

Unit 5

Gases

Objectives

- Discuss the properties of gases (especially in terms of SI units).
- Define and identify the gas laws.
- Perform calculations using the ideal gas law.
- Define conditions of STP (Standard Temperature and Pressure).
- Apply the gas laws to stoichiometric calculations.
- Calculate the molar mass of a gas using laboratory data and the ideal gas law.
- Explain the properties of ideal gases as defined by the Kinetic Molecular Theory.
- Define effusion and diffusion.
- Explain how real gases differ from ideal gases.

Outline

I. Properties of Gases

- A. Properties of Ideal Gases
- B. SI Units of Pressure
 - 1. Barometer

II> The Gas Laws

- A. Relationships Between Properties
- B. Boyle's Law
- C. Charles' Law
- D. Gay Lussac's Law
- E. Avogadro's Law
- F. Ideal Gas Law
- G. The Combined Gas Law
- H. Dalton's Law of Partial Pressures

III. Gas Stoichiometry

IV. Kinetic Molecular Theory

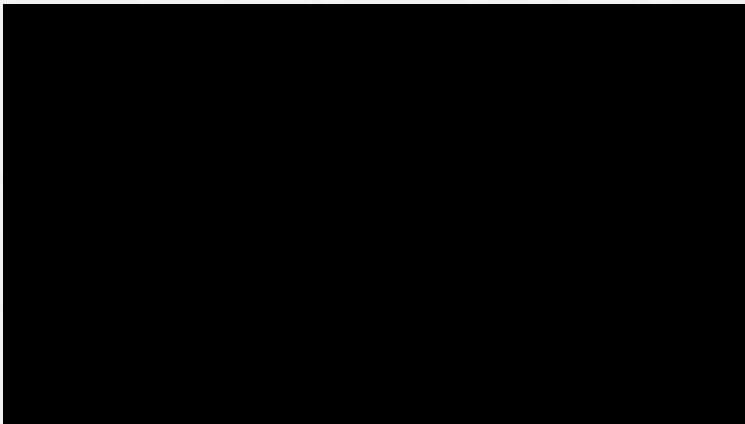
- A. Ideal Gases
- B. Gas Diffusion and Effusion

V. Real Gases

- A. Properties of Real Gases
- B. Intermolecular Forces
- C. Van der Waals Equation
- D. Examples of Real Gases

An Introduction to Gases

- Remember from Unit 1 that gases:
 - Take up the shape AND volume of a container.
 - Are in constant, rapid, and random motion.
 - Are easily compressed
 - Exert force on their surroundings



An Introduction to Gases

- Gases provide instant observations.
- Provide a way to evaluate real world issues.

Pressure

- The amount of force applied over a given area.

$$\frac{\textit{Force}}{\textit{Area}} = \textit{Pressure}$$

Units of Pressure

- SI Units: Pascal (Pa) contains units
 $\frac{\text{Newton}}{\text{Meter}^2}$
- More commonly used
 - Atmosphere (atm)
 - Millimeter Mercury (mmHg)
 - Torr

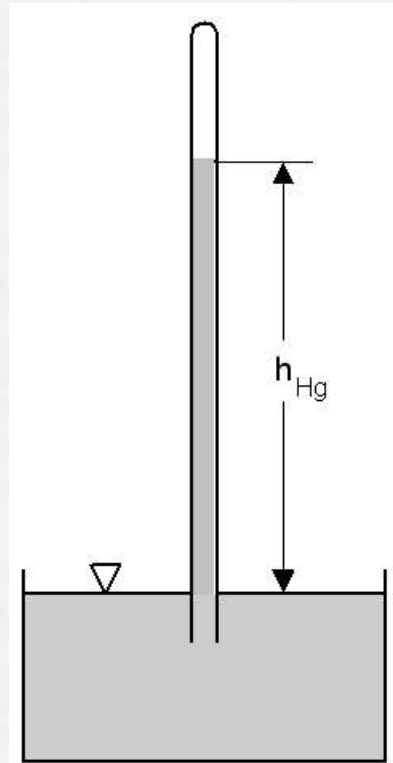
$$101,325 \text{ Pa} = 1 \text{ atm}$$

$$1 \text{ atm} = 760 \text{ mmHg}$$

$$1 \text{ atm} = 760 \text{ torr}$$

Barometers

- Barometers are used to measure atmospheric pressure
- Tube with a vacuum inverted in a petri dish of Hg. Height of Hg rises until the pressure from atmosphere and Hg in tube are equal.
- Height measured in mmHg.



