# Molar Volume of a Gas

## I. PURPOSE

The purpose of this experiment is to determine the volume of one mole of $H_2$ by reacting Mg with HCl to produce $H_2$ gas.

## II. PRE-LAB QUESTIONS

1. 746 mmHg - 19.8 mmHg = 726.2 mmHg
2. $\frac{726.2\ mmHg \times 31.0\ mL}{295\ K} = \frac{760\ mmHg \times V2}{273\ K}$ $V_2 = 27.4$ mL
3. 0.028 g Mg $\times \frac{1\ mol\ Mg}{24.305\ g\ Mg} \times \frac{1\ mol\ H2}{1\ mol\ Mg} = 0.00115$ mol $H_2$
4. $\frac{0.0274\ L}{0.00115\ mol} = 23.8$ L/mol

## III. PROCEDURE

1. Fill a 400-mL beaker about ¾ of the way full of water.
2. Obtain a 4.5-cm piece of magnesium ribbon and create a cage for it using one end of a 15-cm piece of copper wire.
3. Place the straight end of the copper wire into a one-hole rubber stopper and hook the end of the copper wire around the edge of the rubber stopper.
4. Fill a eudiometer with 15 mL of 2M HCl, then slowly fill the rest of the eudiometer with water from a wash bottle.
5. Insert the rubber stopper and magnesium into the eudiometer, then cover the hole of the rubber stopper with your thumb and lower the stoppered end of the eudiometer into the beaker of water, clamping the eudiometer into place afterwards.

6. After the magnesium ribbon has completely reacted, let it stand for 5 minutes. Then move the eudiometer and stopper apparatus into a 500-mL graduated cylinder filled with water.
7. Gently move the eudiometer up and down until the water levels in the eudiometer and in the graduated cylinder are equal. Record the volume of $H_2$ gas, the temperature of the water bath in the graduated cylinder, and the barometric pressure in the lab room.

## IV. MEASUREMENTS TO BE TAKEN

The measurements to be taken are as follows: length of the magnesium strip, volume of 2M HCl, volume of $H_2$ gas produced, temperature of the water bath in the graduated cylinder, and the barometric pressure in the lab room.

## V. MATERIALS

A. 15 mL of 2M HCl
B. Distilled water
C. Magnesium ribbon, Mg, 4.5 cm
D. Barometer
E. 400-mL beaker
F. 15-cm piece of copper wire
G. 100-mL eudiometer tube
H. 500-mL graduated cylinder
I. 25-mL graduated cylinder
J. Metric ruler

K. One-hole rubber stopper

L. Scissors

M. Thermometer

N. Wash bottle

## VI. DATA

| | Trial 1 |
|---|---|
| Length of magnesium ribbon | 4.50 cm |
| Mass of Mg | 0.0666 g |
| Volume $H_2$ gas | 68.80 mL |
| Barometric pressure | 1.00063 atm |
| Water bath temperature | 24.3ºC |

## VII. CALCULATIONS

A. Magnesium ribbon mass calculation: $4.50\ \text{cm} \times 1.48 \times 10^{-2}\ \text{g/cm} = 0.0666\ \text{g}$

B. Moles of $H_2$ calculation: $0.066\ \text{g Mg} \times \frac{1\ mol\ Mg}{24.305\ g\ Mg} \times \frac{1\ mol\ H2}{1\ mol\ Mg} = 0.00274\ \text{mol}\ H_2$

C. Partial pressure of $H_2$: 760.4788 mmHg - 22.79 mmHg = 737.6888 mmHg

D. Corrected volume of $H_2$: $\frac{1.00063\ atm \times 68.8\ mL}{297.4\ K} = \frac{1\ atm \times V2}{273\ K}$ $V_2 = 63.2\ \text{mL}$

E. Molar volume of $H_2$: $\frac{0.0632\ L}{0.00274\ mol} = 23.1\ \text{L/mol}$

F. Percent error: $\frac{(23.1 - 22.4)}{22.4} \times 100 = 3.13\%$ error

G. Density of $H_2$: $\frac{2.02\ g}{23.1\ L} = 0.0874\ \text{g/L}$

## VIII. RESULTS

The molar volume of $H_2$ gas was found to be 23.1 L/mol at STP. Water displacement was used to measure the volume of $H_2$ gas, and calculations were performed to determine the molar volume of $H_2$ gas.

## IX. <u>ANALYSIS</u>

This lab was conducted in order to determine the molar volume of $H_2$ gas. From this experiment, it was determined that the molar volume of $H_2$ gas at STP is 23.1 L/mol.

From this lab, I learned how to collect a gas and measure its volume through water displacement, suspend metals in order to dissolve them, and determine the molar volume of a gas.

This experiment is an effective method for determining the molar volume of a gas at STP. The experiment works because the combined gas law allows for the calculation of a "corrected" volume, or volume at STP, regardless of the surrounding pressure or temperature. The experiment also works because the partial pressure of any gas can be found when the gas is collected and measured through water displacement.

The percent error in the measured molar volume of $H_2$ gas is $\frac{(23.1 - 22.4)}{22.4} \times 100 =$ 3.13% error.

One possible source of error in the experiment is the fact that a few small pieces of magnesium ribbon, totaling roughly 2 $mm^2$ of magnesium, escaped from the cage and did not react with the HCl. This would have decreased the amount of magnesium reacting with the HCl, thus leading to a lower volume of $H_2$ gas being produced. Another source of error was the fact that a small piece of magnesium, roughly 1 $mm^2$ in size, was caught in between the bars of the copper cage and was not able to react with the HCl. This would have decreased the amount of magnesium reacting with the HCl, also leading to less $H_2$ gas being produced.

In order to improve on the procedure, I would make use of a standard copper cage design that is sure to prevent small pieces of magnesium from floating to the top of the eudiometer.

There is value in repeating the experiment, as repeating the experiment allows for the avoidance of previous sources of error, leading to higher quality results and lower percent error, as well as identification of other sources of error not initially observed.

**Post-lab Questions**:

1. Moles of $H_2$ calculation: 0.066 g Mg $\times \frac{1\ mol\ Mg}{24.305\ g\ Mg} \times \frac{1\ mol\ H2}{1\ mol\ Mg}$ = 0.00274 mol $H_2$
2. Partial pressure of $H_2$: 760.4788 mmHg - 22.79 mmHg = 737.6888 mmHg
3. Corrected volume of $H_2$: $\frac{1.00063\ atm \times 68.8\ mL}{297.4\ K} = \frac{1\ atm \times V2}{273\ K}$ $V_2$ = 63.2 mL
4. Molar volume of $H_2$: $\frac{0.0632\ L}{0.00274\ mol}$ = 23.1 L/mol
5. $\frac{(23.1 - 22.4)}{22.4} \times 100 = 3.13\%$ error
6. $\frac{2.02\ g}{23.1\ L}$ = 0.0874 g/L; this value is lower than the literature density of $H_2$ gas, which is 0.08988 g/L.
7. This would raise the measured volume of the $H_2$ gas due to the increased amount of gases in the space occupied by the $H_2$, thus increasing the measured volume and decreasing the calculated molar volume.

8. This would decrease the amount of $H_2$ gas produced due to the decreased amount of reactable magnesium, thus decreasing the volume of $H_2$ produced and leading to a higher molar volume.