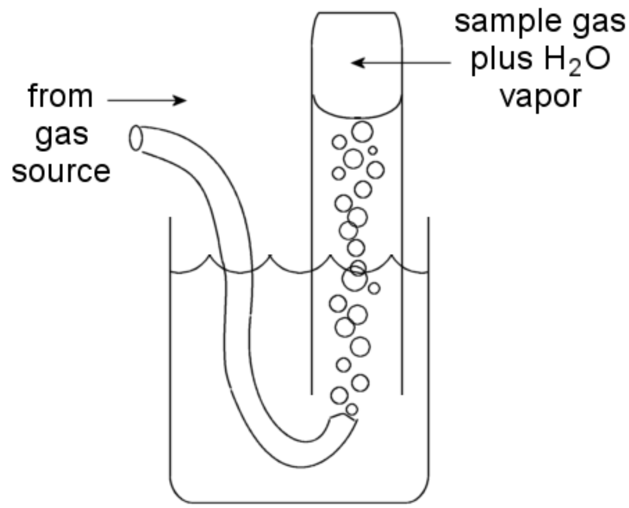
Lab: Determining the Molar Mass of Butane

Introduction

In many laboratory settings, a gas must be collected for study. There are several ways of collecting and storing gases and the preferred method will vary according to the gas being collected and the purpose for which it is needed. In many occasions, chemists collect gases over water.

The following diagram illustrates collecting a gas over water:



In the diagram, a gas is brought in from an outside source through a rubber tube. The tube is passed under water until it opens into an inverted cylinder. At the start of the experiment the cylinder was completely filled with water, but as gas was collected the water level fell. Besides the gas being studied, water vapor also accumulates in the gas pocket. Before you can perform any calculations involving the gas sample's pressure, you must correct for the pressure of water vapor.

In today's experiment you will be collecting the butane gas from a regular cigarette lighter. After collecting it, you will make careful measurements of its mass, volume, temperature, and pressure. This will allow you to calculate the number of moles of butane trapped in the cylinder, which, along with the mass, will provide you with an experimental molar mass for butane.

Pre-lab questions

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

Possible answer: Butane is extremely flammable and will ignite.

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

Possible answer: Because the butane will not dissolve in the water, it is possible for butane gas possible to form under water and get trapped.

3. What are the conditions of STP?

Possible answers: 0° C (273.15 K) and 1 atm (101.3 kPa)

4. What is the molecular formula of Butane?

C_4H_{10}

5. What is the accepted molar mass of butane?

C = 12.01 g/mol * 4 = 48.04 g/mol
H = 1.01 g/mol * 10 = 10.10 g/mol
MM = 48.04 g/mol + 10.10 g/mol = 58.14 g/mol

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.

Propane

$\frac{1000\text{ g } C_3H_8}{44.11\text{ g/mol } C_3H_8} = 22.67\text{ mol } C_3H_8$

Methane

$\frac{1000\text{ g } CH_4}{16.05\text{ g/mol } CH_4} = 62.31\text{ mol } CH_4$

Methane contains the larger number of moles

Objective

- To successfully collect and store butane gas from a cigarette lighter.
- To use the Ideal Gas Law and Dalton's Law of Partial Pressures in calculating the number of moles of butane being stored.
- To use the mass and the number of moles of butane being stored in calculating the molar mass of butane.
- To compare the experimental molar mass of butane with the theoretical mass (based on its molecular formula) and calculate a percent error.

Materials

1 butane cigarette lighter
1 gas-collecting bottle
1 pneumatic trough
thermometer
Analytical balance
glass plate

Safety Precautions

Butane is an EXTREMELY flammable gas. At NO TIME may you ignite your cigarette lighter or have any other source of heat or flame present in lab.

Procedure

A. Obtain a triple-beam balance and make sure it is properly set to zero.

B. Place a dry cigarette lighter on the triple beam balance and record its mass under **Initial Mass of Cigarette Lighter** in the **Data and Observations** section. Remember to record the mass with **all certain digits plus one uncertain digit.**

C. Add water to a pneumatic trough (at least 2/3 full). The water level should be just below the spout on the side of the trough.

