AP Chemistry

Chapter 11 Outline

- ❖ A Molecular Comparison of Gases, Liquids, and Solids
- ▪ Gases = widely separated particles in constant chaotic motion
    - ▪ Average attractions between molecules are much smaller than their average kinetic energy
    - ▪ Gases expand to fill their container because of the lack of strong attractions between particles
- ▪ Liquids = intermolecular attractive forces are strong enough to keep particles close together
    - ▪ Liquids are denser, far less compressible than gases
    - ▪ Attractive forces are strong enough to keep the particles from moving past each other
    - ▪ Liquids can be poured and take the shape of their container.
- ▪ Solids = particles are virtually locked in place because of strong intermolecular attractions
    - ▪ Solids are not very compressible because particles have very little space between them
    - ▪ Solids are rigid because the particles are not free to undergo long-range movement
        - ▪ Crystalline solids = contain highly ordered structures, with a regular pattern
        - ▪ Amorphous solids = structures are not completely regular
- ▪ Condensed phases = solids and liquids
    - o The state of matter depends on two factors: average kinetic energy, and interparticle energies of attraction
    - ▪ State of matter can be changed by heating or cooling, which changes the average kinetic energy of the particles

- ❖ Intermolecular Forces
    - o These attractions vary in strength, but tend to be much weaker than ionic or covalent bonds.
    - o They take less energy to "break", because the molecules themselves stay intact
    - o Many properties of liquids reflect the strengths of the intermolecular attractions

- ▪ Ion-Dipole Attractions
    - o Exists between an ion and the partial charge on the end of a polar molecule.
    - o The magnitude of the attraction increases as either the charge of the ion or the magnitude of the dipole moment increases.
    - o Important for solution process of ionic compounds in polar solvents (more in chapter 13)

- Dipole-Dipole Attractions
    - Neutral polar molecules attract each other when the positive end of one molecule is near the negative end of another.
    - Through random motions, the molecules arrange themselves to maximize attractions and minimize repulsions.
    - These are only significant when the molecules are close together.
    - For molecules of approximately equal mass and size, the strengths of the intermolecular attractions increasing with increasing polarity.

- Dipole-Induced Dipole attractions
    - A polar molecule approaches a non-polar species and causes an instantaneous dipole in the nonpolar species due to uneven electron distribution
    - These are only significant when the interacting particles are close together
    - Explains why nonpolar gases can dissolve in water

- London Dispersion Forces
    - All molecules, even non-polar, symmetric atoms, can create an instantaneous dipole moment due to uneven electron distribution.
    - This instantaneous, temporary dipole can induce an adjacent atom to have a temporary dipole, causing the two particles to be attracted to one another.
    - All substances exhibit dispersion forces.
    - Significant only when molecules are very close together.
    - Depends on polarizability (how easily the electron cloud is distorted)
        - Long, thin molecules are more polarizable than compact molecules, because of increased surface area for contact between molecules.
        - Larger molecules are more polarizable than smaller molecules, because they have more electrons, which are relatively far from the nuclei.
- Hydrogen Bonding
    - A special type of dipole-dipole attraction between the hydrogen atom in a polar bond (particularly to F, N or O) and an unshared electron pair on a nearby small electronegative ion or atom (usually an F, O, or N atom on another molecule).
    - Because of the large electronegativity difference in these bonds, the hydrogen nucleus is nearly exposed.
    - The small, electron-poor hydrogen can approach an electronegative atom very closely and interact with it.
    - The energies of hydrogen bonds are much weaker than ordinary covalent bonds, but stronger than other intermolecular attractions.
    - Key roles in proteins, DNA structure

- Some Properties of Liquids
- Viscosity = resistance of a liquid to flow
    - Related to the ease with which individual molecules of the liquid can move past each other
- Surface Tension = the energy required to increase the surface area of a liquid by a unit amount; a measure of the inward forces that must be overcome
    - Cohesive forces = intermolecular forces that bind similar molecules to one another
    - Adhesive forces = intermolecular attractions that bind a substance to a surface
        - Meniscus
        - Capillary action

- Phase Changes
- Every phase change is accompanied by a change in the energy of the system.
    - Heat of fusion = the energy required to bring about a change from highly ordered solid to a liquid (i.e., melting) = -heat of freezing
    - Heat of vaporization = the energy required to bring about a change from the condensed liquid state to highly separated particles in the gas state = - heat of deposition
        - Heat of vaporization is generally several times bigger than the heat of fusion
            - In order to vaporize, the molecules must essentially sever all intermolecular attractions
            - In melting, most of the intermolecular attractions remain unchanged
    - Heat of sublimation = the energy required to change a solid into a gas, without going through the liquid state = - heat of deposition
- Heating Curves
    - Phase changes occur without a change in temperature! To calculate energy, use $\Delta H = H_{fus/vap}$ * mass of substance
    - For temperature changes, use $Q = mC\Delta T$
        - C = specific heat of substance

- Vapor Pressure
- Molecules can escape from the surface of a liquid into the gas phase; will reach a state of dynamic equilibrium
    - Vapor pressure = the pressure exerted by the vapor when at equilibrium
    - Volatile liquid = a liquid that evaporates readily
    - Boiling point = the temperature at which the vapor pressure equals the external pressure
        - Normal boiling point = the boiling point at 1 atm

- Phase Diagrams
- Graphical way to summarize conditions under which equilibria exist between different states of matter
  - Determined for closed systems
  - Triple point = conditions at which solid, liquid and gas phases coexist
  - Critical point = critical temperature and pressure; beyond this point, gas and liquid are indistinguishable
    - From triple point to critical point = vapor pressure curve; equilibrium between liquid and gas phases
    - Equilibrium between solid and liquid; line gives melting points at different pressures
    - Equilibrium between solid and gas;