Other Pressure Gauges

- Same concept used on
 - Tire gauges
 - Blood pressure cuffs
 - Etc.



Concept Check

- The local weather station reports the pressure as 30.59 inHg. Convert to mmHg, torr and atm.

777.0 mmHg
1.022 atm

The Gas Laws

- Gas behavior allows us to observe:
 - What happens in a situation.
- We want to convert that to WHY something happens.
 - Scientists developed the gas laws.

The Gas Laws

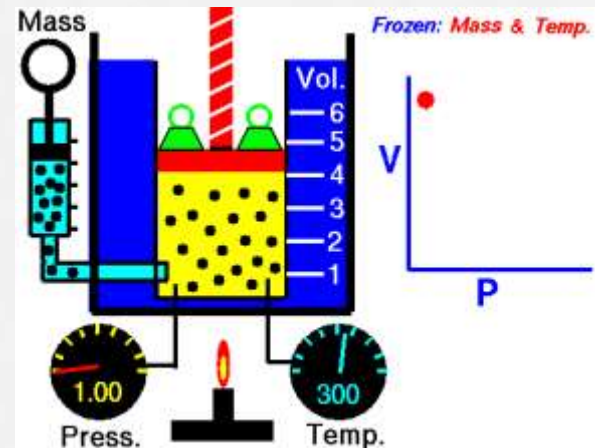
- Relate the properties of gases to one another.
 - Boyle's Law
 - Charles' Law
 - Gay Lussac's Law
 - Avogadro's Law
 - Ideal Gas Law
 - Combined Gas Law
 - Dalton's Law of Partial Pressures.

Boyle's Law

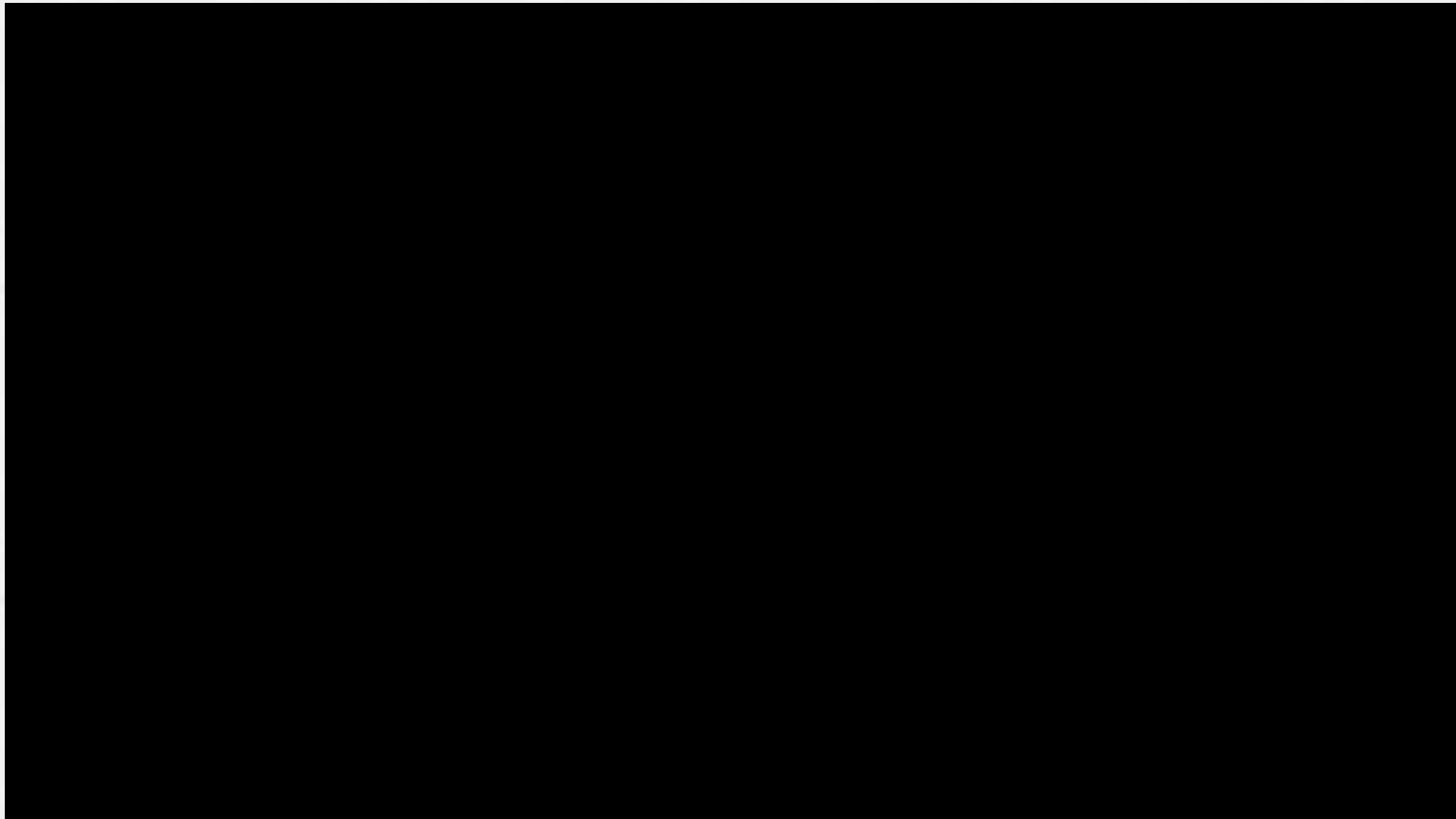
- Pressure is inversely proportional to volume (if temperature and mol are held constant).