D. Fill a gas-collecting bottle with water to the very brim. Place a glass plate over the mouth of the bottle, then turn the bottle upside down and place it in the trough. When the mouth of the bottle is underwater, you may remove the glass plate. Be sure that there are no bubbles in the bottle. If the bottle has air bubbles trapped in it, you must try again to completely fill the bottle with water.

E. Lift the bottle up slightly (*but keep its mouth below the surface of the water*) and hold the cigarette lighter beneath the mouth. Press the button on the lighter so that bubbles of butane rise into the inverted bottle. Be careful that no bubbles of butane miss the mouth of the bottle.

F. As the bottle fills with butane, the level of the water will fall. Continue to collect butane gas until the water level reaches one of the marks on the side of the bottle (for clarity, you should fill to the second or third mark rather than the first)

G. When you have collected a measurable amount of butane, release the button on the lighter and remove it from the water. Dry it with a paper towel and record its mass again under **Final Mass of Cigarette Lighter** in the **Data and Observations** section. *The second mass should be LESS than the first mass you recorded in step A.* If the second mass is higher than or the same as the first mass, be sure that it is thoroughly dry (including inside the metal casing around the gas outlet) and mass it again. If the mass is STILL greater than or the same as the first mass, you should repeat the procedure from the beginning.

H. Read the volume of the butane you collected from the side of the bottle. Make sure you are reading the correct set of measurements. Record this volume under **Volume of Butane Collected** in the **Data and Observations** section**.** When you have recorded the volume, you may set the bottle down inside the trough.

I. Use a thermometer to record the temperature of the water in the trough. You may assume that the gas temperature is the same as the temperature of the water. Record the temperature to the nearest tenth of a degree Celsius under **Temperature of Gas Collected** in the **Data and Observations** section.

J. The instructor will have pulled up the weather.com page with information concerning the atmospheric pressure at your location. This information will be recorded on the board in mmHg. Record this pressure in your **Data and Observations** section exactly as it appears on the board under the heading **Total Pressure of Gas in Cylinder**.

K. Refer to the graph on the next page to determine the vapor pressure of H_2O at the temperature you recorded in Step I. Record the **Vapor Pressure of Water** in your **Data and Observations** section.

L. Perform all calculations and conversions in the **Calculations** section. Don't forget to calculate a percent error when you have finished everything else.

Clean-Up

Dispose of your water in the sink. Avoid inhaling the butane fumes as you empty your cylinder. Encourage the mixing of regular air with the butane sample to disperse it quickly. Carefully dry the cigarette lighter and place it on the lab table.

Data and Observations (Sample Data)

Finding the Mass of your Gas Sample

1. **Initial Mass of Cigarette Lighter:** ________**16.423**____________ **grams**
2. **Final Mass of Cigarette Lighter:** __________**16.344**____________ **grams**

Finding the Volume of the Gas Sample

3. **Volume of Gas Collected in mL:** ___________**30.0**______________ **mL**

Finding the Temperature of the Gas Sample

4. **Temperature of Gas Collected in ºC:** ________**25.0**_____________**ºC**

Finding the Pressure of the Gas Sample

5. **Atmospheric Pressure in mmHg*:** ______**766.10**________ **mmHg**
6. **Vapor Pressure of Water at Measured Temperature:** ______**23.76**________ **mmHg**

Calculations

7. Calculate the mass of the gas in the collecting bottle. Show your work for credit.

   ____0.079_________ g 16.344 – 16.423 = 0.094 g

8. Convert the volume of gas collected (**Data and Observations #3**) to Liters. Show your work.

   ____0.03__________ L 30 ~~mL~~/1000 ~~mL~~/L = 0.030 L

9. Convert the temperature recorded (**Data and Observations #4**) to Kelvins. Show your work.

   ____298.15________ K 25° C + 273.15 = 298.15 K

10. Calculate the pressure of the butane *alone* (#5 – #6) in mmHg. Show your work.

    ____742.34________ mm Hg P_{Butane} = 766.10 – 23.76 = 742.34 mm Hg

11. Convert the pressure of the butane gas from mmHg to atm. Show your work.

___0.977_________ atm 742.34 ~~mm Hg~~/760 ~~mm Hg~~/atm = 0.977 atm

12. Calculate the number of moles of butane collected. Use the ideal gas law and show your work.

___0.00120_______ mol n = (0.977 ~~atm~~)(0.030 ~~L~~) / (0.08206 ~~L~~ ~~atm~~/mol ~~K~~) (298.15 ~~K~~) = 0.00120 mol

13. Using the mass calculated in **Calculation #7** and the number of moles calculated in **Calculation #12**, calculate the experimental molar mass of butane. Show your work.

