Molar Mass of Butane

Applying the Gas Laws

Introduction

Avogadro's law, Dalton's law, and the Ideal gas law—show how these gas laws can be applied to determine the molar mass of butane.

Concepts

- Dalton's law
- Ideal gas law
- Molar mass

Materials

Balance, centigram precision (0.01 g)

Barometer

Pneumatic trough or large beaker, 600-mL

Disposable butane lighter

Graduated cylinder, 100-mL

Rubber stopper, size 5

Thermometer

Safety Precautions

Butane is a flammable gas; keep away from all sparks, flames, and heat. Perform the demonstration in a well-ventilated lab and dispose of the gas in a fume hood or outdoors. Wear chemical splash goggles and chemical-resistant gloves.

Procedure

1. Fill the pneumatic trough or a large beaker with room temperature water.
2. Submerge the disposable butane lighter in water, remove it, and then dry it off as thoroughly as possible.
3. Record the temperature of the water in the pneumatic trough, as well as the barometric pressure.
4. Weigh the disposable butane lighter to the nearest 0.01 g and record the mass.
5. Submerge the graduated cylinder in the trough or beaker and fill it completely with water. Have a student helper hold the inverted graduated cylinder (filled with water) in the pneumatic trough. There should be no air bubbles in the cylinder at the start of the demonstration.
6. Place the butane lighter underneath the opening of the graduated cylinder and fill the cylinder with butane by holding down the trigger on the butane lighter. Do not touch the striker or flint. Be careful not to let any of the gas escape around the graduated cylinder.
7. Displace about 90 mL of water from the graduated cylinder. To collect the last 10 mL of butane, adjust the height of the graduated cylinder so that the 100-mL mark lines up with the level of water in the trough or beaker. Fill the graduated cylinder to the 100-mL mark with butane. *(This ensures that the pressure of gas inside the graduated cylinder will be the same as the atmospheric pressure.)*
8. Dry off the butane lighter and weigh it again. Record the mass.
9. See the Molar Mass of Butane Worksheet for calculations.

Tips

- Consider removing the striking wheel from the lighter with a flathead screwdriver before performing the experiment. This will reduce the possibility of it accidently lighting.
- The biggest source of error in this demonstration is the mass of the "dry" butane lighter before and after the gas has been measured. For best results, immerse the lighter in water before measuring its mass. Dry it off as thoroughly as possible before and after the gas has been expelled.

Answers to Worksheet Questions

1. Water bath temperature: *22° C, 295 K*
2. Barometric pressure: *755 mm Hg, 0.994 atm*
3. Volume of gas collected: *100.0 mL*
4. Initial mass of butane lighter: *22.24 g*
5. Final mass of the butane lighter: *22.01 g*
6. Mass of butane collected: *0.23 g*
7. What two gases are in the graduated cylinder? *Water vapor and butane*
8. Vapour pressure of water (P_{H_2O}) at this temperature: *19.8 mm Hg or 0.026 atm*
9. Partial pressure of butane: $P_{but} = P_{atm} - P_{H_2O}$

   $0.994\ atm - 0.026\ atm = 0.968\ atm$

10. Use the combined gas law to determine the volume (in L) of butane at STP.

    $P_1 \times V_1/T_1 = P_{STP} \times V_{STP}/T_{STP}$

    $0.968\ atm \times 0.100\ L/295\ K = 1\ atm \times V_{STP}/273\ K$

    $V_{STP} = 0.0896\ L$

11. Use Avogadro's law to determine the number of moles of butane gas. Assume that butane is an ideal gas and that one mole has a volume of 22.4 L at STP.

    $V_1/n_1 = V_2/n_2$

    $0.0896\ L/n = 22.4\ L/1\ mole$

    $n = 0.0040\ moles$

12. Experimental molar mass (g/mole) of butane: *0.23 g/0.0040 moles = 58 g/mole*
13. The molecular formula of butane is C_4H_{10}. Calculate its molar mass. *58.1 g/mole*
14. Percent error using the accepted molar mass of butane:

    $\%\ error = |exp - act|/act = 0\%!$

15. Discuss sources of error in this demonstration.

    Although the results of one trial, as shown above, were highly accurate, it was found that the results were not always reproducible. The calculated molar mass varied from 46 g/mole to 74 g/mole over five trials. The major source of error is weighing the butane lighter. A small amount of water will dramatically skew the results. Another possible source of error is the presence of some air in the graduated cylinder before the butane is collected. Finally, some of the butane gas expelled from the lighter may be released into the water bath rather than collected in the graduated cylinder.

Reference

This activity was adapted from *Flinn ChemTopic™ Labs*, Volume 9, *The Gas Laws;* Cesa, I., Editor; Flinn Scientific: Batavia, IL (2004).

Materials for *Molar Mass of Butane—Applying the Gas Laws* are available from Flinn Scientific Canada Inc.

Catalogue No.	Description
AP8334	Pneumatic Trough
AP1884	Barometer, Aneroid
AP6367	The Gas Laws, Flinn ChemTopic™ Labs, Volume 9

Consult the Flinn Scientific Canada website for current prices.

Molar Mass of Butane Worksheet

1. Water bath temperature

2. Barometric pressure

3. Volume of gas collected

4. Initial mass of butane lighter

5. Final mass of the butane lighter

6. Mass of butane collected

7. What two gases are in the graduated cylinder?

8. Vapour pressure of water (P_{H_2O}) at the water bath temperature

9. Partial pressure of butane: $P_{but} = P_{atm} - P_{H_2O}$

10. Use the combined gas law to determine the volume (in L) of butane at STP.

11. Use Avogadro's law to determine the number of moles of butane gas. Assume that butane is an ideal gas and that one mole has a volume of 22.4 L at STP.

12. Experimental molar mass (g/mole) of butane

13. The molecular formula of butane is C_4H_{10}. Calculate its molar mass.

14. Percent error using the accepted molar mass of butane

15. Discuss sources of error in this demonstration.