Chapter 5 Gases, Liquids and Solids

The States of Matter

Forces between one molecule and another are called intermolecular forces.

Intermolecular forces hold molecules together and kinetic energy pushes them apart. Stronger intermolecular forces favor the liquid or solid state while higher temperature favors the gaseous state.

Solid to liquid – melting point
Liquid to gas - boiling point

Gases

Know postulates of the kinetic molecular theory.

Molecules are in constant rapid, random motion.
The average kinetic energy is directly proportional to the Kelvin temperature.
Molecules collide with each other and the walls of their container but do not lose energy in doing so. (perfectly elastic collisions)
The volume of the molecules is negligible.
There are no attractive or repulsive forces between the molecules.
Pressure results from molecular collisions.

The theory above describes the attributes of an ideal gas.

Pressure

Atmospheric pressure is measured using a barometer. You must know this operation.
Pressure in a container is measured with a manometer.
Units
mm Hg = torr
atmosphere = 760 torr = atm = 760 mm Hg

Gas Laws

Boyle's law - The volume of a gas is inversely proportional to the pressure when temperature and amount of substance is constant.

$$P_1V_1 = P_2V_2$$

Charle's law - The volume of a gas is directly proportional to the temperature when pressure and amount of substance is constant.

$$V_1/T_1 = V_2/T_2$$

Gay-Lussac's law - The pressure of a gas is directly proportional to the temperature when volume and amount of substance is constant.

$$P_1/T_1 = P_2/T_2$$

Combined gas law: $P_1V_1/T_1 = P_2V_2/T_2$

Use the gas laws for pressure, volume and temperature calculations.

Avagadro's Law and the Ideal Gas Law

Avagadro's law – Equal volumes of gases at the same temperature and pressure contain equal numbers of molecules.

Standard temperature and pressure, STP, is 273 K and 1 atmosphere.

The volume of a mole of gas at STP, the standard molar volume, is 22.4 L.

A relationship can be written for any gas pressure, volume, temperature and number of moles by combining the above gas laws to generate the ideal gas law; PV = nRT. R is called the universal gas constant or ideal gas constant and is commonly written as 0.0821 L atm/mole K.

Since n = mass/molecular weight, we can substitute into the ideal gas equation and use the relationship to determine the molecular weight of a gas. PV = nRT = mass RT/molecular weight and

Molecular weight = mass RT/PV; or, another rearrangement gives density = mass/V = P molecular weight/RT.

Dalton's Law and Graham's Law

Dalton's law of partial pressures states that the total pressure of a mixture of gases is the sum of the individual partial pressures. The gas molecules are considered to act independently.

$$P_T = P_1 + P_2 + P_3 + \ldots$$

The partial pressure of a gas is the pressure that the gas would exert if it were alone in the container.

The rapid spontaneous mixing of gases is called diffusion.

Graham's law of diffusion – The rate of gas diffusion is inversely proportional to the square-root of the molecular weight of the gas.
Diffusion rate of A/Diffusion rate of B = $(\text{MW of B})^{1/2}/(\text{MW of A})^{1/2}$

Intermolecular Forces

Intermolecular forces are important in the liquid and solid states because the molecules are close together. The attractive forces lead to condensation and solidification.

Dipole-dipole attractions – positive and negative ends of dipoles attract.
Hydrogen bonds - H bound to O, N, or F attracted to another O, N, or F.
London dispersion forces – Instantaneous distortion of electron distributions leads to weak polarity and consequent attraction.

Liquids

The constituent particles are close enough to come into contact with one another but are still free to move past each other.

Know the consequent physical properties of liquids relative to those of gases and solids.

Evaporation and Condensation, Boiling Point

Particles that have enough kinetic energy to escape the surface of a Liquid move into the gas phase. This process is called evaporation.

If the liquid is in a closed container, a sufficient number of gas phase particles of the substance will build up so that the gas phase particles return to the liquid phase at the same rate that liquid particles become gaseous. When this happens a dynamic equilibrium is established and no further net condensation or vaporization occurs as long as the temperature is kept constant.

The vapor pressure of the substance when equilibrium is established with its liquid at a given temperature is called the equilibrium vapor pressure of the liquid at the stated temperature. It depends only on the Kelvin temperature.

At the boiling point of a liquid the equilibrium vapor pressure of the liquid is equal to the atmospheric pressure. The normal boiling point is attained when the pressure is one standard atmosphere or 760 torr.

Solids

Crystalline solids exist as a regular three-dimensional array of atoms, ions, or molecules called a crystal lattice.

The constituents of a crystal are fixed in place and do not move past one another, so crystals have a regular shape.

The same substance may exist in more than one arrangement or solid state.

Know types and characteristics of solids (Table 5.3)

- Ionic
- molecular
- metallic
- polymeric
- network
- amorphous

Freezing and Boiling, Phase Changes

The melting point is the temperature at which a solid changes to a liquid. For the reverse change, the same temperature is called the freezing point.

Changes in physical state are called phase changes.

You must interpret heating curves and cooling curves, heat added versus temperature change.

Heat of fusion
Heat of vaporization

The boiling point is the temperature at which the vapor pressure of a liquid is equal to the atmospheric pressure and the liquid is rapidly vaporized.

The transition from the solid state directly to the vapor state is called sublimation.