Temperature, kinetic energy, and speed of particles in a gas

From the kinetic molecular theory:

The average kinetic energy of gas particles is proportional to the temperature of the gas

- At any given temperature, the molecules of all gases have equal kinetic energy
- If two different gases are at the same temperature, they will have the same kinetic energy

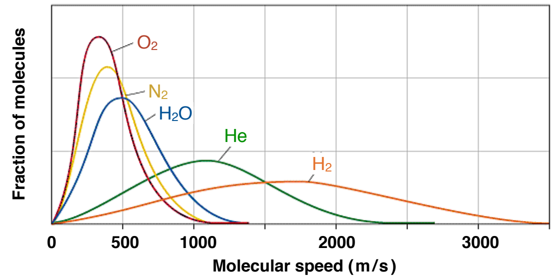
Kinetic energy is a function of both **mass** and **velocity (speed)**

$$KE = (1/2)\, m\, v^2$$

Atoms/molecules of *different gases* have *different masses*

- *while molecules of two different gases at the same temperature will have the same kinetic energy, they will **not** move at the same speed*

Effect of molecular mass on molecular speed

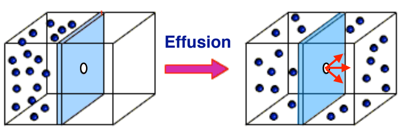


At any given temperature:

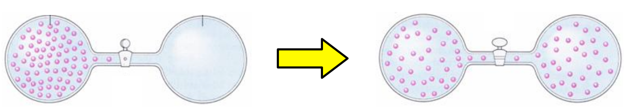
- lighter gas molecules will move at higher average speeds
- heavier gas molecules will move at lower average speeds

Two gas phenomena affected by the dependence of molecular speeds on molecular mass

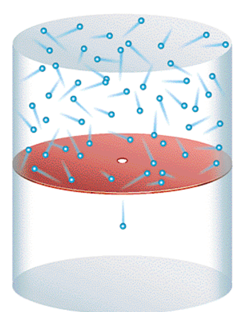
Effusion: The escape of gas molecules through tiny holes in their container



Diffusion: The spreading of gas molecules from a region of high concentration to a region of low concentration



Graham's law of effusion



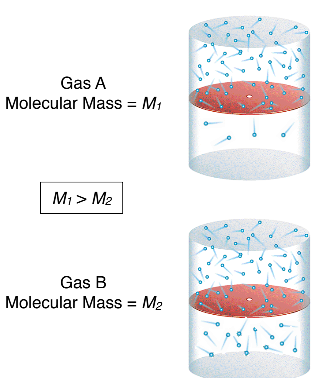
The effusion rate of a gas is inversely proportional to the square root of its molar mass

$$r \propto \sqrt{\frac{1}{M}}$$

The *greater* the molecular mass of a gas, the *slower* its rate of effusion

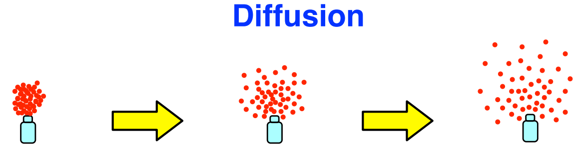
Graham's law of effusion

For two different gases at the same temperature and pressure in identical containers, the *lighter gas effuses more rapidly*



$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

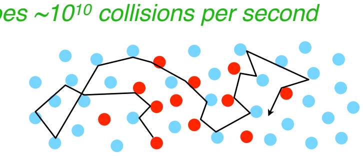
Diffusion



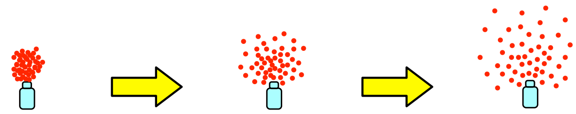
The rate of diffusion is slow relative to the speed of individual molecules (on the order of 100-1000 m/s)

This is due to the frequent collisions between gas molecules as they move around

-- for a gas at atmospheric pressure, each molecule undergoes ~10^{10} collisions per second



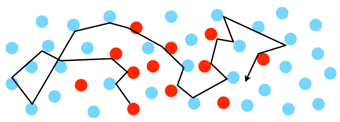
Diffusion



Calculating rates of diffusion is more complicated than calculating rates of effusion

-- *diffusion rates depend strongly on pressure as well as factors like particle size, air currents/turbulence, etc.*

But the general effect of molecular speed / mass summarized by Graham's law for effusion still holds true



At any given temperature: The *greater* the molecular mass of a gas, the *slower* its rate of diffusion