Unit 3 Summary Sheet

Kinetic Molecular Theory

States of Matter: solid, liquid, or gas.
Solid: has small spaces between particles, and slow motion of particles.

Description	- ordered and dense - has a definite shape and volume - virtually incompressible

Liquid: has medium spaces between particles, and medium motion of particles.

Description	- disordered and low density - has definite volume - takes the shape of the container - slightly compressible

Gas: has large spaces between particles, and fast motion of particles.

Description	- disordered and very low density - does not have a definite shape - does not have a definite volume - highly incompressible

Types of Motion: vibrational, rotational, or translational.
Vibrational: has a back and forth motion; occurs in solids, liquids and gases.
Rotational: has a spinning motion; occurs in liquids and gases.
Translational: movement is in a straight line; occurs in liquids and gases.

Kinetic Molecular Theory: states that gas particles behave like hard, spherical objects that are in constant, random motion.
Temperature: is a measure of the average kinetic energy of entities in a sample.
Kinetic Energy: form of energy that an object or particles has. The average kinetic energy of gas particles is directly proportional to the absolute temperature.

$T \propto KE_{avg}$

- $\uparrow$ absolute temperature = $\uparrow$ motion of gas particles
- $\uparrow$ motion of gas particles = $\uparrow$ average KE

At a given temperature, all gas entities have the same average kinetic energy regardless of their size or mass.

Atmospheric Pressure

Atmospheric Pressure: the amount of force per unit area exerted by air on all objects.

$P = \dfrac{F}{A}$

- $\uparrow$ force = $\uparrow$ pressure, $F \propto P$
- $\uparrow$ area = $\downarrow$ pressure, $A \propto \dfrac{1}{P}$
- pressure is a physical property of gas.
- collisions of gas particles occur, pressure is caused when gas particles hit the walls of their container.

Pascal: SI unit for pressure.

- $Pa = \dfrac{N}{m^2} = \dfrac{kg}{m \times s^2}$
- kilopascal is often used, $kPa = 1000\,Pa$

Absolute Temperature: is temperature measured using the Kelvin scale where zero is absolute zero.

- $0\,K = -273.15°C$
- $T_K = T_{°C} + 273.15$
- $T_{°C} = T_K - 273.15$

Standard Atmosphere: 1 atm is approximately Earth's atmospheric pressure at sea level.
Standard Temperature and Pressure (STP)

- temperature = $0°C$ = 273.15 K
- pressure = 1 atm = 101.325 kPa = 760 mmHg = 760 torr
- volume = 22.4 L/mol

Standard Ambient Temperature and Pressure (SATP)

- temperature = 25° = 298.15 K
- pressure = 100 kPa
- volume = 24.8 L/mol

Charles' Law

Volume and Temperature: French scientist Jacques Charles (1746-1823) examined the expansion of a variety of gases.
Charles' Law: the volume of an ideal gas is directly proportional to the absolute temperature, provided the pressure and the amount of gas remain constant.

$\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$, or $\dfrac{V}{T} = a$ (constant)

- Since $V \propto T$, then $V = aT$ (a is a constant).
- $\uparrow$ volume = $\uparrow$ absolute temperature.
- temperature must be in kelvin.

Kelvin Scale: a scale of temperature in which absolute zero is zero (0 K).

- determined that at absolute zero (0 K) the particles in a substance are motionless.
- kinetic energy would be zero.
- theoretically, the volume of gas would be zero.

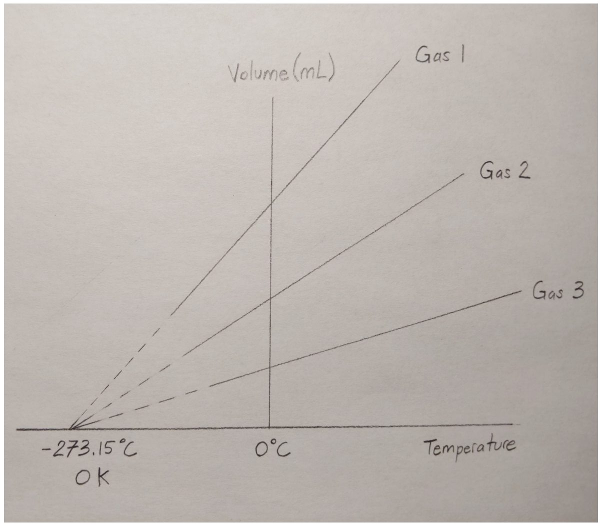

Figure 1: Charles' Law Graph†

†Dashed lines are extrapolated, lines meet at absolute zero.

