Dust Blaster

The Ideal Gas Law Applications

Introduction

Most ingredients in aerosol products are listed on the side of the container. Some cans just list a generic name, like fluorocarbon. Let's use the ideal gas law to find out exactly what gas is in those dust blaster cans used to clean electronics.

Concepts

- Avogadro's law
- Ideal gas law
- Dalton's law
- Molar volume

Background

Avogadro's law states that equal volumes of gases contain equal numbers of molecules under the same conditions of temperature and pressure. It follows, therefore, that all gas samples containing the same number of molecules will occupy the same volume if the temperature and pressure are kept constant. The volume occupied by one mole of a gas is called the molar volume.

In this experiment, the molar mass of an aerosol gas will be determined using the ideal gas law. The can of gas is initially massed on a 0.001-g precision balance. A 250-mL graduated cylinder is inverted in a beaker of water. Gas from the can is released into the graduated cylinder. The volume of gas collected is measured, the temperature of the water is taken, the atmospheric pressure is recorded, and the final mass of the aerosol can is determined.

The relationship among the four gas variables—pressure (*P*), volume (*V*), temperature (*T*), and the number of moles (*n*)—is expressed in the ideal gas law (Equation 1), where *R* is a constant called the universal gas constant.

$$PV = nRT \qquad \textit{Equation 1}$$

The ideal gas law can be expressed in terms of the molar mass of the gas. Since the moles of gas are equal to the mass of the gas divided by its molar mass, Equation 1 can be rearranged to

$$\mathrm{MM} = \frac{\mathrm{g}\,RT}{PV} \qquad \textit{Equation 2}$$

where MM is the molar mass of the gas. If the empirical formula is known, then the combination of the two will yield the molecular formula of the gas.

Experiment Overview

The purpose of this experiment is to determine the molar mass of the gas contained in a "dust blaster" can. Once the molar mass has been determined, the molecular formula will be calculated from this data and data from a separate percent composition determination.

Materials

Water tap, 800-mL
Balance, 0.001-g precision
Barometer
Beaker, 1000-mL
Dust blaster can, with plastic tube
Graduated cylinder, 250-mL
Thermometer, 0–110 °C

Safety Precautions

Wash hands thoroughly with soap and water before leaving the laboratory. Observe all normal laboratory rules and procedures.

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Procedure

1. Fill a 1000-mL beaker about ¾-full with water.
2. Mass the aerosol can on the balance and record this mass in the Data Table.
3. Fill a 250-mL graduated cylinder completely full of water, invert it, and place it inside the 1000-mL beaker. Make sure the cylinder contains no air bubbles.
4. Hold the plastic tubing of the can under the water and below the mouth of the inverted graduated cylinder and press the release button of the can. Make sure all the bubbles of the gas are going into the cylinder.
5. Collect approximately 250 mL of gas.
6. Take the tubing out of the water. Adjust the position of the inverted cylinder so that the level of the water inside and outside the cylinder are equal. Record the volume of gas collected in the Data Table.
7. Mass the aerosol can and record this value in the Data Table.
8. Measure the temperature of the water and the barometric pressure. Record these values in the Data Table.

Data Table

	Trial 1	**Trial 2**
Initial Mass of Aerosol can (g)		
Final Mass of Aerosol can (g)		
Mass of Aerosol Gas (g)		
Volume of Aerosol Gas (mL)		
Temperature of Water Bath (°C)		
Barometric Pressure (mm Hg)		

Post-Lab Calculations and Analysis *(Use a separate sheet of paper to answer the following questions.)*

1. Calculate the molar mass of aerosol gas from Trials 1 and 2.
2. The percent composition of the gas in the can is as follows:

   Carbon—36.36%

   Hydrogen—6.06%

   Fluorine—57.58%

   Calculate the empirical formula and then using the calculated molar mass, determine the molecular formula of the aeroso gas.
3. How do you explain the fact that the gas is liquid in the can, but a gas when it is collected?

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Teacher's Notes

Dust Blaster

Materials (for a class of 30 students working in pairs)

Water, tap
Aerosol cans, with plastic tube, 15
Balances, 0.001-g precision, 3
Barometer (one for entire class)
Beakers, 1000-mL, 15
Graduated cylinders, 250-mL, 15
Thermometers, 0–110 ºC, 15

Safety Precautions

Have students wash hands thoroughly with soap and water before leaving the laboratory. Observe all normal laboratory rules and procedures. Please consult current Material Safety Data Sheets for additional safety, handling, and disposal information.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes Grades K–12
Evidence, models, and explanation
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure and properties of matter, chemical reactions.