___65.83_________ g/mol MM = 0.079 g / 0.0012 mol = 65.83 g/mol

14. Butane has the molecular formula C_4H_{10}. Calculate its theoretical molar mass based on this formula. Show your work.

___58.14_________ g/mol

15. Calculate the percent error. Show your work.

___+/- 13.23______ %

$$\%\ \text{error} = \frac{|\text{exp. value - theo. value}|}{\text{theo. value}} \times 100\%$$

$$\%\ \text{error} = \frac{|65.83 - 58.14|}{58.14} \times 100\%$$

$$= +/- 13.23\ \%$$

Post Lab Questions (Show all work for credit):

1. Identify at least one potential source of error in the experimental procedure that may lead to a loss of accuracy.

Possible answers: Capturing gas from lighter in collection tube, Removing water that collected in lighter before final massing, Water possibly filling in lighter while Butane gas was being expelled.

2. A gas sample is collected over water at 20.0ºC. The volume of the gas collected is 45.0 mL and the atmospheric pressure is 771 mmHg. How many moles of gas were collected? (Remember to take into account the vapor pressure of water. Consult the table on Page 3 of this lab.)

Calculate vapor pressure of gas collected over water

P(gas) = P(atm) – P(H2O)
= 771 – 17.54
= 753.46 mm Hg

$$n = \frac{PV}{RT}$$

$$n = \frac{(753.45\ \cancel{\text{mm Hg}}/760\ \cancel{\text{mm Hg/atm}})(0.045\ \cancel{\text{L}})}{(0.08206\ \cancel{\text{L}}\ \cancel{\text{atm}}/\text{mol}\ \cancel{\text{K}})\ (293.15\ \cancel{\text{K}})}$$

n = 0.00185 mol

3. The mass of the gas sample described in question 2 is found to be 0.0371 grams. What is the molar mass of this gas?

$$MM\ (\text{molar mass}) = \frac{g}{Mol} = \frac{0.0371\ g}{0.00185\ mol}$$

$$= 20.05\ g/mol$$

4. It is known that the gas described in questions 2 and 3 is an element from the periodic table. What is the probable identity of this mystery gas?

Neon

5. Calculate the density of butane at STP.

$$MM = \frac{dRT}{P}$$

$$d = \frac{MM(P)}{RT}$$

$$= \frac{(58.14 g/\cancel{mol})(1\ \cancel{atm})}{(0.08206\ L\ \cancel{atm}/\cancel{mol}\ \cancel{K})(273.15\ \cancel{K})}$$

$$d = 2.59\ g/L\ \text{Butane}$$

6. Calculate the density of water vapor at 400 K and standard pressure.

$$d = \frac{MM(P)}{RT}$$

$$= \frac{(18.02\ g/\cancel{mol})(1\ \cancel{atm})}{(0.08206\ L\ \cancel{atm}/\cancel{mol}\ \cancel{K})(400\ \cancel{K})}$$

$$d = 0.549\ g/L$$

7. What volume will 0.010 grams of isopentane, C_5H_{12}, occupy when stored under 12.0 atm of pressure and 21.0ºC?

$$PV = nRT$$

$$V = \frac{mRT}{P}$$

$$= \frac{(0.01\cancel{g\ C_5H_{12}}/72.17\ \cancel{g/mol\ C_5H_{12}})(0.08206\ L\ \cancel{atm}/\cancel{mol}\ \cancel{K})(294.15\ \cancel{K})}{(12\ \cancel{atm})}$$

$$= 0.000279\ L\ C_5H_{12}$$