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10

Comparing the Masses of Equal Volumes of Gases

According to Avogadro's principle, equal volumes of gases measured at the same temperature and pressure contain equal numbers of molecules. This profound statement will allow you to determine the relative masses of individual molecules of gases. In this experiment you will find the masses of equal volumes of carbon dioxide and oxygen. Both gases will be measured at the same temperature and pressure. Although the number of molecules in the two samples of gas is unknown, Avogadro's principle states that the number in each is the same. Therefore, the ratio of the masses of the carbon dioxide to the oxygen sample must be in the same ratio as one molecule of carbon dioxide to one molecule of oxygen. Review Chapter 11, Section 11.2, for additional information.

Objective

After completing this experiment you should be able to determine the mass ratio of two different gases measured at the same temperature, pressure, and volume.

Apparatus

- plastic bag, approximately 1 liter
- rubber stopper, one-hole No. 6
- rubber band
- medicine dropper
- balance, centigram
- glass bottle, approximately 2 liters
- rubber tubing, 50 cm
- pinch clamp
- pneumatic trough

Materials

- oxygen gas
- carbon dioxide gas

Safety

Take the necessary safety precautions before beginning this experiment. Wear safety goggles, apron, and gloves. Read all safety cautions in your procedures and discuss them with your teacher. It is important to use good safety techniques while conducting experiments. See pages 114 and 115.

Recording Your Observations

Record your observations in the Data Table as instructed in the procedures.

Procedures

1. **Apparent mass of carbon dioxide.** Inspect the plastic bag for any water drops or small holes. If the bag is wet, thoroughly dry it. If there are any holes, obtain another bag. Gather the open end of the plastic bag in small pleats around the wide end of the rubber stopper. Secure the bag tightly with a rubber band. Then insert the tapered end of the medicine dropper through the hole of the stopper. See Figure 10-1.

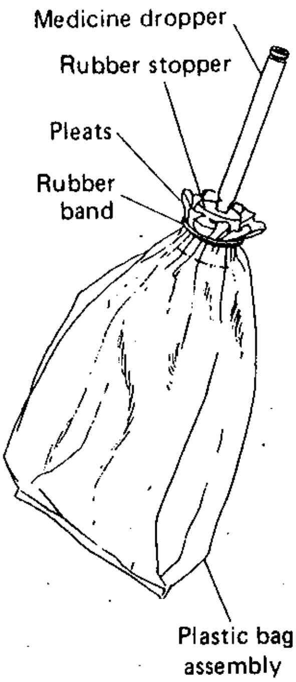

Figure 10-1

CAUTION

Gloves should be worn and a layer of cloth wrapped around the medicine dropper before inserting it into the stopper. See page 114 and observe the precautions for inserting glass tubing. Remember to aim the medicine dropper away from the palm of the hand that holds the stopper.

Check to see if there are leaks in the bag. If so, see your instructor.

Press all the air out of the bag by rolling it up tightly. Then place the rubber cap on the medicine dropper. See Figure 10-2. Weigh the bag assembly to the nearest 0.01 g and record.

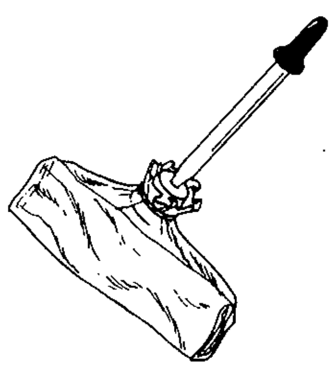

Figure 10-2

2. Your instructor will indicate where you will have your bag filled with carbon dioxide. Hold the bag by the rubber stopper. See Figure 10-3. When the bag is filled, do not replace the rubber cap until the pressure of the carbon dioxide in the bag has equalized with the outside atmospheric pressure. Why?

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When the pressure inside the bag has stabilized, cap the medicine dropper. Remember: Handle the bag assembly by the rubber stopper only. Weigh the bag and carbon dioxide gas to the nearest 0.01 g and record.

