Density of Gases

The Ideal Gas Law Applications

Introduction

Finding the density of a solid or a liquid is easily done. How does one find the density of a gas? Use this demonstration to find the density of three unknown gases and determine the identity of each gas.

Concepts

- Density
- Molar mass

Materials

Gas samples (e.g., carbon dioxide, CO_2; air; methane, CH_4)

Balance, milligram

Clamps, Mohr pinchcock, 3

Electrical tape

Marker, permanent

Nail

Plastic bags, resealable, 1-qt size, 3

String

Syringe, 60-mL, modified*

Syringe tip cap

Tubing, latex, 10-cm length, 3

**See* Preparation *section.*

Safety Precautions

Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

Modified Syringe

1. Pull the plunger out of the syringe barrel to the 60-mL mark.
2. Heat the tip of the nail, then press the hot tip through the plunger shaft near the end of the syringe barrel.
3. Remove the nail.
4. *Optional:* Attach the nail to the syringe barrel with string. Reheat the nail tip and press the tip through one "wing" of the syringe barrel. Tie a knot in one end of a piece of string, large enough so it won't go through the hole. Thread the other end of the string through the hole from the bottom. Tie the free end of the string to the nail.

Gas Delivery Apparatus

1. Label one plastic bag with the letter A, one with the letter B, and the last one with the letter C.
2. Cut one bottom corner off of each bag, leaving a small hole in the corner.
3. Insert a 10-cm piece of latex tubing through the hole in each bag and secure with tape.
4. Pinch the tubing shut outside the bag with a pinch clamp.
5. Seal the bag and check to make sure no air can escape.

Filling with a Gas

1. Evacuate each bag. Remove the pinch clamp and attach the latex tubing to either a vacuum pump or aspirator. When the bag has been evacuated, replace the pinch clamp on the tubing.
2. Attach the end of the tubing to the stem on the valve of the gas source.

3. Remove the pinch clamp.
4. As slowly as possible, fill the bag assembly with the gas. The bag should be taut when filled, but not ready to burst.
5. Turn off the gas source and replace the pinch clamp.
6. Remove the tubing from the valve stem. The bag now contains a slightly pressurized sample of gas.
7. Repeat steps 1–6 for each gas to be massed.

Procedure

1. Push the plunger of the 60-mL syringe to the bottom of the syringe and attach the syringe tip cap to the tip of the syringe.
2. Pull the plunger to the 60-mL mark and place the nail in the prepared hole in the plunger so that the syringe plunger is at about the 60-mL mark (see Figure 1). This step requires two people—one person pulls the plunger out past the 60-mL mark and the other person then inserts the nail in the prepared hole. Push the plunger forward so the nail rests against the syringe bottom.

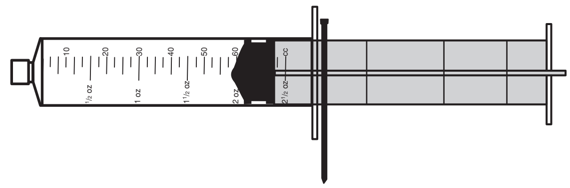

Figure 1.

3. Find the mass of the complete syringe assembly on a balance capable of reading to the nearest 0.01 g. Record the mass in the data table.
4. Record the volume of the syringe with the nail in place.
5. Remove the nail and the syringe tip cap. Depress the plunger completely. Go to the gas delivery bag A and attach the syringe to the latex tubing. (This can be done by angling the tip of the syringe at 45 degrees to the end of the tubing, then working the tubing over the tip of the syringe.)
6. Release the pinch clamp and draw the gas into the syringe until the plunger is slightly past the 60-mL mark.
7. Insert the nail into the hole in the plunger, then push the plunger forward so the nail rests on the syringe barrel.
8. Reattach the pinch clamp to the latex tubing.
9. Hold the plunger in while releasing the syringe from the latex tubing. Immediately attach the syringe tip cap.
10. Mass the syringe assembly containing gas to the nearest 0.01 g. Record the mass in the data table.
11. Release the cap and expel the gas (use a fume hood when releasing gases that are unknown or poisonous).
12. Repeat steps 5–11 with any additional gases.
13. Calculate the mass of each gas by subtracting the mass of the empty syringe from the mass of the syringe and gas.
14. Identify each gas by comparing their relative masses.
15. Determine the density of each gas by dividing the mass of each gas, respectively, by the volume of the gas in the syringe (step 4).

