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Experiment 7-1

The Molar Volume of a Gas

Equal volumes of all gases, when measured at the same temperature and pressure, contain equal numbers of particles. This assumption was proposed in 1811, by Amadeo Avogadro, an Italian chemist. Another Italian chemist, Stanislao Cannizzaro, came upon Avogadro's hypothesis nearly 50 years later and recognized that if equal volumes of gases contain equal numbers of particles, then the masses of those gas volumes should be in the same ratio as the masses of the individual particles.

The volume of gas chosen for comparison was the volume occupied by one mole of a substance. However, since the volume occupied by a gas depends on its temperature and pressure, a standard temperature and pressure were chosen so that valid comparisons could be made. The standard temperature and pressure (STP) are 273 K and 101.3 kPa. At STP, the volume occupied by one mole of a gas is called the *standard molar volume*.

You will determine the standard molar volume of hydrogen gas in this experiment. You will begin by reacting a known mass of magnesium metal with an excess of hydrochloric acid. The hydrogen gas produced will be collected by displacing water in a gas collection tube. But whenever a gas is collected over water, the result is a mixture of the collected gas and water vapor. Dalton's law of partial pressures states that the total pressure of any gas mixture is equal to the sum of the component pressures of each of the gases.

$$P_{total} = P_x + P_y + P_z + \ldots \text{ for any number of gases.}$$

In this experiment, this statement becomes

$$P_{total} = P_{hydrogen} + P_{water\ vapor}.$$

The gas collection tube can be adjusted so that the pressure of the gas inside the tube is the same as the air pressure outside, that is $P_{total} = P_{room}$. The vapor pressure of water can be obtained from a reference table.

Having determined the volume and the pressure of the hydrogen at the temperature of the lab, you can use the combined gas laws to find the volume this sample of gas would occupy at STP. The number of moles of hydrogen can be determined from the balanced chemical equation and the mass of magnesium used.

Objectives

1. ***Observe*** the reaction of magnesium and hydrochloric acid.
2. ***Apply*** Dalton's law to find the partial pressure of collected hydrogen gas.
3. ***Determine*** the volume this gas would occupy at STP.
4. ***Calculate*** the volume of one mole of this gas at STP.

Materials

Apparatus

barometer (for class)
thermometer
Beral pipet
ring stand
utility clamp
gas collection tube
400-mL beaker
1-hole rubber stopper to fit gas collection tube
500-mL or 1000-mL graduated cylinder, battery jar or large plastic bucket
metric ruler
analytical balance (optional)
safety goggles
plastic gloves
laboratory apron

Reagents

magnesium ribbon
copper wire
1*M* hydrochloric acid, HCl

Prelab

1. Read the introduction and procedure before you begin.
2. Answer prelab questions 1–8 on the Report Sheet.

Procedure

1. Put on your safety goggles, plastic gloves, and laboratory apron.
2. Record the barometric pressure on the Report Sheet.

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3. Obtain a piece of magnesium ribbon approximately 4 cm long. Measure the length of this ribbon to the nearest 0.1 cm. Record this value on your data sheet.

4. Obtain a piece of fine copper wire approximately 15 cm long. Roll the magnesium into a loose ball and encase it in a “cage “ constructed from the coppper wire. Be sure to leave several centimeters of the wire free to use as a handle.

5. Assemble a ring stand and clamp for supporting the gas collection tube.

6. Add approximately 250 mL of room temperature water to a 400 mL beaker.

7. Carefully add 15 mL of 3.0 M Hydrochloric acid (HCl) to the collection tube. Then fill the rest of the tube with water. Tap the tube to dislodge any air bubbles.