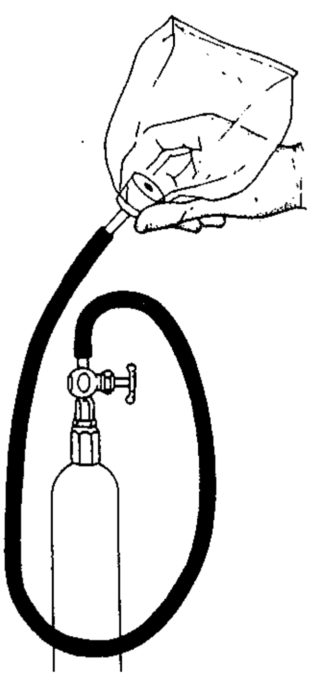

Figure 10-3

3. **Apparent mass of oxygen.** Squeeze out all of the carbon dioxide gas from the bag. Your instructor will indicate where you will have your bag filled with oxygen. Fill the bag with oxygen gas, and again allow the pressure inside the bag to stabilize. Then cap the medicine dropper. Weigh the bag assembly and oxygen gas to the nearest 0.01 g and record.

4. Without allowing any gas to escape, carefully remove the cap from the medicine dropper. Attach a piece of rubber tubing to the dropper. Fasten a pinch clamp on the rubber tubing approximately 5 cm from the end of the dropper.

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CAUTION

Gloves should be worn when inserting the medicine dropper into the hose. See page 114 and observe the precautions for inserting glass tubing.

5. Completely fill a 2-liter bottle with tapwater. Also fill the pneumatic trough with tapwater to the overflow spout. Position the overflow spout over a drain. Place your hand over the mouth of the bottle, invert it, and place the neck in the trough. Remove your hand from the bottle while under water, and allow the inverted bottle to rest on the shelf. Your lab partner will have to keep the bottle from tipping over. Insert the open end of the rubber tubing all the way into the bottle. See Figure 10-4.

6. *Hold the bag above the level of the water.* Remove the pinch clamp. Place one hand tightly around the rubber stopper. This will ensure a good seal where the bag is pleated. Now very gently squeeze the air out of the bag. As the bag deflates, crumple or roll the bag until all the air has been evacuated. Immediately squeeze off the rubber tubing and pull it out of the bottle.

7. Place your hand over the opening of the bottle that rests in water. Invert the bottle and place on the lab desk. Use a large graduated cylinder to determine the volume of water required to refill the bottle. Record this volume to the nearest mL as the volume of your bag.

