Molar Volume of a Gas

Background: Avogadro's principle states that equal volumes of gases at the same conditions of temperature and pressure contain equal numbers of molecules. One mole of any gas contains the number of molecules known as Avogadro's number 6.02 x 10^{23}. Therefore, one mole of any gas at standard conditions of temperature and pressure (STP) must occupy a constant volume. This volume is termed the molar volume. In this experiment the molar volume of hydrogen will be determined by measuring the volume of hydrogen displaced by magnesium.

Objective: To determine the molar volume of a gas.

Safety: Wear chemical splash goggles, gloves, and an apron. Use caution in pouring the acid into the eudiometer. Hydrogen gas is explosive. Remove all ignition sources. Vent the gas generated into a fume hood.

Disposal: Pour the water from the 2L beaker and eudiometer down the drain.

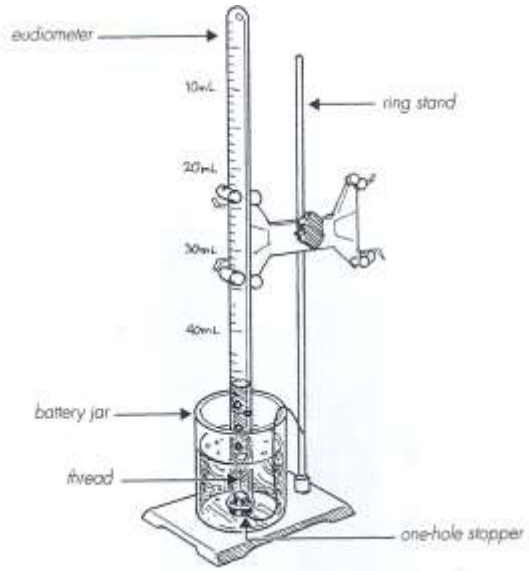

FIGURE 25.1 Experimental setup for determining the molar volume of a gas

Materials

• magnesium sample (pre-cut)	• metric ruler
• 600-mL beaker	• non-mercury thermometer
• water at room temperature	• double buret clamp
• 1-hole stopper to fit the eudiometer	• 20 ml of 3 M sulfuric acid
• 50-ml eudiometer	• 50 cm length of thread
• 150-ml beaker	• funnel

Procedure

1. Obtain a pre-cut piece of magnesium ribbon from your instructor. Measure its mass and record it in the Data Table.
2. Fill a 600-mL beaker with room-temperature tap water.
3. Roll the ribbon into a coil and tie it with a piece of thread. The thread should be approximately 50 cm long.
4. Pour 20 ml of 3M hydrochloric acid into a 150-ml beaker. Lower the eudiometer below eye level. Using a funnel, pour the acid into a clean, dry eudiometer.

Read Steps 5-7 carefully before proceeding. Examine Figure 25.1. Once you are familiar with the procedure, complete Steps 5-7.

5. Add distilled water to fill the eudiometer. Be certain there is no air remaining.
6. Starting at the small end of the stopper, push the thread through the hole leaving the magnesium and about 5 cm of thread dangling from the stopper.
7. Place the stopper in the eudiometer. Grasp the eudiometer with your fingers and place your thumb over the hole in the stopper and invert the eudiometer in the 600-mL beaker. Clamp the eudiometer in a buret clamp and rest the eudiometer on the bottom of the beaker.
8. When the reaction has stopped, use a ruler to measure the height of the water column remaining in the eudiometer using the level of the water in the beaker as the reference point. Be sure to make the measurement from the bottom of the meniscus. Record this height in the Data Table.
9. Use graduations on the eudiometer to record the volume (mL) of H_2 collected. Be sure to make the measurement from the bottom of the meniscus.
10. Record the temperature of the water in the beaker.
11. Record the barometric pressure.
12. Replace the stopper and bring the eudiometer to the fume hood. Vent the hydrogen into the fume hood.
13. Discard the remaining water in the eudiometer into the acid waste disposal container.
14. Repeat Procedure for a second trial.
15. Dismantle the apparatus and empty the contents of the beaker into the sink.

Calculations

1. Determine the **number of moles of magnesium reacted**. Record this in the Calculations Table.
2. Write the balanced equation for the reaction and **determine the number of moles of hydrogen produced from 1 mole of magnesium**. Record this in the Calculations Table.
3. Using the moles of magnesium reacted and the molar ratio, calculate the **theoretical moles of hydrogen** produced. Record this value.
4. Calculate the partial pressure of hydrogen at laboratory conditions as follows:
   a. **Pressure of water column**- Convert the height of the water column in centimeters to a pressure in hectapascals by multiplying by the conversion factor of 0.980 hPa/cm.
   b. **partial pressure of water**-Using a table of water vapor pressure, determine the vapor pressure of water at the temperature of your beaker of water. If the value is not given in hPa, you will need to convert to hPa. Record the value.
   c. **partial pressure of dry H_2**- Determine the partial pressure of hydrogen by subtracting the pressure of the water column and the vapor pressure of water from the barometric pressure. Record this as the pressure of dry hydrogen.
5. **Determine the volume of hydrogen at STP** by using the pressure of dry hydrogen (you will need to convert from hPa to atm: 1 atm = 1013 hPa), the temperature, the volume of the hydrogen, and the combined gas law $P_1V_1/T_1 = P_2V_2/T_2$. Record the result in the Calculations Table.
6. Using the theoretical moles of hydrogen produced and the volume of dry hydrogen at STP, calculate the **molar volume for hydrogen** at STP. Record this value.
7. Determine the percent error for your results.

Data Table

	Trial #1	Trial #2	Units
mass of Mg			
volume of gas(es) collected			
temperature of water			°C
			K
height of water column			
barometric pressure			

Balanced Equation	

Calculations Table

	Trial #1	Trial #2	Units
moles of Mg reacted			
molar ratio H_2 : Mg			
moles of H_2 produced (theoretical yield)			
pressure of water column			
vapor pressure of water			
partial pressure of dry H_2			
volume of H_2 at STP			
molar volume of H_2			
Average molar volume of H_2 (experimental)			
molar volume of H_2 (accepted)	22.414 L/mol		
percentage error			

Scoring

6 points are allocated for your skill, effort, housekeeping, safety, and focus in lab. Keep your work station neat, use careful technique, work safely, and clean up after yourself.

5 points for the Data Table

1 point for the balanced equation

18 points for the Calculations Table