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
  - 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

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

- Ion-Dipole Attractions
  - Exists between an ion and the partial charge on the end of a polar molecule.
  - The magnitude of the attraction increases as either the charge of the ion or the magnitude of the dipole moment increases.
  - 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 \( \Delta H = H_{\text{fus/vap}} \times \text{mass of substance} \)
- 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;