Announcements for Tuesday, 26NOV2024

- Office Hours are **cancelled** today
- Conflicts with Exam 3 and Location Requests
  - Due by Friday, 29NOV2024, 11:59 PM
  - See Canvas Announcement from 25NOV2024
- **This Week: Changes in Designation of Class Days**
  - There **ARE** recitations this week
  - Tomorrow, 27NOV2024, is ***Friday Classes***
- Thanksgiving Break
  - Thursday, 28NOV2024 – Sunday, 01DEC2024
  - No classes for the entire university

ANY GENERAL QUESTIONS? Feel free to see me after class!

Try These On Your Own

- The oil produced from eucalyptus leaves contains the volatile organic compound eucalyptol. At 190. °C, a sample of eucalyptol vapor had a density of 0.400 g/L and a pressure of 60.0 torr. Calculate the molar mass of eucalyptol. **193 g/mol**

- 50.0 g of an unknown gas occupies a volume of 7.686 L at STP. Identify the unknown gas from the following: He, Ne, Ar, Xe, HI, or SF_6?
  SF_6 (146 g/mol)

- Consider a balloon filled with helium at 27 °C at atmospheric pressure. To what temperature should the helium be brought to cause an increase in density by a factor of 1.5? **–73 °C (200 K)**

Try This On Your Own

A mixture of CO_2(g) and O_2(g) that is 60.0% carbon dioxide by mass exerts a pressure of 894 torr at 25 °C. What percentage of the total pressure is due to the partial pressure of the oxygen gas? **47.9%**

$$60.0\ \mathrm{g\ CO_2} \times \frac{1\ \mathrm{mol\ CO_2}}{44.01\ \mathrm{g\ CO_2}} = 1.36\ \mathrm{mol\ CO_2}$$

$$40.0\ \mathrm{g\ O_2} \times \frac{1\ \mathrm{mol\ O_2}}{32.00\ \mathrm{g\ CO_2}} = 1.25\ \mathrm{mol\ O_2}$$

$$\chi_{O_2} = \frac{\mathrm{mol\ O_2}}{\mathrm{mol\ CO_2} + \mathrm{mol\ O_2}} = \frac{1.25\ \mathrm{mol}}{1.36\ \mathrm{mol} + 1.25\ \mathrm{mol}} = \frac{1.25\ \mathrm{mol}}{2.61\ \mathrm{mol}} = 0.479$$

47.9% of the amount of gas mixture is O_2(g), therefore 47.9% of the total pressure of the gas mixture is due to O_2(g)

Try These On Your Own

- A container holds equal masses of He, CO_2, and Ar. The pressure within the container at 156 °C is 18.4 atm. What is the partial pressure of Ar? **P_{Ar} = 1.55 atm**

- In the reaction of Zn with excess HCl(aq), 0.010 mol H_2(g) was collected over water at 25 °C and a total pressure of 802.8 mmHg. What volume of hydrogen gas was collected? The vapor pressure of water at 25 °C is 23.78 mmHg. **V_{H_2} = 240 mL**

- At 2730 °C, hydrogen molecules dissociate into hydrogen atoms according to the equation $H_2(g) \rightarrow 2\ H(g)$. 10.0 g H_2(g) is placed into a 100.0-L container, sealed and heated to 2730 °C so that the hydrogen molecules begin to dissociate. What is the partial pressure of hydrogen molecules and the total pressure within the container once 25% of H_2 has dissociated? **P_{H_2} = 9.2 atm, P_{total} = 15 atm**

Kinetic Molecular Theory of Gases

- simplest ***model*** for gas behavior

1. gases are treated as particles in constant motion
2. particles move in straight lines until there is a collision with another particle or the container wall
   - particles don't exert forces over each other unless colliding
3. the collisions are completely elastic
   - exchanges of energy may occur but there are no overall losses
4. the size of the particles are negligibly small
   - there is lots of empty space between particles
5. the average kinetic energy of a particle is proportional to the temperature in Kelvins
   - temperature is actually a measure of the KE of a particle

- the mathematical relationships found in the gas laws can be conceptually explained by the kinetic molecular theory

Temperature and Molecular Velocities

- **temperature =** measure of the average KE of a particle
- although different gases *at the same temperature* have the same average KE, they don't have the same velocities
  - example He(g) vs. Ne(g) at 373 K

- in a gas mixture at a given temperature, lighter particles move faster (on average) than heavier particles **Why?**
- the relationships between mass, temperature and velocity can be expressed mathematically

