Gas Laws

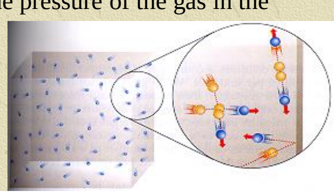
- Gas Properties
- Gases and the Kinetic Molecular Theory
- Pressure
- Gas Laws

Gas Properties

1) Gases have mass - the density of the gas is very low in comparison to solids and liquids, which make it seem lighter.
2) Gases are compressible - Squeezing a gas is much easier than squeezing some solids and liquids.
3) Gases fill containers completely - air is distributed completely throughout a balloon.

Gas Properties

4) Gases diffuse - gases can move through each other very easily.
5) Gases exert pressure - balloons are given their shape due to the pressure of the gas in the balloon.



Measurement of Gases

Amount (n) - standard unit - mole

Volume (V) - st. unit - liter

Temperature (T) - st. unit - Kelvin

Pressure (P) - st. unit - atmosphere

Pressure

Pressure is the result of the gases colliding with the walls of the container it is in. Everytime a particle hits the wall of the container, it exerts a force or push.

Units At Sea Level:

1 atmosphere = 760 mm Hg = 760 torr

=101,325 Pa or 101.325 kPa

= 14.70 psi

Temperature

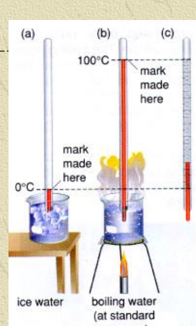
Measure of the movement of the molecules in a substance. In science, either the Celsius or the Kelvin temperature scale is used.

$^{o}C = 5/9(^{o}F - 32)$

$^{o}F = 9/5(^{o}C) + 32$

$K = {}^{o}C + 273$

$^{o}C = K - 273$



Boyle's Law

The pressure and volume of a sample of gas at constant temperature are inversely proportional to each other.

- i.e., one goes up, the other goes down.

Equation: $P_1V_1 = P_2V_2$

Charles' Law

At constant pressure, the volume of a fixed amount of gas is directly proportional to its absolute temperature.

- i.e., one goes up, the other goes up.

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

Avogadro's Principle

Equal volumes of gases under the same conditions have equal number of molecules.

Recall that at STP, the molar volume (volume of one mole of a gas) is 22.4 L

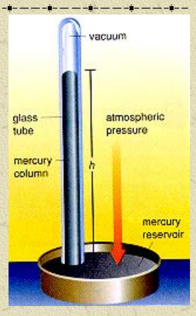
Equation: $\frac{V_1}{n_1} = \frac{V_2}{n_2}$

What is Pressure?

Pressure is the result of the gases colliding with the walls of the container it is in. Everytime a particle hits the wall of the container, it exerts a force or push.

Pressure is a measure of this force over the whole container.

Atmospheric pressure is the weight of the air above an object



Absolute Temperature

An absolute scale means that it has limits on one or both ends of the scale.

The Kelvin temperature scale cannot go below 0 K because this point corresponds to the point where the motion of the particles (their kinetic energy) ceases.

This point is called absolute zero.

Ideal Gas Law

It is possible to combine all the gas laws that we have learned thus far into one gas law.

The ideal gas law describes the physical behavior in terms of the gases' pressure, volume, moles and temperature.

The ideal gas law works for any gas provided it obeys the KMT postulates. Deviations from ideal gas occur at very low temperatures and at very high pressures.

Ideal Gas Law & Constant

When putting the gas laws together, we discover the mathematical equation:

$$PV = nRT$$

where R stands for the universal gas constant.

Values for R:

0.0821 atm•L/mol•K

8.314 kPa•L/mol•K or 8.314 Pa•m^3/mol•K

62.36 mmHg•L/mol•K

Stoichiometry and Ideal Gases

In cases of a chemical reaction in which a gas is either reacted or produced, you may need to use the ideal gas law to determine the moles of gas to complete a stoichiometry problem.

Example: A sample of hydrogen gas is confined to a 500 mL flask at 15 ^{O}C and 850 torr. The gas is released to react with excess oxygen in the air to produce water vapor. How many grams of water will be produced?

Gas Density

The ideal gas law equation can be rearranged to determine the density of a gas:

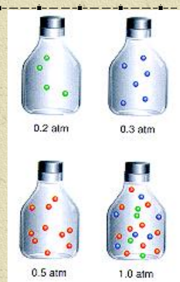
$$D = \frac{PM}{RT}$$

The density will be calculated in g/L.

This equation can be rearranged to calculate the molar mass of a gas:

$$M = \frac{DRT}{P}$$

Dalton's Law of Partial Pressures



The total pressure in a gas mixture is the sum of the partial pressures of the individual components.

Partial pressures are the pressures due to each gas in the mixture.

Equation:

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

Partial Pressure Applications

If each gas obeys the ideal gas law, and all gases are within the same volume and have the same temperature:

$$P_T = \frac{(n_1 + n_2 + n_3 + \ldots)RT}{V} = \frac{(n_T)RT}{V}$$

Also, if the mole fraction of the gas is known:

$$P_1 = \left(\frac{n_1}{n_T}\right)P_T = X_1 P_T$$

Gases and KMT

A gas consists of very small particles, each with a mass.

The distance between particles of a gas is relatively large.

Gas particles are in random, constant motion.

Attractive and repulsive forces between molecules are negligible

Energy is transferred between molecules during collisions, but the average kinetic energy of the molecules does not change.

At any given temperature, the molecules of all gases have the same average kinetic energy

Root mean square (rms) speed

The speed of a molecule of a gas possessing average kinetic energy.

$$u = \sqrt{\frac{3RT}{\mathcal{M}}}$$

The less massive the gas molecule, the higher the rms speed.

R constant must be 8.314 J/mol•K, and molar mass has to be in kg/mol.

Effusion

Effusion is the escape of gas molecules out of a tiny hole in a container.

It is possible to compare the rate of effusion of two gases under identical conditions (Graham's Law):

$$\frac{r_1}{r_2} = \frac{u_1}{u_2} = \sqrt{\frac{3RT/\mathcal{M}_1}{3RT/\mathcal{M}_2}} = \sqrt{\frac{\mathcal{M}_2}{\mathcal{M}_1}}$$

Diffusion

Diffusion is the spread of one substance through a space or second substance.

Diffusion, like effusion, is greater for smaller molecules. However, a greater pressure can slow the molecules movements because of more collisions within the container.

Deviations from Ideal

At high pressures (usually above 10 atm), and at low temperatures (close to the boiling point of the gas), the attractive force between molecules can cause a large deviation in the ideal gas law calculation.

These real gases can be corrected for using the following equation:

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$

a corrects for the attractive forces between molecules of a gas; b corrects for the actual volume occupied by the gas. a and b are different for each gas.

Example

- 9.0 g of water vapor is in a 3.1 L container at 101 ^{O}C.
- A) What is the pressure using the ideal gas law?
- B) What is the pressure using the real gas equation?