8. Record the room temperature (°C) and room pressure (mm Hg).

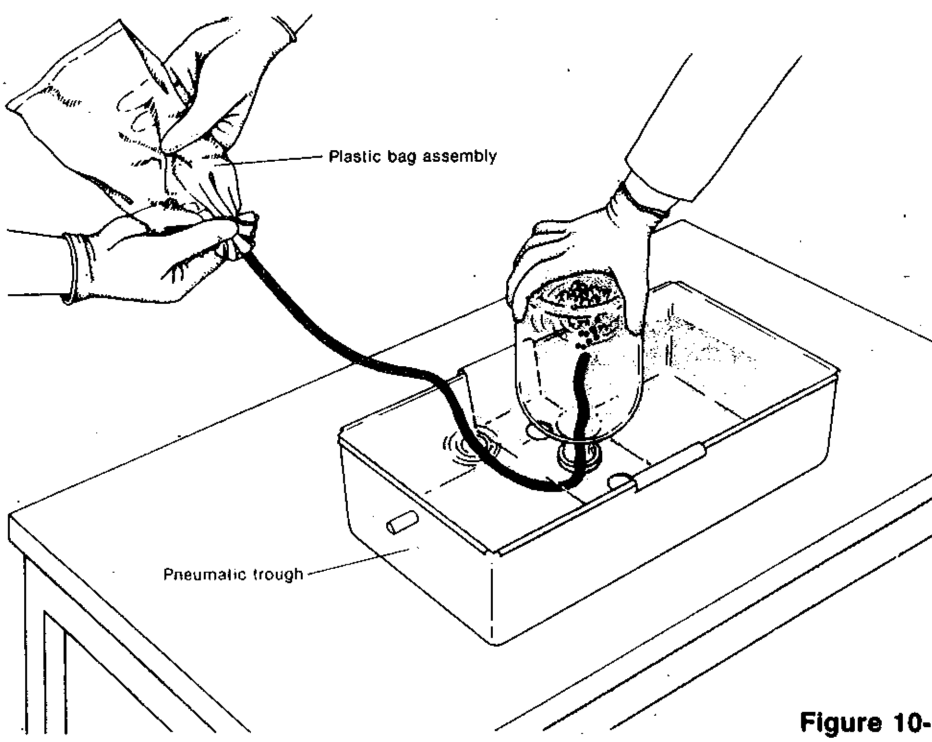

Figure 10-4

9. Clean, dry, and arrange all equipment in an orderly fashion for the next experiment.

DATA TABLE		
Mass of empty bag assembly	________	g
Mass of bag and carbon dioxide	________	g
Mass of bag and oxygen	________	g
Volume of bag	________	mL
Room temperature	________	°C
Room pressure	________	mm Hg

Calculations

Show your computations in the spaces provided below. Place your answers in the Calculations Table.

1. Calculate the apparent mass of carbon dioxide. The apparent mass is simply the difference between the mass of the bag assembly when filled with carbon dioxide and when empty.

2. Calculate the actual mass of carbon dioxide. When we weigh an object in a fluid such as air, the fluid buoys up the object. The density of air at 20 °C and 760 mm Hg is 1.2 g/L. A 1-liter object that is weighed in air will appear to have a mass of 1.2 grams less than if it were measured in a vacuum. For solids, this is not a significant value. One liter of aluminum, for example, has a mass of 2700 g. A liter of gas, however, is not much different than that of air. To find the actual mass of a gas, therefore, the mass of air it displaces must be added to its apparent mass. If the volume of gas is exactly one liter, then 1.2 grams must be added to the apparent mass. What mass must be added if the volume of the gas is 2 liters?

   (a) Use the table on page 169 to find the density of air under the conditions of pressure and temperature at which you performed the experiment and then calculate the mass of air displaced.

   Mass of air displaced = density of air × volume of bag

   (b) Calculate the actual mass of CO_2.

   Actual mass of CO_2 = mass of air displaced + apparent mass of CO_2

3. Calculate the apparent mass of oxygen gas.

4. Calculate the actual mass of oxygen gas.

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5. Determine the ratio of the actual mass of carbon dioxide to the actual mass of oxygen.

$$\frac{\textbf{actual mass } CO_2}{\textbf{actual mass } O_2} =$$

6. Assuming the formula weight of oxygen gas is 32.0 g, what is the formula weight of carbon dioxide according to your ratio in #5?

Formula weight of carbon dioxide = formula weight O_2 × ratio of CO_2 to O_2

CALCULATIONS TABLE		
Apparent mass of carbon dioxide	______	g
Mass of air displaced..................	______	g
Actual mass of carbon dioxide	______	g
Apparent mass of oxygen	______	g
Actual mass of oxygen	______	g
Ratio of actual mass of CO_2 to actual mass of O_2	______	$\frac{g\ CO_2}{g\ O_2}$
Formula weight of carbon dioxide	______	g

DENSITY OF AIR (g/L)

Pressure (mm Hg)	15 °C	20 °C	25 °C	30 °C
690	1.11	1.09	1.08	1.06
700	1.13	1.11	1.09	1.07
710	1.14	1.12	1.10	1.09
720	1.16	1.14	1.12	1.10
730	1.18	1.16	1.14	1.12
740	1.19	1.17	1.15	1.13
750	1.21	1.19	1.17	1.15
760	1.23	1.20	1.18	1.16
770	1.24	1.22	1.20	1.18

Questions

1. What assumption are you making when you determine the formula weight of carbon dioxide?

2. Why is it necessary to know the pressure and temperature when determining the density of air?