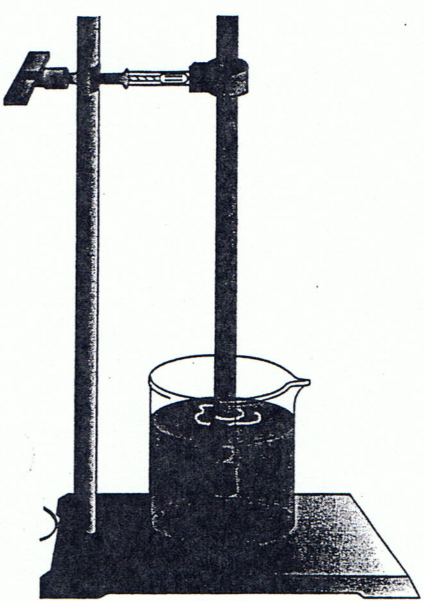
8. Place the copper cage handle into the collection tube. Keep the handle outside the tube. Secure the wire handle with the one-hole stopper.

9. Put your finger over the one-hole stopper. Invert the collection tube and submerge the end in the 400 mL beaker. Secure it in place with the clamp.

10. Observe the reaction of the magnesium with the HCl. After all the magnesium has reacted, allow about 5 minutes for the solution to cool to room temperature. Find the temperature of the water/acid mixture in the beaker and record it.

11. Cover the hole of the stopper and transfer it to the large graduated cylinder filled with room temperature water. Raise or lower the tube until the level of liquid inside the tube is equal to the level outside the tube. Record the volume of gas collected to the nearest 0.1 mL.

12. Remove the wire cage from the collection tube. Discard the water/acid mixtures as directed and clean all glassware.



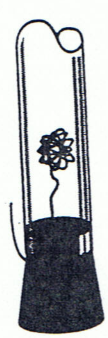


Figure B

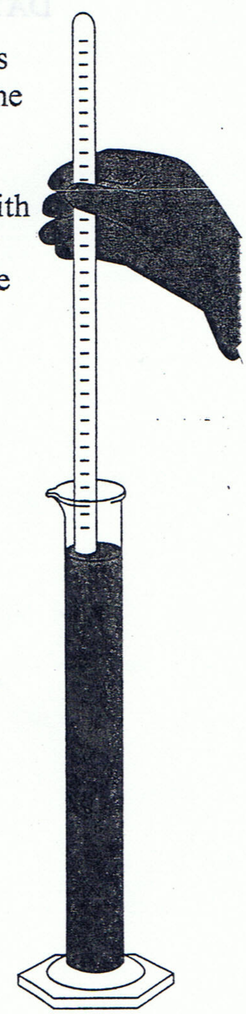


Figure C

Experiment 7-1: Molar Volume of a Gas

Prelab Questions:

1. Write the balanced equation for the reaction of magnesium metal with hydrochloric acid.

   2Mg+2HCl-------> 2MgCl + H2

2. What is the ratio of moles of magnesium used to moles of hydrogen produced in the above reaction?

3. What is meant by STP?

   Standard temperature and pressure

4. What two gases are collected in the collection tube?

   hydrogen gas and water vapor

Data and Observations:

DATA TABLE ONE:

room pressure from barometer	776.7
length of magnesium ribbon	2.5 cm = .06
mass of 100 cm of Mg ribbon	2.4 g
temperature in beaker	18 c
volume of gas collected	42.6 ml

Calculations:

1. What is the mass of the magnesium strip?

   .06 grams

2. How many moles of magnesium does this represent?

   .024 moles

3. How many maoles of hydrogen are produced in this experiment?

   .024 moles

4. What is the vapor pressure of water under these conditions?

   15.48509378

5. What is the partial pressure of *just* the hydrogen gas collected?

   761.21490622

6. What would the volume of the gas be at STP?

7. What is the volume of one mole of this gas?

Analysis and Conclusions:

1. How would the volume of gas differ in 10 cm of magnesium ribbon had been used?

   we used 2.5 cm, so if there were more it would produce more gas

2. The accepted value of 1 mole of any gas at STP is 22,400 mL per mole. What is the percent of error of your experimental value?

3. What are possible sources of error in this experiment?

   -not getting the right lengths for the magnesium and copper ribbons

4. How would changing the concentration of HCl used affect the results?

   adding more would increase the reaction create more hydrogen