$$P_1 V_1 = P_2 V_2$$

- Graph of P vs $\frac{1}{V}$ will give a straight line.



Boyle's Law



Concept Check

- A balloon occupies 5.4 L and has a pressure of 1.04 atm. If the pressure drops to 0.856 atm, what will the new volume be? Assume temperature and mol are held constant.

6.12 L

Concept Check

- A gas inside a balloon occupies 325 mL and exerts a pressure of 4.56 atm. If the pressure drops to 2.26 atm, what will the new volume be? (Assume temperature and mol are held constant.)

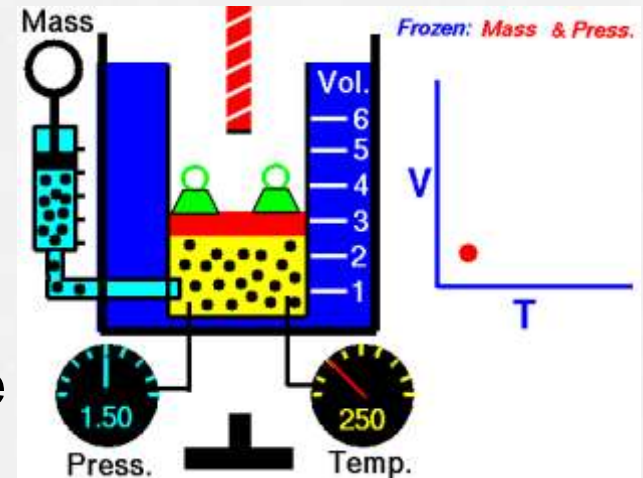
655 mL

Charles' Law

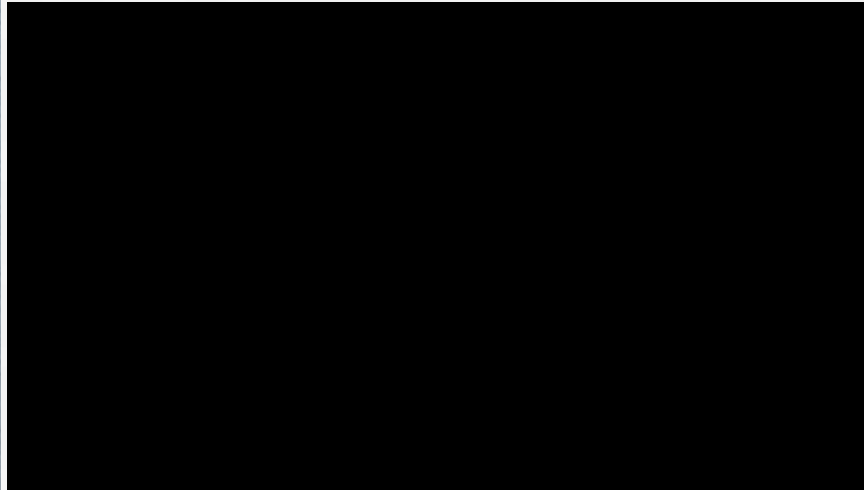
- Temperature (in Kelvin) is directly proportional to volume (if pressure and mol are held constant).

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

- Graph of T (K) vs V will give straight line.



Charles' Law



Concept Check

- A balloon occupies 15.4 L at 25°C. What volume would the gas occupy at 35°C. Assume pressure and mol are held constant.

