Unit 5 Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Gases Date \_\_\_\_\_\_\_\_\_\_\_\_ Block \_\_\_\_

Unit 5C – Molecular Speed and Effusion

### Knowledge/Understanding:

* what Graham’s Law means in relation to Kinetic-Molecular Theory

### Skills:

* calculate molecular speeds of gases
* solve problems using Graham’s Law

effusion: the escape of a gas through a small opening.

Graham’s Law of Effusion: Graham’s Law says that lighter molecules move faster and heavier molecules move more slowly (which makes sense if we assume they have the same amount of energy, knowing KE = 1/2mv2). If you have a small opening, such as a leak in a tank, the lighter molecules will escape faster.

temperature: a measure of the average kinetic energy of the molecules in a substance

root mean square speed: the average speed of the gas molecules. “Root mean square” means this average is calculated by determining the average of the squares of the speeds, then taking the square root of the result.

## Root Mean Square Speed of Gas Molecules

The root mean square velocity (vrms) of gas molecules is given by the formula[[1]](#footnote-1):

1. 2 

where M is the molar mass of the gas in , R is the gas constant for ***energy*** , and T is the temperature in Kelvin. The quantity vrms comes out in units of .

This equation is partially derived using the equation for temperature (Kelvin) as well.

1. KEave = 3/2RT

Again, we are speaking in terms of energy, so the gas constant R should have joules in the units.

**Sample Problem:**

A tank is filled with a mixture of helium and oxygen at a temperature of 25°C. Calculate the root mean square speed (vrms) of the oxygen molecules. (Note: oxygen is O2.)



## Graham’s Law

From physics, the formula for kinetic energy is:



where *m* is the mass and *v* is the velocity (speed).

If two molecules have the same temperature, then they have the same kinetic energy. If molecule #1 has mass *m*1 and velocity *v*1 and molecule #2 has mass *m*2 and velocity *v*2, then the kinetic energies are:



If we cancel the ½ from both sides, and rearrange so the masses are on one side and the speeds are on the other, we get:



Taking the square root of both sides:

(3) 

This formula is called Graham’s Law, named after Thomas Graham who first proposed it.

For the purpose of these calculations, the mass of a molecule is its molar mass, which is simply the same number of grams as the molecule’s atomic mass.

Because the rate of effusion is the velocity divided by time, the units of time cancel, giving

(4) 

### Sample Problem:

If the speed of oxygen molecules in a tank is , calculate the speed of helium molecules in the same tank.



**Sample Problem:**

Sulfur dioxide gas and hydrogen gas are placed in a rigid container together. How much faster or slower does hydrogen effuse from a small opening than sulfur dioxide at the same temperature?

1. This formula is usually given as , but this requires that M be expressed in . Because we are not deriving the formula in this class, it makes sense to change the factor from 3 to 3000 in order to keep molar mass expressed in the more familiar units of .

   2 Velocity (vrms) is depicted as urms on the AP Test [↑](#footnote-ref-1)