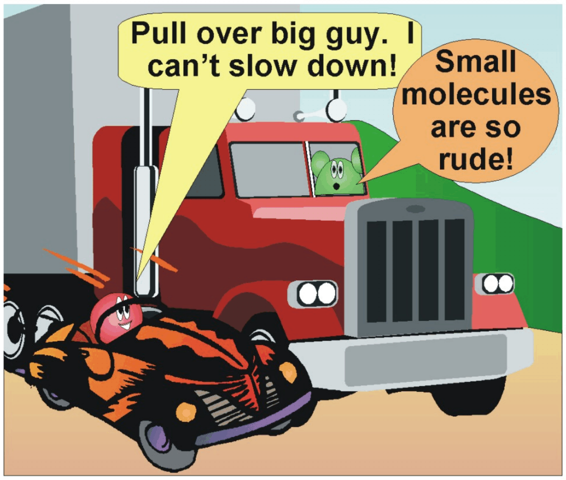
Name ______________________________

Date ________________ Period _____

Graham's Law

A helium balloon bobs up and down, tethered by a string and buoyed by the air. The helium keeps it afloat. In a few days it will fall. The helium escapes from the balloon slowly through microscopic holes. The passage of the gas through microscopic holes is called *effusion*. As the temperature increases, molecules move faster, and the effusion rate increases. Temperature is not the only factor that influences the effusion rate. So does molecular mass.

Temperature is the average kinetic energy of the molecules. Kinetic energy (K.E.) is related to both the mass(m) and speed (v) of the molecules as follows: K.E. = $\frac{1}{2} mv^2$. For two gases at the same temperature, only the masses effect the relative rate of effusion. See below



Graham's law and molecular road rage

For gas A and gas B at the same temperature:

$T_A = T_B \; so \; \frac{1}{2} m_A v_A{}^2 = \frac{1}{2} m_B v_B{}^2$

$\frac{M_A}{m_A} = \frac{M_B}{m_B}$ where M = molar mass

- $\frac{1}{2} M_A v_A{}^2 = \frac{1}{2} M_B v_B{}^2$
- $M_A v_A{}^2 = M_B v_B{}^2$
- $\frac{v_A{}^2}{v_B{}^2} = \frac{M_B}{M_A}$
- $\frac{v_A}{v_B} = \frac{\sqrt{M_B}}{\sqrt{M_A}} \; so \; \frac{rate\ of\ effusion\ of\ A}{rate\ of\ effusion\ of\ B} = \frac{\sqrt{M_B}}{\sqrt{M_A}}$

Graham's Law

$$\frac{rate\ of\ effusion\ of\ A}{rate\ of\ effusion\ of\ B} = \frac{\sqrt{M_B}}{\sqrt{M_A}}$$

Using Graham's law, it is possible to calculate the molar mass of an unknown gas based on its effusion rate compared to a known gas. It is also possible to calculate the relative effusion rates of two known gases. See the sample problems below.

Sample Problem 1

How does the rate of effusion of fluorine compare to the rate of effusion of chlorine?

$$\frac{rate\ of\ effusion\ of\ F_2}{rate\ of\ effusion\ of\ Cl_2} = \frac{\sqrt{71.0}}{\sqrt{38.0}} = 1.37$$

Sample Problem 2

What is the molar mass of a gas that effuses at 1.37 times the speed of oxygen?

$$\frac{rate\ of\ effusion\ of\ A}{rate\ of\ effusion\ of\ O_2} = \frac{\sqrt{M_{O_2}}}{\sqrt{M_A}}$$

$$1.37 = \frac{\sqrt{32.0\,g/mol}}{\sqrt{M_A}} \; so \; (1.25)^2 = \frac{32.0\,g/mol}{M_A}$$

$$M_A = \frac{32.0\,g/mol}{(1.37)^2} = 17.0\,g/mol$$

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Answer the questions below based on the preceding examples.

1. How many times faster does hydrogen sulfide effuse than krypton?

2. What is the molar mass of a gas that effuses 2.00 times faster than methane (CH_4)?

3. What is the molar mass of a gas that effuses 1.19 times faster than carbon monoxide?

4. How many times faster does ammonia (NH_3) effuse than xenon?

5. What is the molar mass of a gas that effuses 1.27 times faster than propane (C_3H_8)?

6. What is the molar mass of a gas that effuses 1.07 times faster than nitrogen?

7. How many times faster does hydrogen effuse than neon?