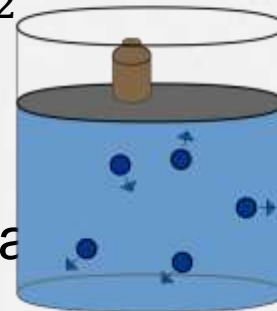
16 L

Gay-Lussac's Law

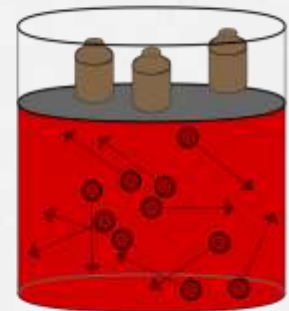
- Temperature (in Kelvin) is directly related to pressure (if volume and mol are held constant).

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

- Graph of P vs T will give a straight line.

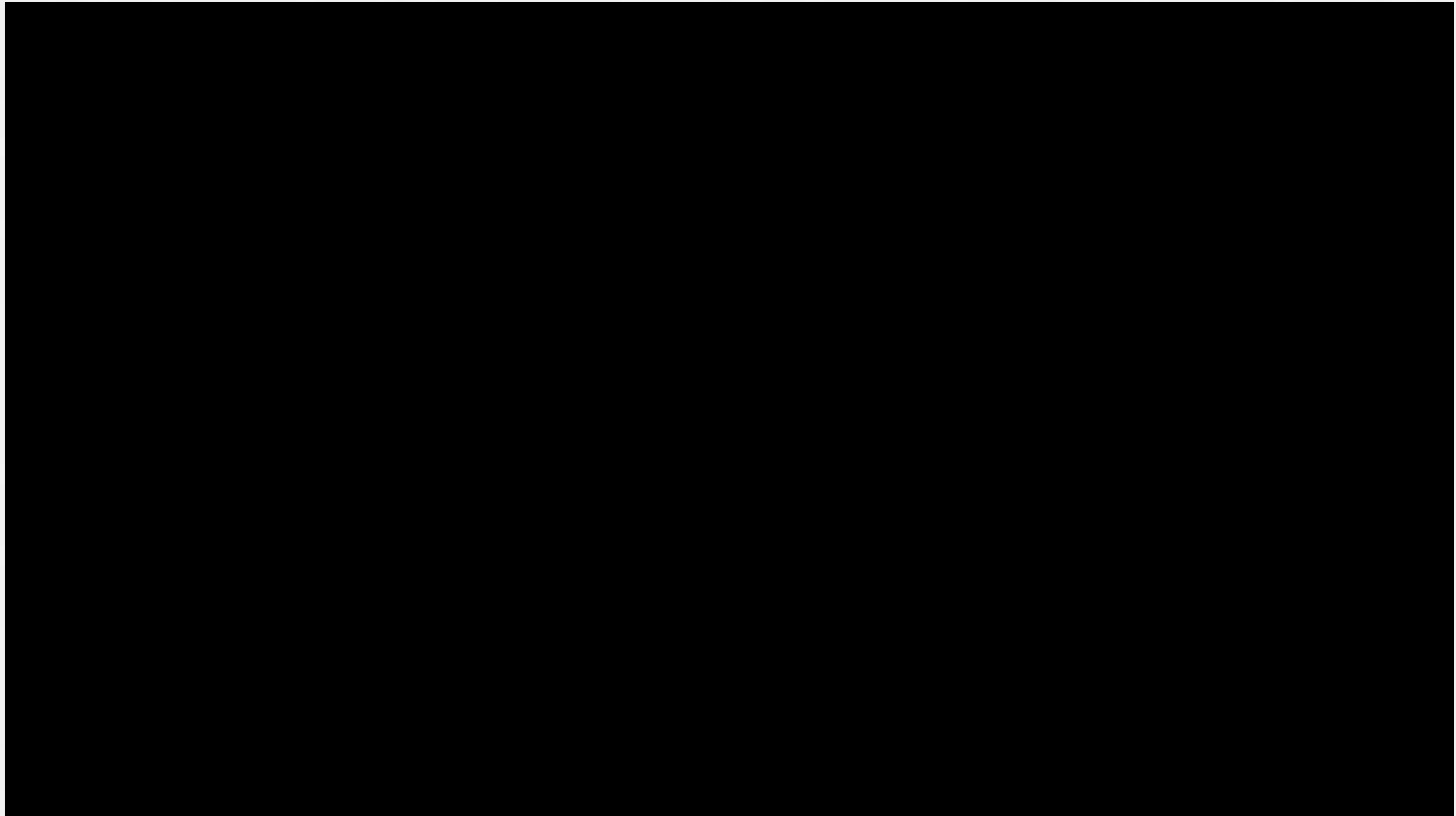


Temperature T



Temperature 3T

Gay-Lussac's Law



Concept Check

- A gas in a closed container (fixed volume and mol) exerts a pressure of 8.64 atm at 50 °C. What would the temperature be (in °C) if the pressure was suddenly raised to 17.2 atm?

