Liquids & Solids

I. Liquid – form of matter that has a definite volume and takes the shape of its container.
- A. Application of KMT
  1. liquid particles are closer together than gas and have a lower kinetic energy
  2. attractive forces between particles is greater than that of a gas
  3. IMF's determine the temperature at which condensation or liquifactiion occurs dependent upon the H-bonding, dipole dipole attractions or VanderWaal's (London Dispersion) forces acting upon the substance
- B. Pressure changes have little or no effect on liquids
- C. Cohesion – ability of a liquid to be attracted to other molecules of itself
- D. Adhesion – ability of a liquid to be attracted to molecules of another substance
  1. Capillary action – ability of a liquid to move up a tube of a solid substance due to IMF's

II. Boiling Point and Melting (freezing) Point
- A. Boiling Point - temperature at which a substance changes phase between liquid and gas at a particular pressure
  1. ex. water can boil at various temperatures depending upon the pressure
     (>1Atm = higher boiling point, <1Atm = lower boiling point)
  2. Normal Boiling Point = vaporization at 1Atm (ex. water is 100°C at 1Atm)
- B. Melting (freezing) Point - temperature at which a substance makes a phase change between the liquid and solid phases
  1. Normal Melting Point = phase change at 1Atm (ex. water is 0°C at 1Atm)
- C. Evaporation - process in which a liquid changes to a gas <u>at the surface of the liquid</u>
  1. happens at any temperature in liquid phase (forms a **vapor)**
     a. Increasing rate of evaporation
        1. raise temperature of liquid
        2. increase surface area
        3. air currents over surface to carry away molecules
  2. tends to lower the temperature of the liquid
- D. Boiling - liquid changes to a gas <u>throughout the liquid</u>
  1. <u>temperature at which the vapor pressure is equal to the pressure on the surface of a liquid</u>
     a. low pressure - low boiling temperature
     b. high pressure - high boiling temperature
  2. Different substances have different boiling points (due to different vapor pressures)
- E. Vapor Pressure - the vapor in equilibrium with its liquid (boiling points at different pressures)
  1. Reducing the pressure will allow a liquid to boil at a lower temperature *****Table G in the reference tables***
  2. Substances have different vapor pressures
     a. higher vapor pressure, lower boiling point
        1. more kinetic energy - molecules escape easier
- F. Condensation - process in which a vapor or gas changes to a liquid
  1. lower energy molecules return to the liquid stage
  2. raises the temperature of the vapor
- G. Distillation - process of evaporating off a liquid and recollecting it by cooling in another container - used to collect pure samples of substances

III. Solids
- A. Crystals - all true solids form characteristic geometric figures in which the atoms or molecules are arranged in regular repeating patterns
  1. Rate of evaporation (cooling) determines size of crystal formation
     - a. slow - atoms attach themselves to previously formed crystals
     - b. fast - atoms form their own centers of crystallization
  2. Types: Ionic crystals, Covalent Network Crystals, Metallic Crystals, Covalent Molecular Crystals (See Bonding)
- B. ***Amorphous Solids – do not have a regular geometric shape or crystal pattern***
  1. ***ex. Glass, plastic***
- C. Solutions of solids and water
  1. evaporation of water may form a pure solid
  2. crystals may contain water mechanically enclosed within the crystal
     - a. ***decrepitation - enclosed water is released explosively, blowing crystals apart (pop rocks)***
- D. Water of Hydration (Hydrates)
  1. Crystals made up of solid substance combined chemically with water in a definite ratio. (hydrate)
     - a. Example $CuSO_4 \cdot 5H_2O$ (1 unit of copper sulfate is chemically united with 5 water molecules)
       1. Anhydrous - removal of water from hydrates
       2. ***Efflorescence - spontaneous loss of water of hydration from a substance at room temperature (ex. $Na_2CO_3 \cdot 10H_2O$)***
- E. ***Hygroscopic & Deliquescent Substances***
  1. ***Hygroscopic - absorb moisture from the air and become damp (silica gel)***
  2. ***Deliquescence - solid substance absorb enough moisture from the air to dissolve themselves in it. (ex. $CaCl_2$, $MgCl_2$)***
- F. Heat of fusion - same as the Heat of Crystallization
  1. quantity of heat given up at a constant temperature, when one gram of liquid is changed to a solid.
- G. Sublimation
  1. ***solids with a fairly high vapor pressure and low intermolecular attractions will sublimate***
     - a. ***Solid CO_2 (1atm at -78.5 °C)***
       1. ***cannot liquefy at normal temperatures***
     - b. ***iodine***
     - c. ***naphthalene (moth balls)***
- H. ***Deposition – process by which a gas changes directly to a solid without passing through the liquid phase***

IV. Equilibrium – a dynamic condition in which two opposing changes occur at equal rates in a closed system
- A. 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
  - a. Concentration
  - b. Increase in concentration of reactant
  - c. increases product

1. Decrease in concentration of product
    a. reduces reactants and produces more product
2. Common Ion Effect - addition of a common ion that is soluble will cause the formation of more product (one of the reactants is increased)
    a. ex. Ag (aq) + Cl (aq) à AgCl
    b. Addition of H + Cl shifts the equilibrium to the right, forming more AgCl
3. Temperature
    a. Increase in temperature - shifts equilibrium to endothermic reaction (shift away from the energy side)
        1. ex. A + B à C + D + kcal
        2. equilibrium shift (extra heat is absorbed)
    b. Decrease in temperature - shifts equilibrium to exothermic reaction (shift to the energy side)
        1. ex. A + B + kcal à C + D equilibrium shift (causes release of heat)
4. Pressure
    a. Increase in pressure - shifts reaction to the side with the least number of moles
        1. ex. 1A + 3B à 2C creates shift to the right
    b. Decrease in pressure - shifts reaction to the side with the greatest number of moles.
5. Effect of Catalysts
    a. increases rate of forward and reverse reactions (no affect on equilibrium)
        1. causes equilibrium to be reached sooner

B. Equilibrium vapor pressure – the pressure exerted by a vapor in equilibrium with its corresponding liquid at a given temperature
    1. Volatile liquids – liquids that evaporate easily

V. ***Phase Diagram***

A. ***Triple Point – The point at which the solid, liquid, and vapor phases may all exist at equilibrium***
    1. ***Pressure and temperature are usually greatly reduced***

B. ***Liquefaction - process in which a substance enters the liquid phase***
    1. ***increased pressure and lowering temperature causes liquefaction***
        a. ***liquefaction point of O_2 = -183 °C (1 atm), -140 °C (20atm)***
    2. ***Critical Temperature and Pressure - maximum temperature and pressure it is possible to liquefy a gas (CO_2 = 31.1 °C at 73 atm) (O_2 = -119 °C)***