## Kinetic Molecular Theory

In order for gases to behave ideally they must follow the four postulates of kinetic molecular theory:
-Gases are mostly empty space.
-Gas molecules are in constant, chaotic motion
-Collisions are elastic (no intermolecular forces)
-Gas pressure is caused by collisions of molecules with the walls of the container

$$P = \frac{Nmu^2}{3V}$$

N = number of molecules
m = mass of molecules
u = average speed (actually u = root mean squared speed of the molecules $u_{rms} = \sqrt{u^2}$)

The 3 is related to the fact that the particle is moving in 3 dimensional space.

N/V is the concentration of the gas; $mu^2$ is related to the collisional energy.

The translational kinetic energy ($E_t$) of a gas molecule:
$E_t = mu^2/2$ since $mu^2 = 3PV/N$
$E_t = 3PV/2N$
$E_t = 3nRT/2N$
$\boxed{\mathbf{E_t = 3RT/2N_A}}$

*-At a given temperature, molecules of different gases must all have the same average translational kinetic energy. (This means less massive particles are moving faster on average at a given temperature)*
*-The average translational kinetic energy of a gas molecule is directly proportional to the Kelvin temperature, T.*

Also, further substitution ($E_t = ½\ mu^2$) yields:

$u = \sqrt{\frac{3RT}{MM}}$ where MM is the molar mass of the substance.

Average speed is:
*-Proportional to the square root of the absolute temperature*
*-Inversely proportional to the square root of the molar mass*

**Graham's Law of Effusion:**
Effusion: The process by which gas escapes from a container through a tiny hole.
Diffusion: The process by which one substance mixes with one or more other substances as a result of the random motion of molecules (e.g. as in the time it takes to smell someone's perfume from across the room).

The rate of effusion of a gas is inversely proportional to the square root of the molar mass of the substance.

$Rate_1/Rate_2 = (Molar\ mass_2 / Molar\ mass_1)^{1/2}$

or written in terms of time

$Time_1/Time_2 = (Molar\ mass_1 / Molar\ mass_2)^{1/2}$

This law works for diffusion as well as effusion.
***Remember: Rate is inversely proportional to time!**

**Example:**
In an experiment it takes an unknown gas 1.5times longer to effuse than the same amount of oxygen gas. Find the molar mass of the unknown gas.

**Answer:**
$1.5T_1/T_1 = (MM_2 / 32.0g/mol)^{1/2}$ where $T_2 = 1.5T_1$
solving for MM2
$MM_2 = (1.5)^2(32.0) =$ **72.0g/mol**

**Example: Explain why a balloon deflates so much faster when it contains helium than when it contains air, which is mostly nitrogen.**

**Answer:**
He = 4.00g/mol $N_2$ = 28.02g/mol
Relative rates of effusion through the porous holes in a balloon

$Rate_2 / Rate_1 = (28.02 / 4.00)^{.5} = 2.65$
Helium effuses 2.65x faster than nitrogen.

## van der Waal Equation: For non-ideal gas behavior

If a gas does not behave ideally (i.e. according to the postulates of kinetic molecular theory), corrections for conditions must be made for the fact that
-molecules may take up a significant amount of the free space of the container
-molecular exhibit inelastic behavior to a greater or lesser degree depending upon the substance.

-*Gases behave most ideally at high temperatures and low pressures.*

**van der Waals correction:**

$$(P + an^2/V^2)(V - nb) = nRT$$

**a and b are constants that must be determined experimentally for a particular gaseous substance.**

The $an^2/V^2$ factor accounts for the attractive interactions between the particles and the walls of the container and the -nb factor corrects for the actual free space in the container.

**Example:** Calculate the difference in pressure between ideal and actual for .50mol of carbon dioxide at 30.0°C in a 2.00L container if a = 3.59$L^2$atm/$mol^2$ and b = 0.0427L/mol

**Answer:**

Actual:
$(P + (3.59)(.50^2) /(2.0^2)) (2.0 - (.0427)(.50)) = (.5)(.0821)(303.15)$
P = 6.06atm

Ideal:
P = (.50)(.0821)(303.15)/(2.0)
P = 6.22atm

**ΔP = .16atm**

**Question:**

A compound composed of carbon, hydrogen and chlorine effuses through a pinhole 0.411 times as fast as neon. Select the correct molecular formula for the compound from the following choices; $CHCl_3$, $CH_2Cl_2$, $C_2H_2Cl_2$, $C_2H_3Cl$

**Answer:**

$Rate_2/Rate_1 = 0.411 = (20.18g/mol / M)^{.5}$
.168921 = 20.18 / M
**M = 119.5g/mol This molar mass is consistent with $CHCl_3$**