370 °C

Avogadro's Law

- Volume is directly proportional to mol (if pressure and temperature are held constant).

$$\frac{n_1}{V_1} = \frac{n_2}{V_2}$$

- Graph of n vs V will give a straight line.

Concept Check

- 4.15 mol of He occupy a 75 L balloon.
What volume will 3.75 mol occupy (at the same temperature and pressure).

68 L

Ideal Gas Law

- We can combine the gas laws into one equation:

$$PV = nRT$$

P = pressure (atm)

V = volume (L)

n = amount (mol)

R = Constant $0.08206 \frac{L \text{ atm}}{\text{mol K}}$

T = temperature (K)

Concept Check

- What volume will a 82.6 g sample of N_2 exerting 7.25 atm at 62.1 °C fill?

11.19 L

Combined Gas Law

- Ideal Gas law can be rearranged to give

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

- R and n are left out because they cancel.

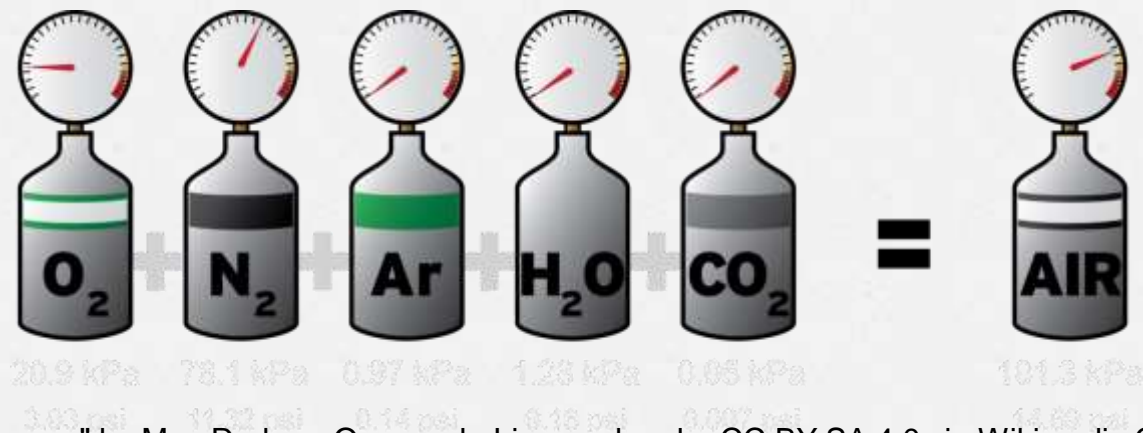
Concept Check

- A sample of He at 37 °C exerts 15.1 atm in a 2425 mL container. If the temperature suddenly cools to 20.1 °C and the volume adjusts to 1815 mL, what will the new pressure be?

19.1 L

Dalton's Law of Partial Pressures

- The pressure of a mixture of gases is equal to the partial pressure of all the individual components.
- A gas exerts the same pressure whether alone or in a mixture.



Real World Application

- Scuba divers use various mixtures of gases depending on the depth of their dive.
 - Mixtures may be Nitrox, Trimix, Oxygne or Heliox
- For very deep dives, they use a mixture called Heliox which contains He and O₂.

Concept Check

- 22.1 L of oxygen gas originally at 25°C and 1.75 atm and 9.20 L of He gas originally at 25 °C and 17.84 atm are pumped into a single scuba tank with a volume of 10.0 L.
 - Calculate the partial pressure oxygen:
 - Calculate the partial pressure of helium:
 - Calculate the pressure in the scuba tank.
- 3.87 atm Oxygen
16.41 atm He
20.28 atm total

Gas Stoichiometry

- Can use the gas laws to perform stoichiometric calculations.

