AP Chemistry Lab

Molar Volume of a Gas

Introduction

Avogadro's hypothesis states that equal volumes of all gases contain equal numbers of molecules under the same conditions of temperature and pressure. It follows from this hypothesis that all gas samples containing the same number of molecules will occupy the same volume under the same conditions of temperature and pressure. A special name is given to the volume occupied by 1 mole samples of gases at STP. This volume is called the *molar volume.* In this experiment, you will make an experimental determination of the molar volume.

Pre-lab Questions

1. In this experiment, you will react a known mass of magnesium with excess hydrochloric acid to produce hydrogen gas. Write a balanced chemical equation for this reaction. Be sure to include the phase of each reactant and product.

2. What is the mole ratio of magnesium to hydrogen gas for this reaction?

3. What is the accepted value for the molar volume of a gas at STP?

4. What temperature and pressure are considered to be *standard temperature and pressure*?

5. What is *Dalton's Law of Partial Pressure*?

Materials and Equipment

magnesium ribbon
6.0 M hydrochloric acid
thermometer
barometer
a wash bottle containing tap water
rubber stopper with hole
eudiometer (50 ml)
beaker (400 ml or larger)
safety goggles
fine gauge copper wire
small beaker for transporting acid

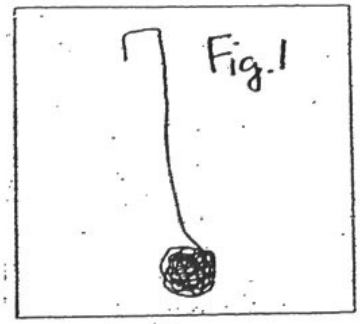
Safety

Handle the 6.0M HCl with care. Always wear safety goggles when handling acids. Handle glassware carefully to avoid breakage.

Procedures

1. Obtain a piece of magnesium ribbon approximately 3.5 cm in length. Measure the length of the ribbon to the nearest 0.1cm and record this length in your data table. Also record the mass of a piece of magnesium ribbon 100.0cm (1.000m) long. This data will be provided by your teacher.

2. Roll the piece of magnesium loosely. Look at figure 1 to see how the magnesium ribbon is encased in a cage of fine copper wire. Notice that the cage has no large openings through which small pieces of magnesium ribbon could escape. The copper cage must also be small enough to fit in the eudiometer tube.



3. Set up a ring stand and utility clamp or buret clamp to hold a 50 ml glass gas measuring tube (eudiometer). Fill a 400 ml beaker two-thirds full of tap water. Place it near the ring stand.

4. Use the small beaker to obtain about 10 ml of 6.0 M HCl from your teacher. Handle the acid with extreme care. It is very concentrated! Remove the eudiometer from the clamp and holding it at a slight incline, add the HCl to the tube. Do not attempt to pour the acid into the eudiometer while it is in the clamp. When adding the acid to the eudiometer, the tube should be held at a level below the level of your eyes and face.

5. With the tube in the same position, slowly fill it with tap water from a wash bottle. While pouring, rinse down any acid that may be on the side of the tube so that the liquid in the top of the tube will contain very little acid. Try to avoid stirring up the acid layer in the bottom of the tube. Bubbles clinging to the side of the tube can be dislodged by tapping the tube gently. Fill the tube as full as possible.

6. Holding the copper coil by the handle, insert the cage about 5 cm into the eudiometer. Hook the copper wire over the edge of the tube and hold it there by inserting a rubber stopper. Insert the stopper firmly! The tube should be completely filled with water so that the stopper displaces a little water when pushed into place. See figure 2.

