*Kinetic Molecular Theory of Gases

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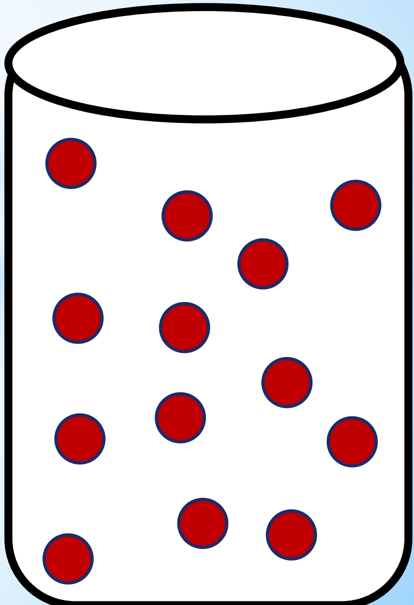
*The Microscopic Basis for Gas Pressure…

* Gas molecules are in constant random motion in a container.
* Molecules create "pressure" through collisions with the walls of the container.
* Pressure is a force per unit area



$$\mathbf{P = \frac{Force}{Area}}$$

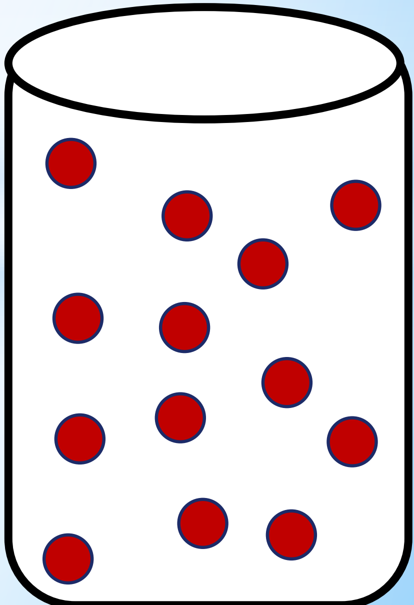
The Microscopic Basis for Gas Pressure…

- Suppose we decrease the volume of the container, but keep the temperature and moles of gas constant.

- What happens to the pressure?

- **It increases…**

  (more collisions per unit area)



Pressure is related to *molecular motion*.

The Microscopic Basis for Temperature…

* What about temperature?
* **Recall kinetic energy**

$$K.E. = \frac{1}{2} mv^2$$

Kinetic molecular theory says that the average velocity of gas molecules increases with increasing temperature.

Temperature ↑, Avg velocity ↑

* The Microscopic Basis for Temperature…

* Since the average velocity of gas molecules increases with increasing temperature, the number of collisions with the walls of the container increases, as well.

Temperature ↑

Avg velocity ↑

 # collisions↑

The Microscopic Basis for Temperature…

* More energy, through momentum, is transferred to the walls of the container.

Temperature ↑, Avg velocity ↑, # collisions ↑

Energy transferred to the walls of the container increases!

* **Temperature is a measure of the average kinetic energy of the gas molecules.**

* The Kinetic Theory of Gases

The Kinetic Theory of Gases derives relationships between the macroscopic properties of gases (pressure, volume, and temperature) and the microscopic behavior of the molecules in the gas.

It provides a *microscopic* definition of temperature as a measure of the average kinetic energy of the molecules in a gas.

Assumptions in the Kinetic Theory of Gases

- **The gas is ideal.** (The molecules do not interact with each other.)
- **Collisions** of the molecules with the walls of the vessel **are elastic** (i.e., no energy is lost in the collision).
- **Gas molecules move constantly** in random directions with a distribution of speeds. Overall, they have an **average velocity**.
- The **average kinetic energy** of the gas particles is **proportional to temperature**.

*Other Info Regarding the Kinetic Theory of Gases

The kinetic theory of *gases* only involves kinetic energy…no potential energy. (This is why the collisions are 'elastic.') This will change when we talk about *real gases*, as opposed to ideal *gases*!

Molecules at the same temperature have the same <u>average</u> kinetic energy, regardless of their identity. *However, remember that kinetic energy is related to both mass and velocity.*

*The Average Kinetic Energy of Gas Molecules

According to the Kinetic Theory of Gases, the average kinetic energy per mole of gas molecules can be calculated

$$\mathbf{KE} = \frac{\mathbf{3}}{\mathbf{2}}\mathbf{RT}$$

Notice that the average kinetic energy (in J) of a sample of gas molecules only depends on the temperature (in K)!

The gas constant R is the **"Energy R":** $\mathbf{R = 8.314\,\frac{J}{mol\ K}}$

The "Joule" is an energy unit (J). $1\,\mathrm{J} = 1\,\frac{\mathbf{kg\ m^2}}{\mathbf{s^2}}$

*The Average Velocity of Gas Molecules

The rms speed (v_{rms}) or type of average speed of the gas molecules can also be calculated

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

Where M is the molar mass of the gas (**in kg**)
T is the temperature (**in K**)
R is the gas constant **in J!** $\mathrm{R} = 8.314\,\frac{\mathrm{J}}{\mathrm{mol\ K}}$

The "Energy R"

Comparing the Average Velocity of Gas Molecules

Suppose we have a sample of O_2 and H_2 gas molecules in the same flask at the same temperature (298K).

Which type of gas molecules have a higher average velocity (v_{rms})?

* Comparing the Average Velocity of Gas Molecules

Suppose we have a sample of O_2 and H_2 gas molecules in the same flask at the same temperature (298 K). Which type of gas molecules have a higher average velocity?

Ask yourself:

Does O_2 or H_2 have greater molar mass (M)?

If the T is constant (and thus the avg KE is the same for both gases), how would v_{rms} relate to M?
$KE = \frac{1}{2}mv^2$

* Comparing the Average Velocity of Gas Molecules

Suppose we have a sample of O_2 and H_2 gas molecules in the same flask at the same temperature. Which type of gas molecules have a higher average velocity?

Does O_2 or H_2 have greater molar mass (M)?

O_2 has a larger M

How does v_{rms} relate to kinetic energy (and thus the temperature?) $KE = \frac{1}{2}mv^2$

The molar mass of the gas molecules is inversely related to the avg velocity, if KE is held constant.

* Comparing the Average Velocity of Gas Molecules

Suppose we have a sample of O_2 and H_2 gas molecules in the same flask at the same temperature. Which type of gas molecules have a higher average velocity?

$$KE = \frac{1}{2}mv^2$$

If M increases ↑, then v_{rms} decreases ↓

The H_2 molecules would have higher avg velocity, since they have a smaller molar mass (M).

* Comparing the Average Velocity of Gas Molecules

Suppose we have a sample of O_2 and H_2 gas molecules in the same flask at the same temperature. Which type of gas molecules have a higher average velocity?

We could also rationalize this using

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

If M increases ↑, then v_{rms} decreases ↓

We get the same answer. ☺