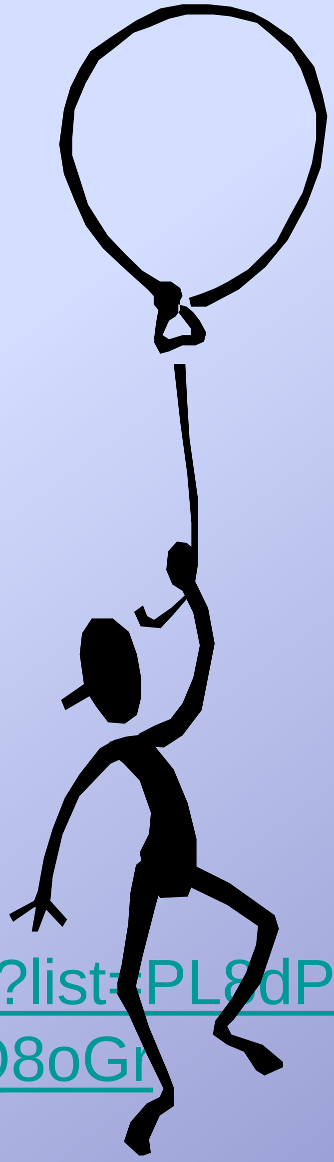
Gases

Chapter 11



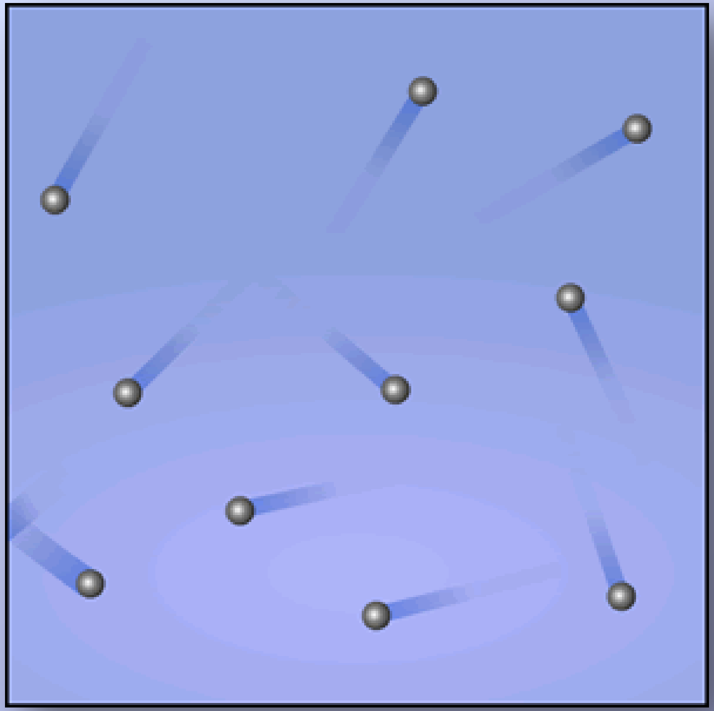
https://youtu.be/TLRZAFU_9Kg?list=PL8dPuuaLjXtPHzzYuWy6fYEaX9mQQ8oGr

The Nature of Gases

- Gases expand to fill their containers
- Gases are fluid – they flow
- Gases have low density
  - 1/1000 the density of the equivalent liquid or solid
- Gases are compressible
- Gases effuse and diffuse

Kinetic Molecular Theory (gases)

- Gas particles are ALWAYS in motion.
- Volume of individual gas particles is ≈ zero.
- Collisions of gas particles with container walls cause the pressure exerted by gas.
- Particles exert no forces on each other.
- Average kinetic energy is proportional temperature (move faster if hotter)



Kinetic Energy of Gas Particles

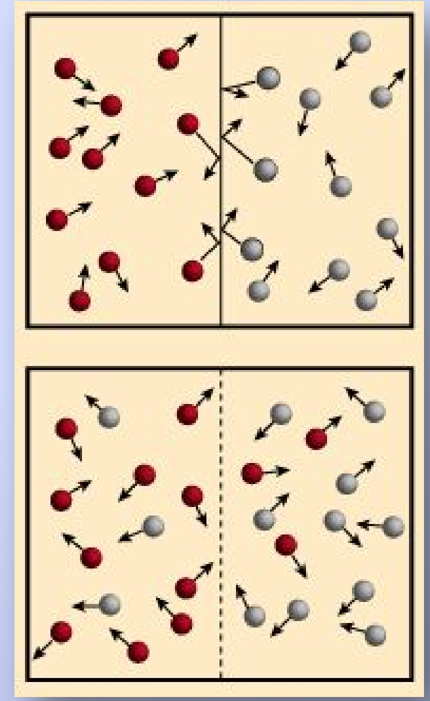
At the same conditions of temperature, all gases have the same average kinetic energy.