Velocities of Gas Particles

$$u_{rms} = \sqrt{\frac{3RT}{\mathcal{M}}}$$

- **u_{rms}** = root mean square velocity
  - conceptually and numerically similar to the average velocity
- R = 8.314 J/mol·K
- T = temperature (K)
- $\mathcal{M}$ = molar mass (**kg**/mol)

Velocities of Gas Particles

$$u_{rms} = \sqrt{\frac{3RT}{\mathcal{M}}}$$

He(g) vs. Ne(g) at 373 K

$$u_{rms} = \sqrt{\frac{(3)(8.314\ \mathrm{J/mol \cdot K})(373\ \mathrm{K})}{\mathbf{0.004003\ kg/mol}}}$$

$$u_{rms} = \mathbf{1520\ m/s}$$

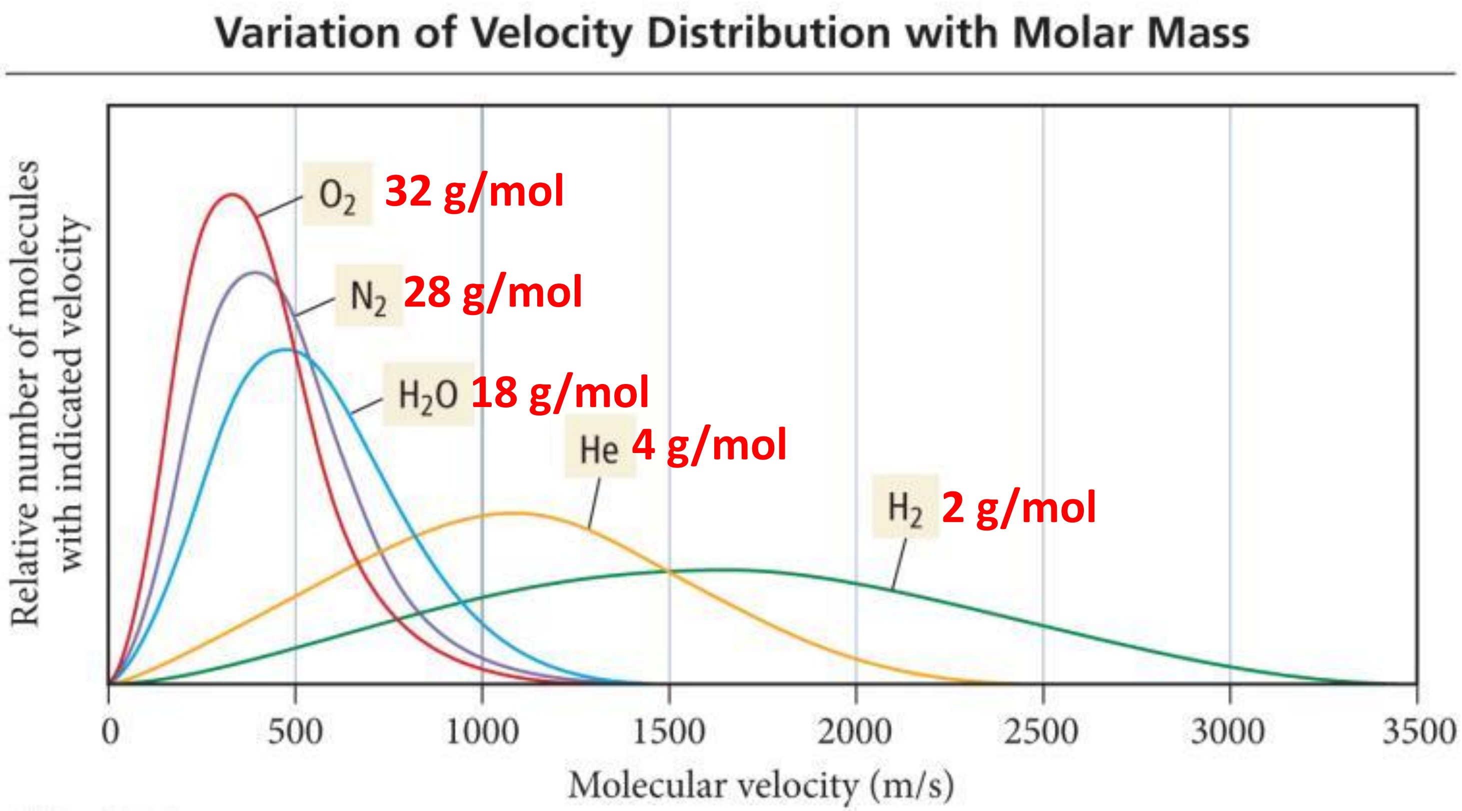
$$u_{rms} = \sqrt{\frac{(3)(8.314\ \mathrm{J/mol \cdot K})(373\ \mathrm{K})}{\mathbf{0.02018\ kg/mol}}}$$

$$u_{rms} = \mathbf{679\ m/s}$$

The Relationship between Molar Mass and Velocity

$$u_{rms} = \sqrt{\frac{3RT}{\mathcal{M}}}$$

- under a given set of conditions gas particles will exhibit a distribution of velocities