STP

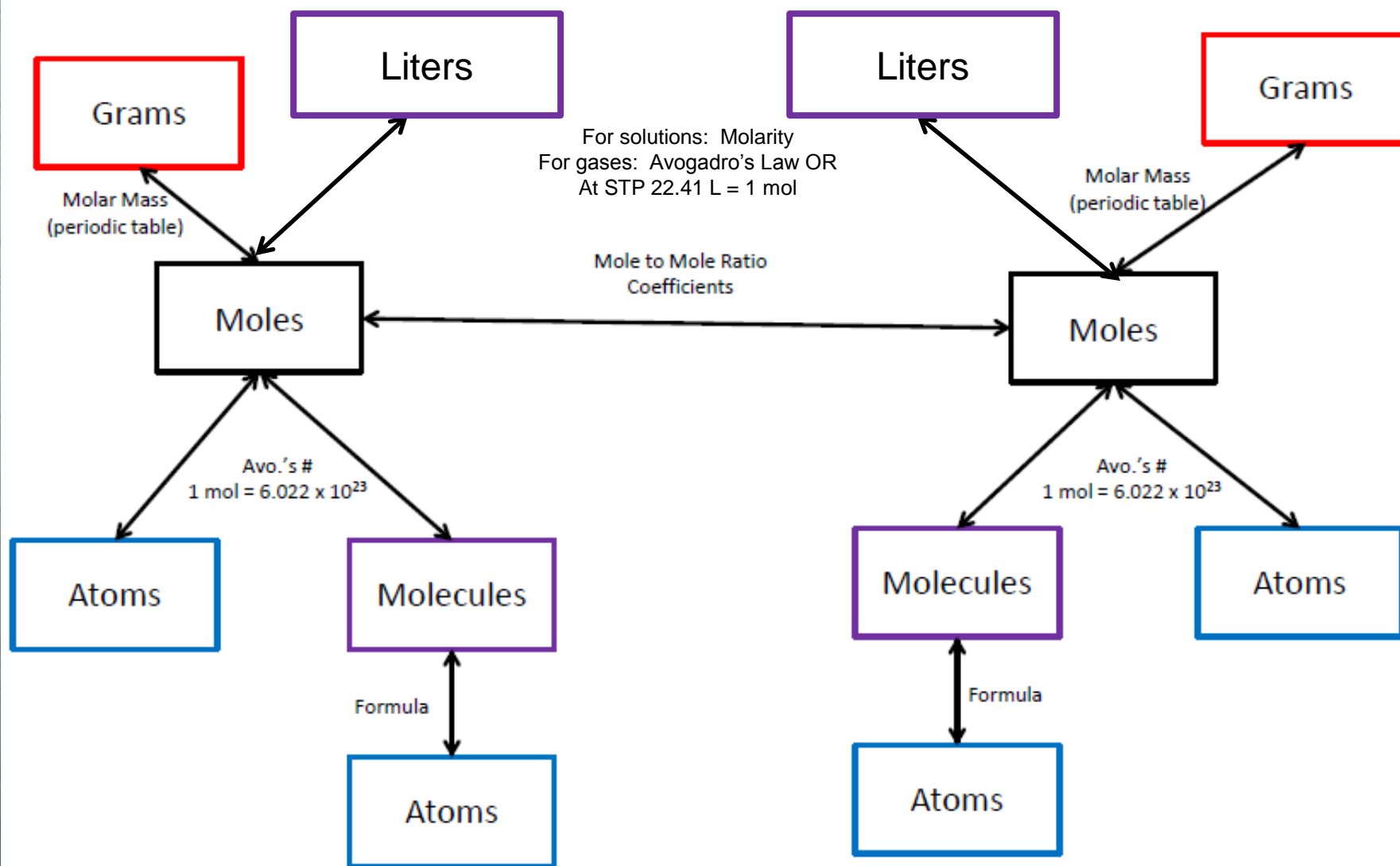
- Standard conditions allow scientists to communicate worldwide.
- STP = Standard Temperature and Pressure
- 0 °C and 1 atm

Molar Volume of a Gas

- At STP 1 mol of ANY gas occupies 22.41 L.

$$PV = nRT$$
$$V = \frac{1.00 \text{ mol} \times 0.08206 \frac{\text{L atm}}{\text{mol K}} \times 273 \text{ K}}{1.00 \text{ atm}} = 22.41 \text{ L}$$

Solution Stoichiometry



Concept Check

- At STP, a balloon containing 4.92 mol of gas has a volume of 15.1 L. If the balloon has a leak and eventually contained only 3.14 mol, what volume would the balloon occupy?

9.64 L

Molar Mass of a Gas

- Can use the ideal gas law to solve for n (mol)
- If you also know the mass of the gas, can solve for molar mass.

