Sections 5.24 - 5.25: Average Speed of Gas Particles

$E_T = \frac{1}{2} mv^2$ Average Translational Kinetic Energy

m = mass of particle

v = average speed

$$E_T = \frac{1}{2} m v^2 = C T$$

$$v^2 = \frac{2CT}{m}$$

$$v = \sqrt{\frac{2CT}{m}} \quad \text{and} \quad C = \frac{3R}{2N_{avogadro}}$$

Note: $R = 8.31\ kg.m^2.s^{-2}.mol^{-1}.K^{-1}$!!!

$$v = \sqrt{\frac{3RT}{M}} \qquad M = m \times N_{avogadro}$$

MEMORIZE THIS EQUATION — molar mass — particle mass

$$v = \frac{1}{\sqrt{M}}$$

For two types of molecules A and B, there will be two average velocities v_A and v_B.

$$\frac{v_A}{v_B} = \sqrt{\frac{M_A}{M_B}}$$

"The speed of gaseous particles is inversely proportional to the square root of the molar mass at constant Temperature, T". Hence, the higher the molar mass, the lower the average speed of that molecule at constant temperature, T.

Now we can also compare the average speed for particles of a given gas at two different temperatures, T_1 and T_2.

$$v \propto \sqrt{T} \Rightarrow \frac{v_1}{v_2} = \sqrt{\frac{T_1}{T_2}}$$

"The average speed of same gas molecules is directly proportional to the square root of the absolute temperature."

Example 1: Calculate the average speed of O_2 molecules at 25.00 ^oC.

$$v = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.31\ kg.m^2.s^{-2}.mol^{-1}.K^{-1} \times 298.15\ K}{32 \times 10^{-3}\ \frac{kg}{mol}}}$$

$$v_{O_2} = 482\ m/s$$

Example 2: Consider the following gases: He, Cl_2, CH_4, and NH_3. Rank the average speeds of this gases at the same temperature T.

He = 4.0 g/mol
Cl_2 = 71.0 g/mol
CH_4 = 16.0 g/mol
NH_3 = 17.0 g/mol

$$v_{He} > v_{CH_4} > v_{NH_3} > v_{Cl_2}$$

$$v = \frac{1}{\sqrt{M}}$$

The lower the molar mass, the higher the average speed.
Hence, Helium has the lowest molar mass and the highest average speed.