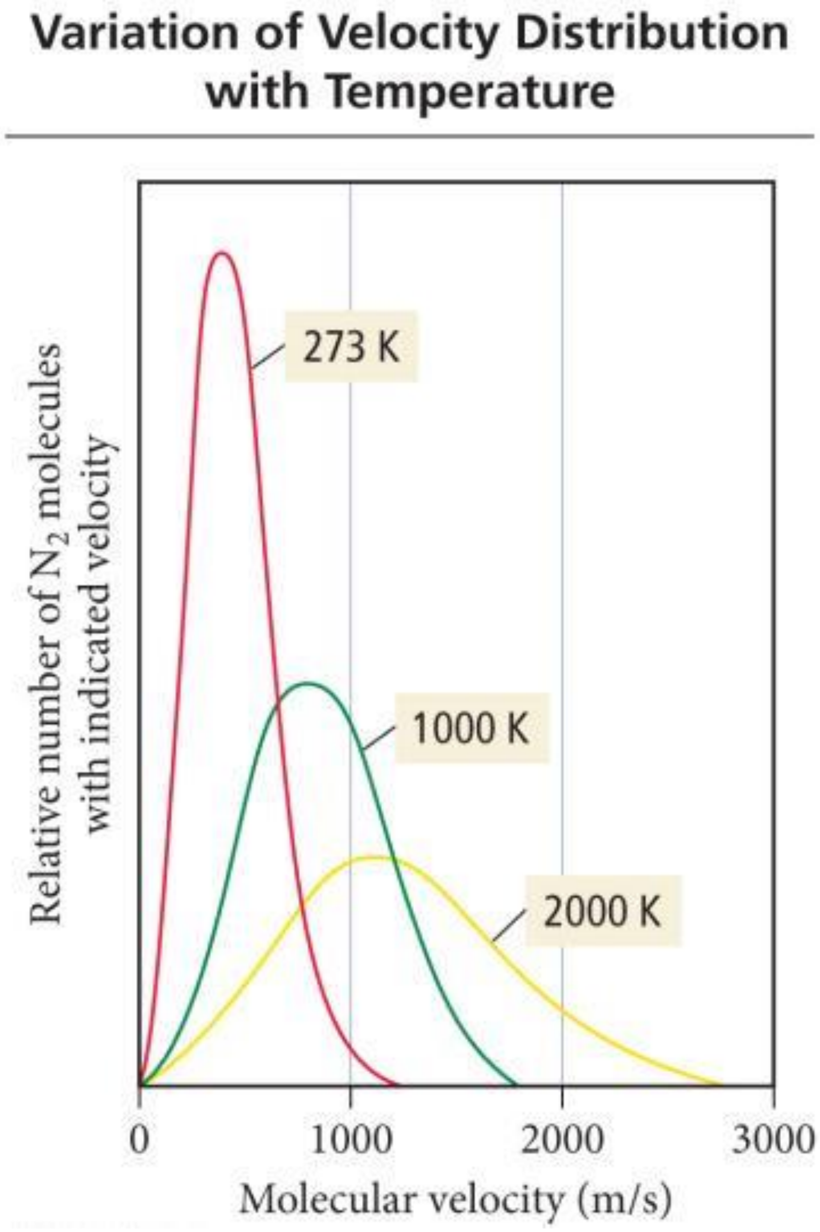


at a given temperature, lighter particles have a higher average velocity (and a broader distribution) than heavier particles

The Relationship between Temperature and Velocity

$$u_{rms} = \sqrt{\frac{3RT}{\mathcal{M}}}$$

- as the temperature of a gas sample increases, the velocity distribution of the molecules shifts toward higher velocity
- the distribution spreads out resulting in more molecules with faster speeds