Concept Check

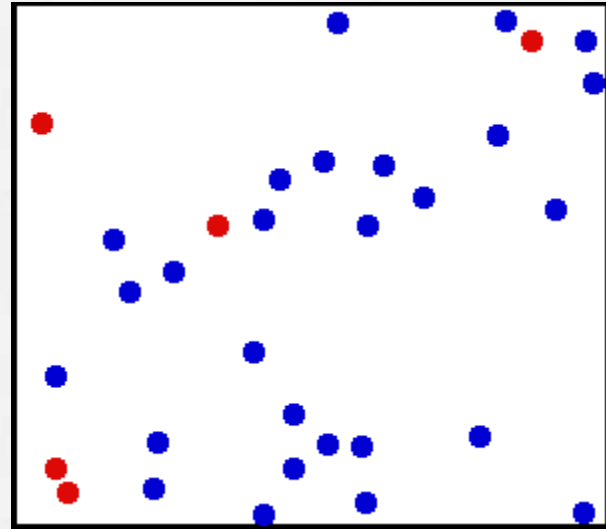
- A laboratory group measures an excess of a volatile liquid. They add this to an empty flask with a volume of 257.6 mL. They heat the sample to 76.8 degrees C until all the liquid is vaporized. The pressure in the lab is 0.924 atm. How many mol of gas are present?
- If the volatile liquid had a mass of 0.142 g, what was the molar mass of the unknown liquid?

8.29 x 10⁻³ mol

17.1 g/mol

Kinetic Molecular Theory

- Explains the properties of gases and why the gas laws are accurate.
- Contains 4 postulates.



Kinetic Molecular Theory

- 1. The volume of gas particles is negligible compared to the volume which they occupy.

Kinetic Molecular Theory

- 2. Gas particles are in constant, rapid, and random motion.

Kinetic Molecular Theory

- 3. Gas particles have no (attractive or repulsive) intermolecular interactions.
- All collisions between gas particles are elastic so that all kinetic energy is conserved during collisions.

Kinetic Molecular Theory

- 4. The kinetic energy of a gas is directly proportional to the K temperature.

Concept Check

- Using the Kinetic Molecular Theory, consider two balloons...



Concept Check

- If you had two balloons of exactly the same volume. One contains H_2 , the other Ne...
- Do the balloons have the same or different pressure?



Concept Check

- If you had two balloons of exactly the same volume. One contains H_2 , the other Ne ...
- Do the balloons have the same or different temperature?



Concept Check

- If you had two balloons of exactly the same volume. One contains H_2 , the other Ne...
- Do the balloons have the same or different mol?



Concept Check

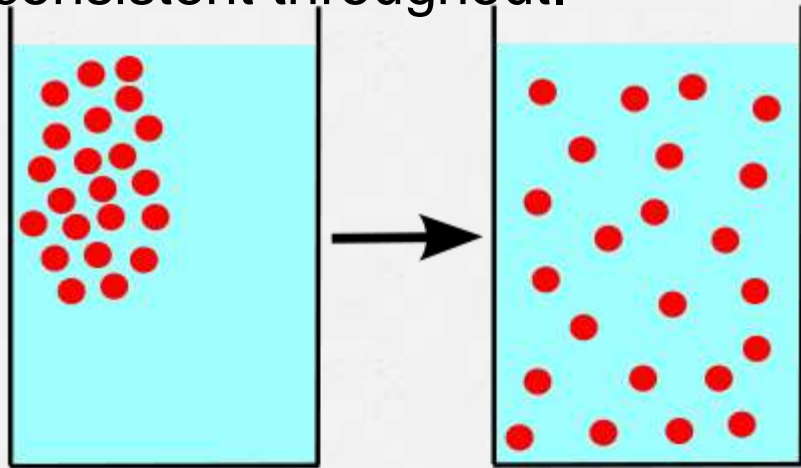
- If you had two balloons of exactly the same volume. One contains H_2 , the other Ne...
- Do the balloons have the same or different grams?



Gas Diffusion and Effusion

- Diffusion:

