High School Science Virtual Learning

Chemistry

Diffusion, Effusion, and Graham's Law

May 14, 2020

High School Chemistry
Lesson: [5/14/20]

Objectives/Learning Targets:

Students will be able to explain effusion and diffusion.
Students will be able to do calculations with Graham's Law.

Let's Get Started:

Gas Laws Summary

Name	Equation	Things that change	Things held constant
Combined	$P_1 \times V_1 \times T_2 = P_2 \times V_2 \times T_1$	Pressure, volume and temperature	Amount of gas
Boyles	$P_1 \times V_1 = P_2 \times V_2$	Pressure and Volume	Temperature Amount of gas
Charles	$V_1 \times T_2 = V_2 \times T_1$	Volume and Temperature	Pressure Amount of gas
Gay-Lussac	$P_1 \times T_2 = P_2 \times T_1$	Pressure Temperature	Volume Amount of gas

1. A balloon is filled with 5.0 L of helium in the morning when the temperature is 20.00℃. By noon the temperature has risen to 35.00°C. What is the new volume of the balloon?

2. 5.0 L of gas in a piston at a pressure of 1.0 atm are compressed until the volume is 1.5 L. What is the new pressure inside the piston?

Let's Get Started: Answer Key

1. $V_1 \times T_2 = V_2 \times T_1$

   $5.0\ L \times 293\ K = V_2 \times 308\ K$

   $V_2 = 4.8\ L$

2. $P_1 \times V_1 = P_2 \times V_2$

   $1.0\ atm \times 5.0\ L = P_2 \times 1.5\ L$

   $P_2 = 3.3\ atm$

Lesson Activity:

Directions:

1. Take notes as you watch the following video.
2. Write down the information in the notes slides.

Links:

- Video: Crash Course

Notes

- Particles in a mixture of gases at the same temperature have the same kinetic energy.
  - The kind of particle is not important.
  - The contribution each gas in a mixture makes to the total pressure is called the partial pressure exerted by that gas.
  - The total pressure of dry air is the sum of the partial pressures of the component gases.

Composition of Dry Air		
Component	**Volume (%)**	**Partial pressure (kPa)**
Nitrogen	78.08	79.11
Oxygen	20.95	21.22
Carbon dioxide	0.04	0.04
Argon and others	0.93	0.95
Total	**100.00**	**101.32**

Notes

- In a mixture of gases, the total pressure is the sum of the partial pressures of the gases.
- The chemist John Dalton proposed a law to explain this.
- Dalton's law of partial pressures states that, at constant volume and temperature, the total pressure exerted by a mixture of gases is equal to the sum of the partial pressures of the component gases.

$$P_{total} = P_1 + P_2 + P_3 + \ldots$$

Notes

- Diffusion
  - Tendency of molecules to move toward areas of lower concentration until the concentration is uniform throughout
  - Examples
  - Deodorizers
  - Perfumes/colognes
  - “Breaking wind”

Notes

- Effusion
  - The process by which a gas escapes through a tiny hole in a container
  - Graham's Law
  - Thomas Graham (1829)
    - The rate of effusion of a gas is inversely proportional to the square root of its molar mass

$$\frac{\text{Rate}_A}{\text{Rate}_B} = \sqrt{\frac{\text{molar mass}_B}{\text{molar mass}_A}}$$

Practice

Complete the following questions using the information you learned during the lesson activity.

Questions:

1. A sample of hydrogen gas is collected over water. The total pressure of the wet hydrogen in a 500 mL container is 756.5 mmHg at 21 °C. If the hydrogen is dried and placed in a 200 mL container at 18 °C, what will its pressure be?
2. A 500.0 mL sample of a gas is collected over water at 30 ºC and 0.923 atm. What volume would the gas occupy if dry and at 100 ºC and 1.000 atm?
3. The atmosphere in a sealed diving bell contained oxygen and helium. If the gas mixture has 0.200 atm of oxygen and a total pressure of 3.00 atm, calculate the mass of helium in 1.00 L of the gas mixture at 20 ºC.
4. A quantity of nitrogen gas originally at 4.60 atm in a 1.20 L container at 23.9 ºC is transferred to a 10.0-L container. A quantity of oxygen originally at 3.50 atm and 23.9 ºC in a 4.00 L container is transferred to the same 10.0 L container with the nitrogen. What is the total pressure of the two gases in the 10.0 L container at 19.7 ºC?

Once you have completed the practice questions check with the answer key.

1.

$$P_{total} = P_{H_2} + P_{H_2O\ vap} \qquad \text{initial } P_{H_2} = P_{total} - P_{H_2Ovap} = 756.5\ \text{mmHg} - 18.7\ \text{mmHg} = 737.8\ \text{mmHg}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad P_2 = P_1\left(\frac{V_1}{V_2}\right)\left(\frac{T_2}{T_1}\right) = 737.8\ \text{mmHg}\left(\frac{291\ \text{K}}{294\ \text{K}}\right)\left(\frac{500\ \text{mL}}{200\ \text{mL}}\right) = \mathbf{1.83 \times 10^3\ mmHg}$$

2.

$$P_{initial} = P_{total} - P_{water\ vapor} = 0.923\ \text{atm} - 31.824\ \text{mmHg}\left(\frac{1\ \text{atm}}{760\ \text{mmHg}}\right) = 0.881\ \text{atm}$$

$$V_2 = 500.0\ \text{mL}\left(\frac{373\ \text{K}}{303\ \text{K}}\right)\left(\frac{0.881\ \text{atm}}{1.000\ \text{atm}}\right) = \mathbf{542\ mL}$$

Once you have completed the practice questions check with the answer key.

$$P_{He} = P_T - P_{O_2} = 3.00 \text{ atm} - 0.200 \text{ atm} = 2.80 \text{ atm He}$$

3.

$$PV = \frac{g}{M}RT \qquad g = \frac{PVM}{RT} = \frac{2.80 \text{ atm } (1.00 \text{ L}) \, 4.0026 \, \frac{g}{mol}}{0.082058 \frac{\text{L atm}}{\text{K mol}} \, (293 \text{ K})} = \mathbf{0.466 \text{ g He}}$$

4.

$$P_{total} = P_{N_2} + P_{O_2} = 0.544 \text{ atm} + 1.38 \text{ atm} = \mathbf{1.92 \text{ atm total}}$$

$$P_{N_2} = 4.60 \text{ atm} \left(\frac{1.20 \text{ L}}{10.0 \text{ L}}\right)\left(\frac{292.9 \text{ K}}{297.1 \text{ K}}\right) = 0.544 \text{ atm} \qquad P_{O_2} = 3.50 \text{ atm} \left(\frac{4.00 \text{ L}}{10.0 \text{ L}}\right)\left(\frac{292.9 \text{ K}}{297.1 \text{ K}}\right) = 1.38 \text{ atm}$$

More Practice:

Follow the links below to do more practice.

1. Dalton's Law Practice
2. Partial Pressures and the Kinetic Molecular Theory of Gases

Additional Practice:
Click on the link below for additional practice.
Quiz