Molar Mass of Butane

Cautions

Butane is toxic and flammable. No OPEN Flames should be used in this experiment.

Purpose

The purpose of this experiment is to determine the molar mass of butane using Dalton's Law of Partial Pressures and the ideal gas law.

Introduction

When a new substance is prepared in the laboratory, its identity must be determined. Knowing the molar mass of the substance limits the list of possible identities. To determine the molar mass, two pieces of information must be known; the mass of the sample and the number of moles of substance present in that particular mass. For any sample, determining its mass is straightforward – place a quantity on or in a container on the balance, and read the mass it displays. Determining the number of moles is not as straightforward. In the case of a gaseous sample, knowing its pressure and volume at a specific temperature provides enough information to determine the number of moles present. Using the mass and number of moles, the molar mass can be determined.

One method of determining the volume of a gas sample at a known pressure is to collect it over water using a setup similar to Figure 5.15 on page 195 in your chemistry textbook (Chang, 8th Ed.). If the volume (V), temperature (T) and total pressure (P_{gas}) of the collected gas are measured, the ideal gas law can be used to determine the moles of hydrogen produced by the sample:

$$P_{gas}V = n_{gas}RT \qquad \text{(Equation 1)}$$

Determining the pressure of collected gas is not as straightforward as simply measuring atmospheric pressure. Samples of liquid water in any container always have a small amount of water vapor present just above the surface (vapor pressure), which must be accounted for. Accounting for this small quantity of water vapor requires using Dalton's law of partial pressures:

$$P_{Total} = P_{gas} + P_{H_2O} \qquad \text{(Equation 2)}$$

Since the gaseous sample is collected over water in an enclosed flask, one can assume the gas is saturated with water vapor at barometric pressure. Thus, the total pressure observed under these conditions is equal to the sum of the vapor pressure of water at that temperature and the pressure of the gas from the experiment. The vapor pressure of water is constant at various temperatures; these values are listed in a table on the next page and in Table 5.3 on pg. 196 of your textbook.

Butane is a gas at normal room conditions, however in disposable lighters it is a liquid. This phase change is achieved by putting a sample of butane under high pressure within the lighter. When the valve of the lighter is depressed it provides an opening, depressurizing the container and allowing the liquid butane to escape in the form of a gas. Butane is a hydrocarbon, composed of only carbon and hydrogen atoms connected by covalent bonds. The composition of butane leads to its physical and chemical properties; butane molecules do not interact significantly with each other or with other molecules. Hence, butane is a gas at room temperature and does not dissolve significantly in water. These properties make butane an ideal sample for this particular experiment.

In this experiment you will collect a butane gas sample in a container by the water displacement method, allowing direct measurement of the volume of butane gas collected. The pressure of the butane gas can be determined using Equation 2 above, and the temperature of the gas can be assumed to equal the temperature of the water it is passing

Molar Mass of Butane

through. Knowing the volume of the butane gas collected and its pressure and temperature, the number of moles of butane gas can be calculated. The total mass of the butane gas collected may be determined by taking mass readings of the disposable lighter before and after the water displacement process. Once this information is obtained it is possible to calculate the mass of one mole (the molar mass) of the butane.

Procedure

1. Weigh the lighter to the nearest 0.001 grams or better. Attach a plastic tube to the gas opening on the top of the lighter.
2. Submerge a 100 mL graduated cylinder in water so that the cylinder fills completely with water. Invert the cylinder. Make sure there are no air bubbles remaining in the graduated cylinder.
3. Take the plastic tube and insert it in the graduated cylinder under the water. Carefully release the butane from the lighter and collect it in the cylinder. Release enough butane to fill the tube to the 80 mL mark. Remove the plastic tube from the graduated cylinder and the lighter.
4. Allow the butane in the cylinder to reach room temperature (about five minutes). Then adjust the level of the water inside and outside the tube to be the same. With the pressure inside the same as the pressure outside, record the volume to the nearest ml. This makes the pressure of the combined water vapor and butane gas equal to the pressure of the atmosphere.
5. Measure the mass of the lighter again.
6. Repeat the steps 1-5 three more times for a total of 4 trials.
7. Record the air temperature in Kelvin.
8. Record the water temperature and barometric pressure.
9. Use the derivation of the ideal gas law equation (MM = mRT/PV) to find the molar mass.
10. Find the average molar mass for the 4 trials and the percent error.

Vapor Pressure of Water	
Temp (°C)	**VP (torr)**
16	13.6
17	14.5
18	15.5
19	16.5
20	17.5
21	18.6
22	19.8
23	21.0
24	22.4
25	23.7
26	25.2
27	26.7
28	28.3
29	30.0
30	31.8

Molar Mass of Butane

Data Sheet

Show all work for calculations on a separate piece of paper.

Name: _____ **Lab Partner:** _____

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4
Initial Mass of Lighter				
Final Mass of Lighter				
Mass of Butane				
Volume of Gas Collected				
Water Temperature				
Vapor Pressure of H_2O				
Barometric Pressure				
Pressure of Butane gas				
Moles of Butane				
Molar Mass of Butane				
Average Molar Mass of Butane				
Accepted Molar Mass of Butane				
% Error				

Molar Mass of Butane

Post-Lab Questions

Name: _____

1. What is your percent error?

2. Discuss how the percent error in this experiment could be reduced.

3. Indicate the required conditions for

    a. Boyle's Law

    b. Charles' Law

4. In your own words, define and discuss Dalton's Law of Partial Pressures.

5. A sample of zinc metal is allowed to react completely with an excess of hydrochloric acid. The hydrogen gas produced is collected over water at 25.0^{o}C. 7.80 L of the gas was collected at a total pressure of 0.980 atm. The vapor pressure of water at 25^{o}C is 23.8 mm Hg.

    a. Write the balanced chemical equation.

    b. Calculate the amount of zinc metal that was consumed in the reaction.

Molar Mass of Butane

Pre-lab Assignment

Name: _____

1. Why should no flames be used in this laboratory?

2. Why is the insolubility of butane in water critical to performing this experiment?

3. What are the conditions of STP?

4. What is the molecular formula of Butane?

5. What is the accepted molar mass of butane?

6. Propane and Methane are other hydrocarbon fuels. If a 1000 g sample of each of these compressed gases was taken on a camping trip which one would contain the largest number of moles? Show a calculation to support your answer.