Boyle's Law

Volume and Pressure: Anglo-Irish chemist Robert Boyle (1627-1691) examined how the volume of a gas decreases with increasing pressure and vise versa.
Boyle's Law: The volume of a gas is inversely proportional to its pressure, provided the temperature and the amount of gas remain constant.

$P_1V_1 = P_2V_2$, or $PV = k$ (k is a constant)

- Since $V \propto \frac{1}{P}$, then $V = \frac{k}{P}$ (k is a constant).
- as volume ↑, then pressure ↓.
- as volume ↓, then pressure ↑.

Gay-Lussac's Law

Pressure and Temperature: French chemist Gay-Lussac (1778-1850) examined how the pressure of a gas increases proportionally as its temperature increases and vise versa.
Gay-Lussac's Law: The pressure of a gas is directly proportional to its temperature, provided the volume and the amount of gas remain constant.

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$, or $\frac{P}{T} = k$ (k is a constant)

- Since $P \propto T$, then $P = kT$ (k is a constant).
- as absolute temperature ↑, then pressure ↑.
- temperature must be in kelvin.

Combined Gas Law

The **combined gas law** describes the relationship between volume, temperature, and pressure for any fixed amount of gas.
The **Combined Gas Law**: The product of the pressure and volume of a gas divided by its absolute temperature is a constant, provided the amount of gas is kept constant.

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, or $\frac{PV}{T} = constant$

- amount of gas remains constant.
- temperature must be in kelvin.

Law of Combining Volumes

Gay-Lussac proposed the **law of combining gases** during when the kinetic molecular theory had not yet been developed.
Amedeo Avogadro later on proposes the explanation for the law of combining volumes.
Law of Combining Volumes: gases always react to produce products in whole-number ratios when measured at the same temperature and pressure.
Volume Ratios: are the same as the coefficients in a balanced chemical equation.

Avogadro's Law

Volume and Amount of Gas: Italian scientist Amedeo Avogadro (1776-1856) discovered that equal volumes of gases, at the same temperature and pressure, contain the same number of molecules.
Avogadro's Law: The volume of a gas is directly proportional to the amount of gas, provided the temperature and pressure remain constant.

$\frac{V_1}{n_1} = \frac{V_2}{n_2}$, or $\frac{V}{n} = constant$

- Since $V \propto n$, then $V = kn$ (k is a constant).
- equal volumes of gas at the same temperature and pressure contain an equal number of molecules.
- this explains why the mole ratios in a balanced chemical equation are also the ratios of volumes.

Molar Volume

Molar Volume: is the volume occupied by one mole of gas at a specified temperature and pressure.

- At STP, one mole of any gas occupies 22.4 L.
- At SATP, one mole of any gas occupies 24.8 L.

Gas Density

$$density = \frac{mass}{volume}$$

- for mass, use the molar mass (g/mol).
- for volume, use the molar volume (L/mol).

Ideal Gases

An **ideal gas** has the following properties:

- all entities of an ideal gas have high translational energy, moving randomly in all directions (in straight lines).
- collision of ideal gas entities with each other or with the wall of a container are perfectly elastic.
- the volume of an ideal gas entity is negligible (zero) compared to the volume of a container.
- there are no attractive or repulsive forces between ideal gas entities.
- ideal gases do not condense into liquid when cooled.

There is no such thing as an ideal gas.

The Ideal Gas Law

Combining Charles' Law, Avogadro's Law, and Boyle's Law, we arrive at the **ideal gas law**:

$PV = nRT$

- universal gas constant $R = 8.314 \frac{kPa \times L}{mol \times K}$

Gas Stoichiometry

Use one or a combination of the following to solve gas stoichiometry problems:

1. Law of Combining Volumes
2. Avogadro's Law
3. Ideal Gas Law

Law of Partial Pressures

Dalton's Law of Partial Pressures: The total pressure of a mixture of non-reacting gases is equal to the sum of the individual gases' partial pressures.
$P_{total} = P_1 + P_2 + P_3 + ...$

The **partial pressure** of each individual gas:
$P_1 = P_{total} \times (\% of\, gas\, 1)$
$P_2 = P_{total} \times (\% of\, gas\, 2)$
$\vdots$