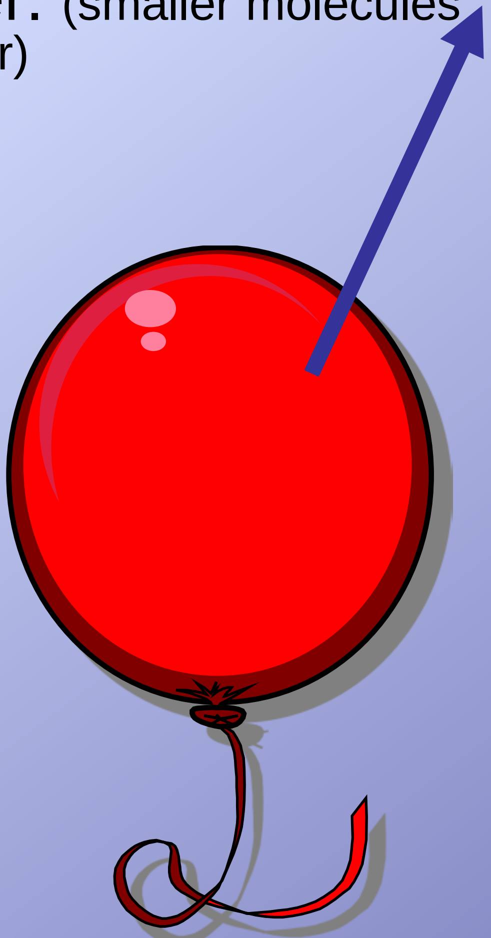
∴ At the *same temperature*, small molecules move ***FASTER*** than large molecules

GAS DIFFUSION AND EFFUSION

- **Diffusion** is the gradual mixing of molecules of different gases. (smaller molecules mix faster, increase temp speeds up process)

- **Effusion** is the movement of molecules through a small hole into an empty container. (smaller molecules move faster)





GAS DIFFUSION AND EFFUSION

Graham's law calculates the effusion & diffusion <u>RATE</u> of gas molecules.

Rate of effusion is inversely proportional to its molar mass- lighter moves faster!

Thomas Graham, 1805-1869. Professor in Glasgow and London.

Graham's Law of Diffusion/effusion

$$\frac{\text{Rate gas 1}}{\text{Rate gas 2}} = \sqrt{\frac{M_2}{M_1}}$$

M_1 = Molar Mass of gas 1

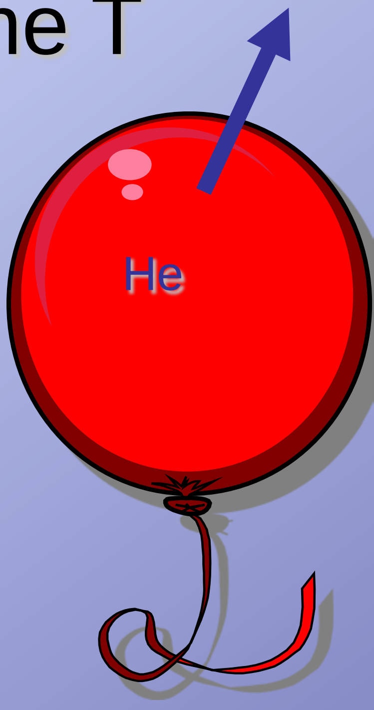
M_2 = Molar Mass of gas 2

Example: Will a balloon filled with He or N_2 deflate faster if P & T are constant?

He Molar mass= 4g

N_2 molar mass = 28g.

He effuses more rapidly than N_2 at same T because it is lighter.