Lab Hints

- The laboratory work for this experiment can reasonably be completed within a typical 50-minute class period. The set up and procedure take about fifteen minutes. This allows students the opportunity to conduct two or more trials in a typical lab period.
- This lab does not take into account the partial pressure of water vapor in the cylinder. This should not impact the determination of molar mass and molecular formula. Include Dalton's law of partial pressures to have the students complete a more rigorous set of calculations.
- Not all graduated cylinders are created equal. We have found that the best results are obtained using glass, tall-form, 250-mL graduated cylinders marked with 0.5-mL or 1.0-mL increments. Economy-choice graduated cylinders are shorter and are marked only in 2-mL minor increments—these are not recommended.
- If a barometer is not available in the lab or classroom, students may consult an Internet site such as the national weather service site (http://weather.gov) to obtain a current "sea-level" pressure reading for your area. Note that these are NOT actual barometric pressure readings. Meteorologists convert station pressure values to what they would be if they had been taken at sea level. The following equation can be used to recalculate the barometric pressure (in inches Hg) from the reported sea-level pressure (in inches Hg). Elevation must be in meters.

$$\text{barometric pressure} = \text{sea-level pressure} - (\text{elevation}/312)$$

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Teaching Tips

- For an alternative lab activity dealing with molar volume and applications of the ideal gas law, see the demonstration "Molar Mass of Butane" in *The Gas Laws*, Volume 9 in the *Flinn ChemTopic*™ *Labs* series. This demonstration uses disposable butane lighters to generate a measured mass of butane gas. The molar mass of butane is also calculated based on the theoretical molar volume of an ideal gas.
- See "Construction of Gas Volume Cubes" in the Demonstrations section of *The Gas Laws* (*Flinn ChemTopic*™ *Labs*, Vol. 9, Catalog No. AP6367) for a follow-up assessment activity. Different groups of students are assigned different numbers of moles of gas and are asked to construct a cube to represent the volume of the given number of moles of gas at STP. The examples have been chosen so that all of the cubes will have dimensions to the nearest centimeter (e.g., 0.0446 moles of gas will have a volume of 1.00 L at STP, corresponding to a cube 10.0 cm in length on each side).
- Ask your students to come up with a list of interesting questions regarding the amount of gas in familiar, everyday objects. The questions (and answers) can be assigned as extra credit to reinforce gas law calculations or to prepare for tests. How much helium gas is needed to fill the Goodyear blimp? How much gas is present in an aerosol container pressurized at 2.2-atm? How many air molecules does it take to blow up a party balloon? What volume of butane gas would be generated if all the liquid butane in a barbecue lighter were converted to gas at STP?

Sample Data *(Student data will vary.)*

	Trial 1	Trial 2
Initial Mass of Aerosol can (g)	290.408	
Final Mass of Aerosol can (g)	289.744	
Mass of Aerosol Gas (g)	0.664	
Volume of Aerosol Gas (mL)	244	
Temperature of Water Bath (°C)	27.2	
Barometric Pressure (mm Hg)	752	

Answers to Post-Lab Calculations and Analysis *(Student answers will vary.)*

1. Calculate the molar mass of aerosol gas from Trials 1 and 2.

   Trial 1

   $$MM = \frac{[0.664\ g \times 0.08021 L{\cdot}atm \times 300.2\ K]}{K{\cdot}mol} / 0.99\ atm{\cdot}0.244\ L$$

   $$MM = [\ (0.664)(0.08021)(300.2) / (0.99)(0.244)]\ g/mol$$

   $$MM = 66.2\ g/mol$$

2. The percent composition of the gas in the can is as follows:

   Carbon—36.36%

   Hydrogen—6.06%

   Fluorine—57.58%

   Calculate the empirical formula and then using the calculated molar mass, determine the molecular formula of the aerosol gas.

   In 100 g of gas, there is 36.36 g of carbon, 57.58 g of fluorine, and 6.06 g of hydrogen. If we convert these masses to moles, we get:

   Moles C = 36.36 g/12.00 g/mole = 3.03 moles C

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Moles F = 57.58 g/19.00 g/mole = 3.03 moles F

Moles H = 6.06 g /1.01 g/mole = 6.00 moles H

The empirical formula lists the lowest whole numbers ratio of the molecular components. For this gas that empirical formula is $C_1F_1H_2$ or CFH_2 with a molar mass of 33 g/mole. Since the actual molar mass of the gas was determined to be 66.2 g/mole, the molecular formula must have twice the subscript numbers of each atom per molecule or $C_2F_2H_4$; the gas is difluoroethane.

3. How do you explain the fact that the gas is liquid in the can, but a gas when it is collected?

   The gas is under pressure in the can. This keeps the molecules in the liquid form. When released, the liquid vaporizes at room temperature under reduced pressure.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Dust Blaster* activity, presented by Penney Sconzo, is available in *The Ideal Gas Law Applications*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Dust Blaster* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP6367	The Gas Laws, Vol. 9 of Flinn ChemTopic™ Labs Series
GP1040	Beaker, 1000-mL
OB2097	Balance, 0.001-g
AP1884	Barometer, Aneroid
GP2025	Graduated Cylinder, 250-mL

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

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