Equilibrium

I. Equilibrium - a state of balance between two opposing reactions (physical or chemical) - concentration of the reactants and products remain constant
   A. Equilibrium reactions are reversible reactions
   B. Equilibrium is dynamic - continually moving
      1. Interaction of reactants in one direction is balanced by interaction of products in the other direction.
   C. Factors affecting the equilibrium point
      1. temperature
      2. changing concentrations of reactants or products
      3. pressure (affects gases only)

II. Phase Equilibrium - in a closed system equilibrium can be reached between the solid, liquid and gas phases
   A. Solution Equilibrium Gases in Liquids - equilibrium is reached between the gas in the liquid and the gas above the liquid (must be closed system)
      1. Temperature increase - decreases gas solubility
      2. Temperature decrease - increases gas solubility
      3. Pressure increase - increases gas solubility
      4. Pressure decrease - decreases gas solubility
   B. Solids in Liquids - equilibrium is reached when the saturation point is reached
      1. Solubility - concentration of a solute in a saturated solution
      2. maximum mass of the solute dissolved in a given volume of solvent under specified conditions

III. Reactions which go to completion
   A. Removal of the product from the equilibrium system
   B. formation of a gas (open system)
   C. formation of a precipitate (insoluble product)
   D. formation of an unionized product (ex. Water)

IV. ***Law of Chemical Equilibrium***
   A. ***Law of Chemical Equilibrium - at constant temperature, the concentration of the products, divided by the concentration of the reactants is a constant (K_{eq}) (only include (g) or (aq) in the calculation)***
      1. ***Concentrations are measured in moles per liter - written [ ]***
         a. ***Products / Reactants***
      2. ***ex. 2A + B à 3C + 2D would be written:***
         a. ***(the power of each concentration is derived from its coefficient)***
         b. ***$[C]^3 [D]^2 / [A]^2 [B]$***
   B. ***Concentration of solid or liquid is constant (and included in the constant)***
      1. ***Equilibrium Constants***
         a. ***Keq = constant for all forms of chemical reactions***
         b. ***Ksp = for solubility of solids***
            1. ***When calculating K_{sp} only include (g) or (aq) in the calculation***
         c. ***Ka = for acids***
         d. ***Kb = for bases***
         e. ***Kw = for ionization of water***

C. ***At any given temperature the constant changes for a substance***
   1. ***Temperature is the only factor which changes the Keq***
   2. ***Magnitude of K determines the extent of the reaction***

D. ***Keq = 1.0 X 100 the reactants and products are in equilibrium***
   1. ***Keq > 1.0 X 10^0 the products are favored***
      a. ***(ex. Keq = 1.7 X 105)***
   2. ***Keq < 1.0 X 10^0 the reactants are favored***
      a. ***(ex. Keq = 4.2 X 10-4)***

V. Le Chatelier's Principle - When a system at equilibrium is subjected to a stress (a change in concentration of a reactant, in temperature, or in pressure), the equilibrium will shift in the direction that tends to counteract the effect of the stress
   1. Concentration
   2. Increase in concentration of reactant
   3. increases product

A. Decrease in concentration of product
   1. reduces reactants and produces more product

B. Common Ion Effect - addition of a common ion that is soluble will cause the formation of more product (one of the reactants is increased)
   1. ex. Ag (aq) + Cl (aq) à AgCl
   2. Addition of H + Cl shifts the equilibrium to the right, forming more AgCl

C. Temperature
   1. Increase in temperature - shifts equilibrium to endothermic reaction (shift away from the energy side)
      a. ex. A + B à C + D + kcal
      b. equilibrium shift (extra heat is absorbed)
   2. Decrease in temperature - shifts equilibrium to exothermic reaction (shift to the energy side)
      a. ex. A + B + kcal à C + D equilibrium shift (causes release of heat)

D. Pressure
   1. Increase in pressure - shifts reaction to the side with the least number of moles
      a. ex. 1A + 3B à 2C creates shift to the right
   2. Decrease in pressure - shifts reaction to the side with the greatest number of moles.

E. Effect of Catalysts
   1. increases rate of forward and reverse reactions (no affect on equilibrium)
      a. causes equilibrium to be reached sooner