. Dialysis
      1. Transfer of solvent molecules as well as small solute molecules and ions
   D. Isotonic Solutions
      1. Solutions that have the same osmotic pressure
   E. Osmotic Pressure and Living Cells
      1. Crenation
         a. Cells placed in a hypertonic solution lose water to the solution, and shrink
      2. Hemolysis
         a. Cells placed in a hypotonic solution gain water from the solution and swell, possibly bursting
   F. Reverse Osmosis
      1. External pressure applied to a solution can cause water to leave the solution
         a. Concentrates impurities (such as salt) in the remaining solution
         b. Pure solvent (such as water) is recovered on the other side of the semipermeable membrane

11.7 Colligative Properties of Electrolyte Solutions
    A. van't Hoff factor i:

    1. $$i = \frac{moles \quad of \quad particles \quad in \quad solution}{moles \quad of \quad solute \quad dissolved}$$

    2. For ionic compounds, the expected value of i is an integer greater than 1
            a. NaCl, $i = 2$
            b. $BaCl_2$, $i = 3$
            c. $Al_2(SO_4)_3$, $i = 5$
    B. Actual values of i
        1. Values of i are less than expected due to ion pairing (clustering)
        2. Refer to table11.6
        3. Values of i are closer to the expected the more dilute the solution becomes
    C. Incorporation of van't Hoff factor in Problem Solving
        1. Boiling-elevation and freezing-point depression
                a. $\Delta T = imK$
        2. Osmotic pressure
                a. $\pi = iMRT$

11.8 Colloids
    A. Colloidal Dispersions (Colloids)
        1. Tiny particles suspended in some medium
        2. Particles range in size from 1 to 1000 nm.
    B. Tyndall Effect
        1. Scattering of light by particles
                a. Light passes through a solution
                b. Light is scattered in a colloid

Table 11.7 Types of Colloids			
Examples	Dispersing Medium	Dispersed Substance	Colloid Type
Fog, aerosol sprays	Gas	Liquid	Aerosol
Smoke, airborne bacteria	Gas	Solid	Aerosol
Whipped cream, soap suds	Liquid	Gas	Foam
Milk, mayonnaise	Liquid	Liquid	Emulsion
Paint, clays, gelatin	Liquid	Solid	Sol
Marshmallow, polystyrene foam	Solid	Gas	Solid foam
Butter, cheese	Solid	Liquid	Solid emulsion
Ruby glass	Solid	Solid	Solid sol