Graham's Law

$$\frac{\text{Rate gas 1}}{\text{Rate gas 2}} = \sqrt{\frac{M_2}{M_1}}$$

Compare the rates of effusion of Helium (gas 1) & Nitrogen (gas 2)…

$$\frac{\textbf{Rate He}}{\textbf{Rate } \mathbf{N_2}} = \sqrt{\frac{28 g N_2}{4 g He}} = \mathbf{2.7}$$

Helium gas effuses 2.7 times faster than nitrogen gas.

Variables that Describe a Gas

- Pressure (atm, mmHg, kPa)
- Volume (L)
- Temperature (˚C or K)
- Number of moles (mol)

What happens if you…

- decrease the volume of the container?
  - Pressure may increase
  - Temperature may increase
- increase the temperature?
  - Pressure may increase
  - Volume may increase
- Increase the pressure?
  - Temperature may increase
  - Volume may decrease

Boyle's Law

- Boyle's Law states that the volume of a gas varies inversely with its pressure if temperature is held constant.

What does that mean?

- If volume goes up the pressure goes down! (or vice versa!)

$$P_1V_1 = P_2V_2$$

Lets Practice Boyle's Law

- A sample of oxygen occupies a volume of 250.0mL at 740.0 torr pressure. What volume will it occupy at 800.0 torr pressure?

Identify what you know:

V_1=250.0 mL

P_1=740.0 torr

P_2= 800.0 torr

V_2=?

- Solve for what you don't know

$P_1V_1 = V_2 P_2$

(740 torr) (250 ml) = V_2 (800.0 torr)

V_2 = 231 mL

Charles' Law

- The volume of a gas varies directly with the Kelvin temperature (when pressure is constant)

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Temperature must be converted into Kelvin

$K = {}^{o}C + 273$

Lets Practice Charles' Law

- A sample of nitrogen occupies a volume of 250.0mL at 25 ^oC. What volume will it occupy at 95 ^oC?

1) Identify what you know:

V_1=250.0 mL T_1= 25 ^oC (298 K)

T_2= 95 ^oC (368 K) V_2=?

2) Convert Temp into kelvin:

K= 25^{o}C + 273= 298 K & K= 95^{o}C + 273= 368 K

3) Solve:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad \frac{250mL}{298\ K} = \frac{V_2}{368K} \qquad V_2 = 309\ mL$$

Gay-Lussac’s Law

- Temperature and Pressure are directly proportional if mass and volume are kept constant.
- When one increases, the other increases and vice versa.
- Why? Think collisions—remember volume is constant.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Temperature must be in Kelvin.

Example: Tire will not stretch with energy increase. Aerosol can will not expand with energy increase.

Let's Practice

A gas has a pressure of 6.58 kPa at 540 K. What will the pressure be at 210 K if the volume remains constant?

Identify what you know:

P_1 = 6.58 kPa; T_1 = 540 K

P_2 = ? T_2 = 210 K

Solve for what you don't know

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad \frac{6.58\ \text{kPa}}{540\ \text{K}} = \frac{P_2}{210\text{K}}$$

$$P_2 = \frac{(6.58\ \text{kPa})\ (210\text{K})}{540\ \text{K}} = 2.56\ \text{KPa}$$

The Combined Gas Law

- If you write Boyle's, Charles' and Gay-Lussac's gas laws as one formula, then all three variables can change; only mass remains constant.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Why are we interested?

It allow us to predict what will happen to a gas if the conditions change.

So, what's the relationship?

between volume, temperature, and pressure

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

AKA:

The Combined Gas Law

Allows you to predict what will happen to a gas if some of the conditions change!

Lets Practice!

- A gas with a volume of 4.0L at 90.0kPa expands until the pressure drops to 20.0kPa. What is the new volume if the temperature remains constant?
- Identify what you know

  V_1=4.0L

  P_1=90.0kPa

  P_2=20.0kPa

  T_1=T_2
- Solve for what you don't know

$$V_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{P_2}$$

V_2 = 18.0L

Now you try!

- A gas with a volume of $3.00x10^2$mL at 150.0˚C is heated until its volume is $6.00x10^2$mL.What is the new temperature of the gas if the pressure remains constant at 1.0 atm during the heating.

T_2= 846 K