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. Carefully release the samples of air and carbon dioxide into the atmosphere. Burner gas should be released under an efficiently operating fume hood.

Tips

- This demonstration may easily be done as a student lab. Tell students the names of the gases they are massing, just not which bag contains which gas.
- There are various sources for gases to test. Propane and butane are available from hardware supply stores. Burner gas is a source for methane. Lecture bottles of gases, ranging from low molecular weight gases, hydrogen and helium, to the high molecular weight gas, sulfur hexafluoride, are available from Flinn Scientific.
- Step 2 requires a good amount of force to pull the syringe plunger out. Keep fingers away from the plunger shaft to avoid pinching fingers if the plunger should slip.
- Have students determine the percent error of their calculations by dividing the molar mass of each gas, respectively, by the molar volume of gas at room temperature (24 L) and comparing these values to their experimental values.
- To see if students have grasped the concept of mass and density of gases, ask the following question. "If a flask is evacuated and weighed, then filled with a low-density gas such as helium, would the flask weigh more, the same, or less than it did empty?"

Discussion

Air, like water, exerts a positive or upward buoyant force on all objects. This force is compensated for in balances when "massing" liquids and solids. When massing gases, however, this force is not negligible. The apparent mass of gas will be less than the actual mass of the gas.

$$\text{True mass of gas} = \text{apparent mass of gas} + \text{mass of air displaced.}$$

By evacuating the syringe volume of all gas (step 1), the last term, mass of air, is eliminated and the true mass of the gas can be directly determined.

The molar mass of any gas can be estimated using the ideal gas law.

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

$$PV = (\text{mass}/\text{Molar mass})RT \qquad \textit{Equation 2}$$

$$\text{Molar mass} = (\text{mass})RT/PV \qquad \textit{Equation 3}$$

However, this determination requires accurate values for temperature (T), pressure (P), and syringe volume (V).

The principles of Avogadro's law can be used to eliminate the need for these values. Avogadro's law states that the number of moles of a gas is directly proportional to its volume, when pressure and temperature are held constant.

$$n = kV \text{ (at constant P, T)} \qquad \textit{Equation 4}$$

$$k = P/RT$$

If two gases are at the same temperature, pressure, and volume, it follows that they have the same number of moles.

$$n_1 = kV_1 = n_2 \text{ (at constant P, T)} \qquad \textit{Equation 5}$$

The moles of any gas are equal to the mass of the gas divided by its molar mass. Substituting into equation 5;

$$\frac{\text{mass}_1}{\text{Molar mass}_1} = \frac{\text{mass}_2}{\text{Molar mass}_2} \qquad \text{or}$$

$$\frac{\text{mass}_1}{\text{mass}_2} = \frac{\text{Molar mass}_1}{\text{Molar mass}_2} \qquad \textit{Equation 6}$$

If the molar mass of one gas is known, the molar mass of the other gas can be determined from Equation 6.

In this demonstration, pure carbon dioxide or air can be used for the known gas. The molar mass of carbon dioxide is 44.0 g/mole. Air is a homogeneous mixture of gases and has an apparent molar mass of 28.9 g/mole. A sample calculation using carbon dioxide as the reference gas and air as the "unknown" gas is summarized below.

If the mass of air is determined to be 0.074 g and the mass of carbon dioxide is 0.12 g, then the experimental molar mass of air is calculated as follows:

$$\text{Molar mass}_{\text{air}} = \frac{0.074\text{ g}}{0.12\text{ g}} \times 44.0\text{ g/mole} = 27.1\text{ g/mole}$$

$$\%\text{ error} = \frac{|\text{ experimental value} - \text{accepted value }|}{\text{accepted value}} \times 100$$

$$\%\text{ error} = \frac{|\ 27.1\text{ g/mole} - 28.9\text{ g/mole}\ |}{28.9\text{ g/mole}} \times 100 = 6.2\%$$

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Density of Gases* activity, presented by Bob Becker, is available in *The Ideal Gas Law Applications*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Density of Gases* are available from Flinn Scientific, Inc.

Catalog No.	Description
AP8754	Syringe, 60-mL
AP8958	Syringe Tip Caps, Pkg/10
AP2077	Latex Tubing
LB1005	Carbon Dioxide Lecture Bottle
OB2141	Flinn Electronic Balance, 0.01 Readability
AB1004	Bags, Zipper-Lock, 6″ × 12″, Pkg/50

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