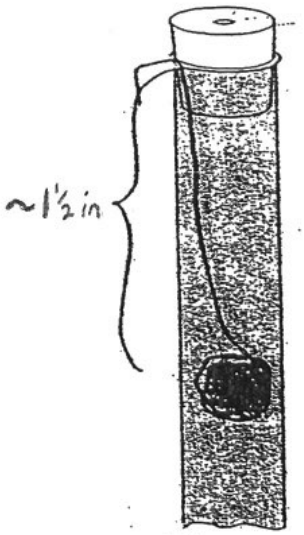


Figure 2

7. Cover the hole in the stopper with your finger and invert the tube in the large beaker of water. Remove your finger from the hole. Carefully clamp the tube in place. See figure 3.

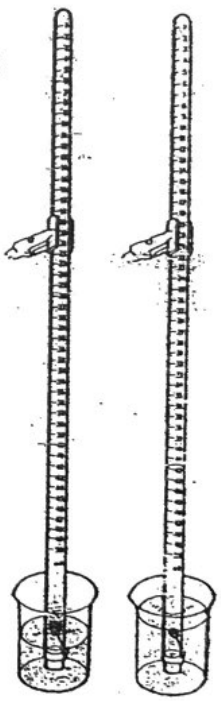


Figure 3

8. The acid, being more dense than the water, will fall down through it and eventually react with the magnesium. After the reaction stops, wait for about 5 minutes to allow the tube to come to room temperature. Dislodge any bubbles that cling to the sides by gently tapping the sides of the eudiometer.

9. Reach into the water and cover the hole with your finger. Keep the tube in the same position (with the stopper downward) and transfer it to a large cylinder or battery jar which is filled with water at room temperature. See

figure 4. Lower or raise the eudiometer until the level of the liquid in the tube is the same as the level outside the tube. This permits you to measure the volume of the gases in the tube (hydrogen and water vapor) at room pressure.

Read the gas volume. Your eye should be at the same level as the bottom of the meniscus. Record the volume of the gas as precisely as you can.

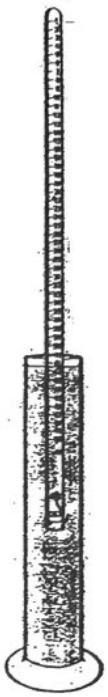


Figure 4.

10. Remove the gas measuring tube from the water and pour the acid solution in the tube down the sink. Rinse the tube with tap water several times.

11. Record room temperature and barometric pressure.

Data and Observations

Measurements Needed to Determine Molar Volume

Length of magnesium ribbon	1.71 cm
Mass of 1 meter of magnesium ribbon	1.986g / 100.0 cm
Volume of hydrogen gas collected (at atmospheric pressure)	37.00 mL
Room temperature	23.2°C
Atmospheric pressure	28.75 inHg
Water vapor pressure at room temperature (see chart)	21.324 mmHg

Visual Observations:

Calculations and Analysis

1. Find the mass of the piece of magnesium ribbon used in your experiment. Convert cm of Mg to grams of Mg using the mass of 1 meter of Mg. Use dimensional analysis to show all units and how they cancel.

2. Calculate the number of moles of Mg that reacted.

3. Find the pressure exerted by the hydrogen gas in the cylinder. Remember, that when a gas is collected by water displacement, water vapor is also present. The total pressure of the mixture of gases is equal to the pressure exerted by the water vapor plus the pressure exerted by the hydrogen (*Dalton's Law of Partial Pressure*).

4. Convert room temperature from degrees Celsius to Kelvin. Show work.

5. Calculate the volume of the collected hydrogen at STP.

6. Use your data to find the volume of one mole of hydrogen gas at STP. Use the answer to number 2 (moles Mg) and the answer to number 5 (ml H_2) to make a conversion factor for converting 1 mole H_2 to milliliters. Convert ml to liters.

7. The accepted value for the molar volume of a gas is 22.4 liters (22,400 ml). How does your experimentally determined value compare with this accepted value? Calculate your percentage error.

8. What happens to the other product of the reaction in this experiment?

9. How many cm of magnesium ribbon would be required to produce 100.0 ml of hydrogen gas at the same temperature and atmospheric pressure as in your experiment? Show all work.