11: Liquids and Solids

Key Chemistry Terms

- **Intramolecular forces:** chemical bonds within a molecule.
- **Intermolecular forces (IMF):** physical attractions between separate molecules.
- **Dipole:** Partial separation of charge.
- **London Dispersion Forces:** Temporary dipole due to electrons ganging up on one side of the molecule.
- **Dipole-Dipole Forces:** Attractions between opposite charges in two polar molecules.
- **Ion Dipole Forces:** Attraction between an ion and the opposite charge on a polar molecule.
- **Hydrogen bonding:** Very strong dipole present when an H bonds to an N, O or F. The H can then "hydrogen bond" with the lone pairs on an N, O or F of a different molecule.
- **Vapor Pressure:** Pressure caused by particles evaporating from a solid or liquid.
- **Equilibrium:** The rate of change is equal to the rate of the opposite change.
- **Amorphous solid:** No repeatable structure of components.
- **Crystalline solid:** Repeating unit cell of the components.
- **Lattice:** Overall structure of crystalline solid.
- **Unit Cell:** Repeating unit in lattice.
- **Atomic solids:** Atoms are the components of the unit cells.
- **Molecular solids:** Molecules are the components of the unit cell.
- **Phase change:** Matter changes from one state to another.
- **Phase Diagram:** Shows the state of matter at various temperature and pressures.
- **Enthalpy of fusion (Hfus):** Energy needed to break enough intermolecular forces to melt.
- **Enthalpy of vaporization (Hvap):** Energy needed to break remaining IMF's to evaporate a liquid.

Intermolecular Forces

IMF	Happens with	Relative strength
London Dispersion Forces	All molecules	Weakest IMF
Dipole-Dipole Forces	2 polar molecules	Medium strength
Ion-Dipole Forces	Ion and a polar molecule	Medium strength
Hydrogen Bonding	H on an N, O or F with an N, O or F on another molecule	Strongest IMF

London Dispersion Forces are temporary, and therefore weaker. The larger the molecule, the greater the London Dispersion Forces

Liquids

Properties of liquids:

- Definite volume but not shape.
- Particles are free to move past one another.
- Not very compressible.

Vapor Pressure

Vapor Pressure

- If a particle on the top surface of the liquid has enough energy, it can escape the intermolecular forces and evaporate—causing vapor pressure..
- As temperature increases, more particles have the necessary energy to evaporate—vapor pressure increases.

Vapor Pressure Equilibrium

- Initially the liquid particles escape resulting in gas particles, those gas particles can collide with the liquid and re-join it.
- The rate of gas evaporating remains the same. The rate of gas particles re-joining the liquids increases as more gas particles are made from evaporation.
- Vapor Pressure equilibrium is established over time.

Solid

Properties of solids:

- Definite shape and volume.
- Particles are not free to move past one another.
- Not compressible.

Amorphous solid particles are "trapped" in place before they can arrange themselves into a repeating pattern.

Three types of crystalline solids:

- Atomic solids
  - Metallic solids—closest packing of metal atoms. Electrons are in a pool and are free to move throughout.
  - Network solids—one giant molecule. Each atom is covalently bonded to surrounding atoms
- Molecular solids—strong covalent bonds within the molecular, weaker physical attractions between them
- Ionic solids—electrostatic attraction between ions. Ions are stacked to minimize like-charge repulsions

Phase Changes

Melting / freezing: solid ⇆ liquid
Boiling / condensing: liquid ⇆ gas
Sublimation / deposition: solid ⇆ gas

- Melting: Requires energy to break some IMF.
- Boiling: Requires energy to break remaining IMF.
- Subliming: Requires energy to break all the IMF.
- Deposition, condensation and freezing: Energy is released as IMF's formed.

Boiling / Condensation Point: Temperature at which liquid and gas are at equilibrium.

- Vapor pressure of liquid = atmospheric pressure

Melting / Freezing Point: Temperature at which solid and liquid are at equilibrium.

- Vapor pressure of solid = Vapor pressure of liquid

Substances **sublime** when the IMF are so weak that all of them are broken at that temperature and pressure.

Energy of Phase Changes

Equations for energy change (ΔH) during a phase change:

Melting: $\Delta H = m \times H_{fus}$

Evaporating: $\Delta H = m \times H_{vap}$

For **freezing and condensing**, use $-H_{fus}$ and $-H_{vap}$ since energy is released.