Determination of the Molar Volume of a Gas

Avogadro's law states that equal volumes of gases contain an equal number 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, you will determine the molar volume of the gas produced by the chemical reaction shown below.

$$Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

You will react a known mass of solid magnesium with an *excess* of hydrochloric acid, in a sealed vessel, and use the pressure change to calculate molar volume at STP.

OBJECTIVES

In this experiment, you will

- Measure the gas production of a chemical reaction by a pressure change.
- Determine the molar volume of the gas produced in the reaction.
- Calculate the molar volume of a gas at STP.

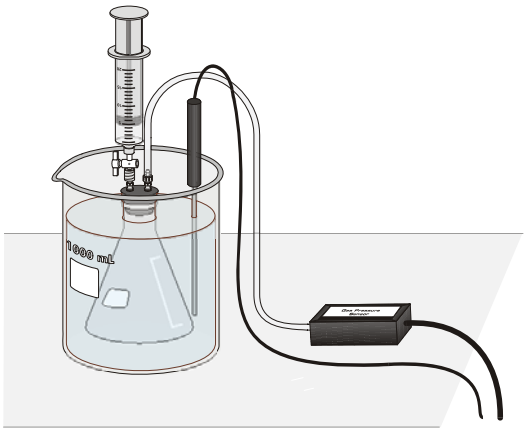

Figure 1

MATERIALS

Data Collection Mechanism
sand paper or steel wool for polishing Mg ribbon
Gas Pressure Sensor
Temperature Probe
600 mL or one liter beaker
waterproof marker
magnesium ribbon, pre-cut (one approx. 15 mm piece per trial)
3.0 *M* hydrochloric acid, HCl, solution (5 mL per trial)
small beaker for HCl solution
ruler (if analytical balance is not available)
125 mL Erlenmeyer flask
20 mL gas syringe
plastic tubing with two Luer-lock connectors
rubber stopper assembly with two-way valve

PROCEDURE

1. Obtain and wear goggles. Obtain the 125 mL Erlenmeyer flask that you will use for the experiment. Determine and record the available volume of the flask that the hydrogen gas will occupy as it is produced from the reaction of the solid magnesium and the hydrochloric acid solution. Account for the following items when you determine the volume of your flask:
    - A 125 mL flask does not have a volume of precisely 125 mL.
    - During the experiment, you will seal the flask with a rubber stopper and the stopper will occupy some of the volume of the flask.
    - You will add 5 mL of solution (3.0 *M* HCl solution) to the flask.
2. Obtain a piece of magnesium ribbon. Use a piece of sandpaper or steel wool to polish it until it is silver and shiny. Measure its mass on the analytical balance. If one is unavailable, then measure and record its length to the nearest mm. Ask your instructor for the mass of one meter of polished magnesium ribbon, and record this information. Use a simple proportion to calculate the mass of your sample of Mg ribbon and record its value. Place the piece of magnesium ribbon in a clean and dry 125 mL Erlenmeyer flask.
3. Prepare a room temperature water bath in a large beaker. The bath should be deep enough to completely cover the gas level in the Erlenmeyer flask.
4. Set up the data collection system.
    a. Connect a Gas Pressure Sensor and a Temperature Probe to the interface.
    b. Start the data collection program.
    c. Set up data collection for 2 seconds per sample and 150 samples.
5. Use the clear tubing to connect the white rubber stopper to the Gas Pressure Sensor. (About one-half turn of the fittings will secure the tubing tightly.) Twist the white stopper snugly into the neck of the Erlenmeyer flask to avoid losing any of the hydrogen gas that will be produced in the reaction (see Figure 1). **Important**: Close the valve on the white stopper by turning the white handle so it is perpendicular with the valve stem.
6. Obtain a small amount of 3.0 *M* hydrochloric acid. **CAUTION:** *Handle the hydrochloric acid with care. It can cause painful burns if it comes in contact with the skin*. Draw 5 mL of HCl solution into the 20 mL syringe. Thread the syringe onto the two-way valve on the white stopper (see Figure 1). Submerge the Erlenmeyer flask into the water bath. Position the Temperature Probe in the water bath so that the tip of the probe is not touching the beaker.
7. With the flask still submerged in the water bath, begin data collection. After about 20 seconds, open the two-way valve directly below the syringe, press the plunger to add all of the 5 mL of HCl solution to the flask, and close the two-way valve.
8. Gently swirl the flask, while keeping it immersed in the water bath, as the reaction proceeds. Data collection will stop after 5 minutes.
9. Carefully remove the white stopper from the flask to relieve the pressure in the flask. **Important**: Do not open the two-way valve to release the pressure in the flask.
10. Examine the pressure data to determine the change in pressure, ΔP, during the reaction. In addition, determine the mean temperature of the water bath during the reaction. Record these values in your data table.

11. Store or record your data.
12. Rinse, clean, and dry the flask.
13. Conduct two more trials.

DATA TABLE

	Trial 1	Trial 2	Trial 3
*Mass of Mg (g)			
Volume of flask (mL)			
Maximum pressure (atm)			
Initial pressure (atm)			
Pressure change, ΔP (atm)			
Temperature (K)			

PRE-LAB QUESTION

A reaction of 0.028 g of magnesium with excess hydrochloric acid generated 31.0 mL of gas.
The gas was collected by water displacement in a 22 °C water bath. The barometric pressure that day was 746 mm Hg.

(a) Use Dalton's law and the vapor pressure of water at 22 °C (the table value is 19.8 mm Hg) to calculate the partial pressure of hydrogen gas collected.

(b) Use the combined law to calculate the "corrected" volume of hydrogen gas collected at STP.

(c) What is the theoretical number of moles of hydrogen that can be produced from 0.028 g of Mg?

(d) Divide the corrected volume of hydrogen by the theoretical number of moles of hydrogen to calculate the molar volume (L/mol) of hydrogen at STP.

POST-LAB QUESTIONS AND DATA ANALYSIS

1. *Calculate the mass of each piece of magnesium that you used if an analytical balance was unavailable.

2. Calculate the number of moles of each piece of magnesium that you used.

3. Calculate the theoretical number of moles of hydrogen gas produced in *each* trial.

4. Use your results to calculate the molar amount of hydrogen gas that was produced in your reactions at STP.

5. Compare your calculated molar volume, at STP, with the accepted molar volume of an ideal gas at STP, 22.4 L/mol. Calculate the % error for each trial.

6. A student fails to polish each sample of Mg ribbon before massing them. What effect does this error have on the calculated molar volume of hydrogen gas? Mathematically justify your answer.

7. A different student fails to insert the stopper into the flask while determining the available volume of the 125 mL flask. What effect does this error have on the calculated molar volume? Mathematically justify your answer.