Gas Laws

- The gas laws describe the relationship between pressure, temperature, volume, and amount of moles.
    - Boyle's Law (1662) ----- Pressure vs. Volume
    - Charles' Law (1787) ----- Volume vs. Temperature
    - Gay-Lussac's Law (1808) ----- Pressure vs. Temperature
    - Avogadro's Law (1811) ----- Volume vs. Moles
    - Ideal Gas Law

Ideal Gas

- A theoretical substance that uses assumptions to simplify our understanding of how gases behave under different conditions (P, T, V, n).
- Assume:
    - The particles in a gas are very small (no volume) and spaced far apart.
    - The particles move in constant, random, straight-line motion.
    - The particles don't transfer energy when they collide. Only elastic collisions.

Real Gas

- In general,
    - A real gas will behave like an ideal gas at low pressure and high temperature.
    - A real gas contains particles that take up space (have a volume).
    - A real gas contains particles that forcefully interact with other particles.
    - The volume of a real gas is Larger than the volume of an ideal gas.
    - The pressure of a real gas is Smaller than the volume of an ideal gas.

Check it out:

- TedTalk --- The Mole
- Professor Dave --- Kinetic Theory of Matter
- Professor Dave --- Gas Laws
- Professor Dave --- Molar Volume of a Gas
- Professor Dave --- Gas Solubility
- Demo --- Boyle's Law
- Demo --- Charles' Law
- Demo --- Gay Lussac's Law
- Demo --- Avogadro's Number
- Demo --- Molar Volume

Pressure (P)

- The measure of particle collisions on the inside of the container walls. At high pressure, the particles are striking the walls of the container at a high rate.
    - Conversion Factors
        - 1 atm = 101,325 Pa
        - 1 atm = 14.69 psi
        - 1 atm = 760 mmHg

Temperature (T)

- The average kinetic energy of a substance. As the temperature increases, the speed of the particles will increase because the thermal energy is converted into kinetic energy.
    - Conversion Factors
        - 0 K = -273.15 ºC = -459.67 ºF ABSOLUTE ZERO
    - Equations
        - $T_K = T_C + 273.15$
        - $T_F = T_C * (9/5) + 32$
        - $T_C = (T_F - 32) * (5/9)$

Volume (V)

- The amount of 3-dimensional space or size of the container. When the container is elastic (like a balloon), it means the container can expand or be compressed.
    - Conversion Factors
        - 1 m^3 = 1000 liters
        - 1 L = 1000 cm^3

Amount of Moles (n)

- The amount of a substance. We have learned that there is a relationship between (grams <--> moles <--> particles). This means we know how many particles of a gas are added by knowing the mass of the gas. Also, the molar volume for 1 mole of any gas is equal to 22.4 Liters at Standard Temperature Pressure (STP).

Gas Constant (R)

- The gas constant (R) is used in the Ideal Gas Law.

$$R = 0.082 \frac{L * atm}{mol * K}$$

$$R = 8.314 \frac{J}{mol * K} = 8.314 \frac{m^3 * Pa}{mol * K}$$

Standard Temperature & Pressure (STP)

- Pressure = 1 atm
- Temperature = 0 ºC

Boyle's Law

- Pressure vs. Volume
    - As pressure decreases, the volume will increase ---- INVERSE RELATIONSHIP
    - Constant:
        - Temperature
        - Number of Moles

$P_1V_1 = P_2V_2$

Charles' Law

- Volume vs. Temperature
    - As temperature increases, the volume will increase ---- DIRECT RELATIONSHIP
    - Constant:
        - Pressure
        - Number of Moles

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Gay-Lussac's Law

- Pressure vs. Temperature
    - As temperature increases, the pressure increases ---- DIRECT RELATIONSHIP
    - Constant:
        - Volume
        - Number of Moles

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Avogadro's Law

- Number of Moles vs. Volume
    - As the number of moles increases, the volume increases ---- DIRECT
    - Constant:
        - Pressure
        - Temperature

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Combined Gas Law

- This law is used to combine pressure, temperature, and volume.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Ideal Gas Law

- This law is used to combine all 4 conditions to calculate the value of one at any moment.

PV = nRT

Practice Problems

1) At a constant temperature and fixed amount of gas, suppose you have 50 mL of gas at a pressure of 4.50 atm. Calculate the volume of the gas if you decrease the pressure to 0.75 atm. Use Boyle's Law.

2) At a constant pressure and fixed amount of gas, suppose you have 21 mL volume of CO_2 gas at 40 ^oC. Calculate the volume of the gas if you increase the temperature of the gas to 60 ^oC. Use Charles' Law.

3) At a constant volume and fixed amount of gas, suppose you have N_2 gas at 60 ^oC temperature and 2 atm of pressure. Calculate the temperature of the gas (in Kelvin) if you decrease the pressure of the gas to 0.25 atm. Use Gay Lussac's Law.

4) At constant temperature and pressure, suppose you have 3.2 grams of O_2 gas in a 150 mL container. If 1.6 grams of O_2 is added to the container, what will the volume of the container change to? Use Avogadro's Law.

5) Suppose the pressure, temperature, and volume of a gas is (380 mmHg, 25 ^oC, 500 mL) respectively. How many moles of the gas are in this sample? Use the Ideal Gas Law.

HW - Gas Laws

1) Convert 25 ^{o}C to kelvin

2) Convert 40 ^{o}C to fahrenheit

3) Convert 290 K to celsius

4) Convert 325 K to fahrenheit

5) Convert 360 mmHg to atm

6) Convert 2.5 atm to mmHg

7) Convert 1.2 atm to Pa

8) Convert 5.0 atm to psi

9) Convert 0.33 L to mL

10) Convert 3500 cm^3 to Liters

HW - Gas Laws

11) If 35.75 L of nitrogen gas at a pressure of 752 mmHg is compressed to 721 mmHg at constant temperature. What is the new volume?

12) A gas with a volume of 4.2 L at a pressure of 219 kPa is allowed to expand to a volume of 10.5 L. What is the pressure in the container if the temperature remains constant?

13) What pressure is required to compress 146.0 liters of air at 1.01 atmosphere into a cylinder whose volume is 26.0 liters?

14) A 45.0 L tank of ammonia has a pressure of 18.2 kPa. Calculate the volume of the ammonia if its pressure is changed to 9.3 kPa while its temperature remains constant.

15) Calculate the decrease in temperature when 6.00 L at 25.0 °C is compressed to 3.00 L.

HW - Gas Laws

16) A container containing 3.00 L of a gas is collected at 90 K and then allowed to expand to 18.0 L. What must the new temperature be in order to maintain the same pressure?

17) If 8.0 liters of neon at 12.0 °C is allowed to expand to 40.0 liters, what must the new temperature be to maintain constant pressure?

18) The gases in a hair spray can are at a temperature of 24 ^{o}C and a pressure of 30 psi. If the gases in the can reach a pressure of 90 psi, the can will explode. If the volume is held constant, At what temperature must the gases be raised in order for the can to explode?

19) What is the volume of 50 grams of N_2 gas at STP?

20) A gas is heated from 265.0 K to 296.0 K and the volume is increased from 22.0 liters to 30.0 liters by moving a large piston within a cylinder. If the original pressure was 1.25 atm, what would the final pressure be?