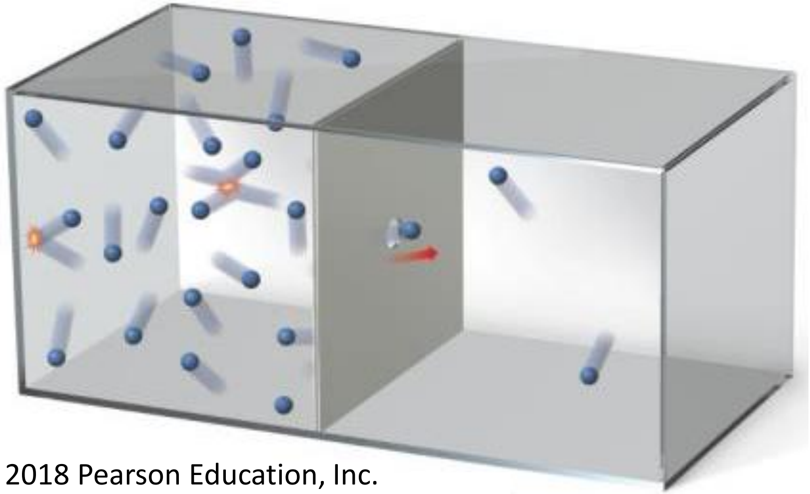
Kinetic Molecular Theory of Gases – Simulation

https://media.pearsoncmg.com/bc/bc_0media_chem/chem_sim/kmt/KMT.php

Diffusion and Effusion

- **diffusion =** gas spreading out in response to concentration differences
- **effusion =** gas escaping from a container into a vacuum through a small hole
  - i.e., a gas leak
- both are functions of gas velocity and are mathematically related to temperature and particle mass

perfume diffusing from a bottle



gas particles effusing from a hole

Effusion/Diffusion Rates

- units for effusion/diffusion rates can vary

$$\frac{\text{amount}}{\textbf{time}} \text{ or } \frac{\text{volume}}{\textbf{time}} \text{ or } \frac{\text{mass}}{\textbf{time}} \text{ or } \frac{\text{distance}}{\textbf{time}} \text{ or} \ldots$$

- the rate of diffusion or effusion of a gas is *inversely proportional* to the **square root** of its molar mass

- Graham's Law of Effusion

$$\frac{rate_{\mathbf{A}}}{rate_{\mathbf{B}}} = \sqrt{\frac{\mathcal{M}_{\mathbf{B}}}{\mathcal{M}_{\mathbf{A}}}}$$

$rate_A$ = effusion rate of **gas A**
$rate_B$ = effusion rate of **gas B**
$\mathcal{M}_A$ = molar mass of **gas A**
$\mathcal{M}_B$ = molar mass of **gas B**

  - the effusion rate of a known gas can be compared against the effusion rate of an unknown gas to identify it

Effusion ***Rate*** vs Effusion ***Time***

- effusion **rate** = related to the **speed** at which a gas escapes a container
- effusion **time** = the **time** it takes for a gas to escape a container

rate ≠ time!! (compare units)

- a gas exhibiting a large effusion rate exhibits a correspondingly small effusion time and vice-versa
  - a gas with effusion rate = 100 m/s takes 1 s to travel 100 m
  - a gas with effusion rate = 1 m/s takes 100 s to travel 100 m

- Graham's Law of Effusion

$$\frac{rate_{\mathbf{A}}}{rate_{\mathbf{B}}} = \sqrt{\frac{\mathcal{M}_{\mathbf{B}}}{\mathcal{M}_{\mathbf{A}}}} \quad \mathbf{BUT} \quad \frac{\text{effusion time}_{\mathbf{B}}}{\text{effusion time}_{\mathbf{A}}} = \sqrt{\frac{\mathcal{M}_{\mathbf{B}}}{\mathcal{M}_{\mathbf{A}}}}$$

An unknown gas effuses at a rate that is 1.578 times that of Ar(g) (39.95 g/mol) under the same conditions. Calculate the molar mass of the unknown gas.
16.04 g/mol

Try These On Your Own

- To what temperature (°C) would Xe atoms (131.3 g/mol) have to be brought to so that they have the same average velocity as He atoms (4.00 g/mol) at –10 °C?

- Under a certain set of conditions it takes 25.0 s for an amount of CO_2(g) to escape from a container. How long would it take for the same amount of N_2O_4(g) to escape from the same container under the same conditions?

- 2.0 g He atoms occupy a rigid container at a pressure of 2.00 atm. The root mean square velocity of the atoms is 1580 m/s. What is the volume of the container?