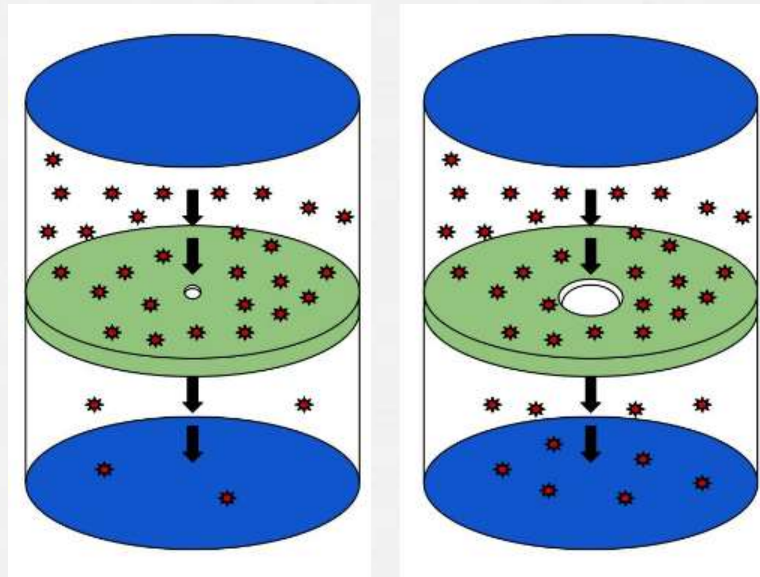
- The movement of particles from an area of high concentration to an area of low concentration... spreading out until the concentration is consistent throughout.



Gas Diffusion and Effusion

○ Effusion:

- The process where a gas escapes through a small hole from one chamber to another.



Gas Diffusion and Effusion

- Root Mean Square Velocity

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M_m}}$$

- Graham's Law of Effusion:

$$\frac{\text{Rate of effusion of gas}_1}{\text{Rate of effusion of gas}_2} = \sqrt{\frac{M_2}{M_1}}$$

Real Gases

- The Kinetic Molecular Theory assumes ideal behavior.
- Only holds at high temperature and low pressure. Under these conditions gas particles are moving rapidly and very far apart so intermolecular forces are negligible.

Real Gases

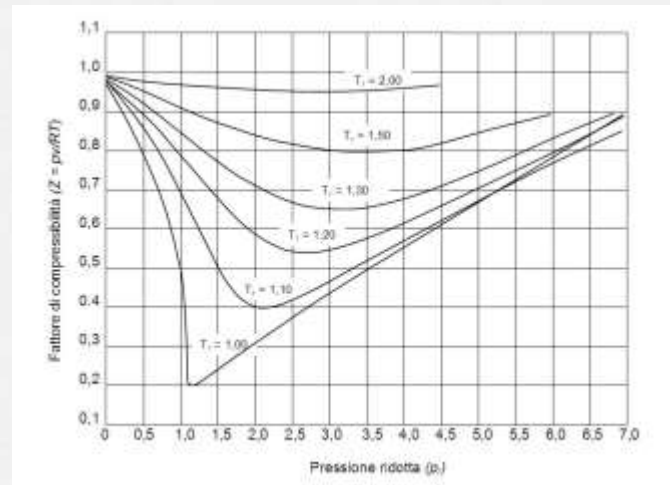
- Have Intermolecular forces that reduce observed pressure.
 - Small for Noble Gases and nonpolar molecules.
 - Large for ionic and polar compounds.
 - Include
 - London Dispersion Forces
 - Dipole-Dipole Interactions
 - Hydrogen Bonding
 - Ionic Interactions

Real Gases

- Take up volume.
 - Increases with molecular mass.
 - Observed volume will be too low since molecules take up some of the volume measured.

Real Gases

- Graph shows how increasing pressure affects the PV/nRT value.



Van der Waals Equation

- Ideal gas law can be corrected for volume and pressure using the van der waals equation. Observed pressure is always lower, observed volume is always higher than actual.
 - The higher the value of a the greater the attraction between molecules and the more easily the gas will compress.
 - The b term represents the volume occupied by the gas particles.

$$\left(p + \frac{n^2 a}{V^2} \right) (V - nb) = nRT$$

Air Pollution

- One of the best places to observe gases.
- Primary sources emitted directly into the atmosphere.
 - NO_x
 - SO_x
 - VOCs
 - Particulates
 - Free Radicals

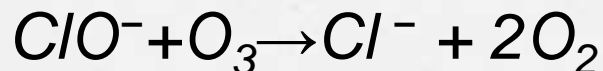
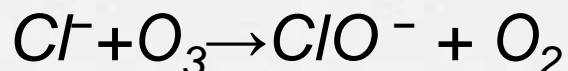
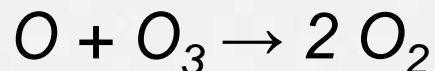
Air Pollution

- Secondary sources are derived (or reacted) from primary sources.
 - Smog
 - O₃

Ozone Depletion

- Depleted through free radicals.

- Some reactions include:



- A single Cl from CFCs can regenerate and continue reacting with ozone for ~ 2 years.

Unit 5 Review Activity

- This is NOT meant to replace homework questions or studying.
- Unit 5 Review Problems