**Avogadro’s Hypothesis**

- **Avogadro’s Hypothesis:** Equal volumes of gases at the same temp. and pressure contain equal numbers of particles.
- Conversely, gases with the same number of particles, at the same temp & pressure, have the same volume.
- What are the implications???

**Dalton’s Law of Partial Pressures**

- The total pressure inside a container is equal to the partial pressure due to each gas.
- The partial pressure is the contribution by that gas.

\[ P_{\text{Total}} = P_1 + P_2 + P_3 \]
Another Twist of Dalton's Law of Partial Pressures

To find the partial pressure of a component A in an ideal gas mixture, use the equation:

$$P_A = X_A P$$

where $X_A$ is the mole fraction of A in the gas and $P$ is the total pressure.

 Dalton Partial Pressure Problems

- What is the total pressure in a balloon filled with air if the pressure of the oxygen is 170 mm Hg and the pressure of nitrogen is 620 mm Hg?
- In a second balloon the total pressure is 1.3 atm. What is the pressure of oxygen if the pressure of nitrogen is 720 mm Hg? 0.35 atm

Partial Pressure Problems

- A container of gases consists of the following mixture of gases:
  - 5.0 moles of helium 100 mm Hg
  - 6.0 moles of carbon dioxide 120 mm Hg
  - 12.0 moles of neon 240 mm Hg
  - 15.0 moles of xenon 300 mm Hg
- If the total pressure is 760 mm of Hg, determine the partial pressure of each gas.

An Extension of Dalton's Partial Pressure: Collection of Gas Over Water

- When collecting gas over a body of water, the total pressure is a combination of the atmospheric pressure, and the vapor pressure of water.
- $P_{total} = P_{atm} + P_{water}$
- How do we know the vapor pressure of water? ... A vapor pressure of Water Table.

Partial Pressure Problems

- 17 g of Hydrogen and 17 g of CO$_2$ are placed in a 54.5 L container at 48°C.
- What is the total pressure of the container? 4.3 atm
- What is the pressure of the hydrogen? 4.1 atm
- What is the pressure of the CO$_2$? 0.19 atm

An Extension of Dalton's Partial Pressure: Collection of Gas Over Water

- Carbon Dioxide is collected over water at 22°C, and a pressure of 1.2 atm.
- What is the pressure of CO$_2$?
- $P_{total} = P_{CO_2} + P_{water}$
- 1.2 atm = $P_{CO_2} + (19.8/760)$
- $P_{CO_2} = 1.17$ atm
An Extension of Dalton’s Partial Pressure: Collection of Gas Over Water

- Hydrogen is collected over water at 60°C, and a pressure of 97.2 kPa.
- What is the pressure of H₂?

\[ P_{H_2} = 0.76 \text{ atm} \]

Collection of Gas Over Water Problems

- 193 mL of O₂ was collected over water on a day when the atmospheric pressure was 762 mm Hg. The temperature of the water was 23°C. How many grams of oxygen were collected?
  - Find the partial pressure of the dry gas at these conditions
    \[ P_{O_2} = 741 \text{ mm Hg} = 0.975 \text{ atm} \]
  - Find the number of moles of O₂ from the Ideal Gas Law:
    \[ n = \frac{PV}{RT} = \left(0.975 \text{ atm}\right)\left(0.193 \text{ L}\right)\left(0.0821 \text{ atm}\cdot\text{L} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}\right) \]
    \[ n = 7.69 \times 10^{-3} \text{ mol} \]
    \[ \Rightarrow 2.46 \times 10^{-2} \text{ g} \]

Collection of Gas Over Water Problems

- 24.3 mL of hydrogen gas was collected over water at 16°C and 756.2 mm Hg.
  - Find the partial pressure of the dry gas at these conditions.
    \[ 742.6 \text{ mm Hg} \]
  - What volume would the dry gas occupy at 1 atm? (Hint: Use Boyle’s Law)
    \[ 23.7 \text{ mL} \]

Diffusion vs Effusion??

Diffusion:
- Molecules moving from areas of high concentration to low concentration.
- Example: perfume molecules spreading across the room.

Effusion:
- Gas escaping through a tiny hole in a container.
- Depends on the speed of the molecule.

The Rate of Effusion/Diffusion using Graham’s Law

\[ \frac{Rate_A}{Rate_B} = \frac{\sqrt{\text{Mass}_B}}{\sqrt{\text{Mass}_A}} \]

- The rate of effusion and diffusion is inversely proportional to the square root of the molar mass of the molecules.
- Kinetic energy = 1/2 mv²
- m is the mass v is the velocity.

Graham’s Law

- Since KE = 1/2 mv², at the same Temperature (the same KE), heavier molecules move slower (by Square root)
- Heavier molecules effuse and diffuse slower
- Helium effuses and diffuses faster than air - escapes from balloon.
Diffusion/Effusion Rate Problems

1. Compare the effusion rates of O₂ (molar mass, 32 g/mol) and N₂ (molar mass 28 g/mol)

   Answer: 0.94

2. The neon and helium filled tires are punctured with equal size pinholes. If the helium-filled tire goes flat in 4.0 hours, how long would it take for the neon-filled tire to go flat?

   Answer: 8.98 hrs

3. It required 45.0 seconds for a certain number of moles of gas to pass through a small opening into a vacuum. Under the same conditions, it took 28.0 seconds of the same number of moles of argon gas to effuse. Find the molar mass of the unknown gas.

   Answer: 103.3 grams

4. Hydrogen diffuses at 13.6 cm/s. At what rate would sulfur hexafluoride diffuse under similar conditions?

   Answer: 1.59 cm/s

5. Carbon Dioxide diffuses through a small hole at the rate of 56.8 ml/min. Under the same conditions, what effusion rate would CO have?

   Answer: 71.2 ml/min

Collecting Gas Over Water Worksheet, Partial Pressure Worksheet 3 & Rate of Effusion Worksheet 4