SCH3U3 Period # 2 / Room 311

"Standard Molar Volume of H_2 "

Given: Dec. 9, 2019

Due: Dec. 10, 2019

Lab Partners:

Dhrumil Patel

Kevin Wang

Purpose:

The ideal gas law, $PV = nRT$, demonstrates the relationship between pressure, volume, moles, and temperature. This relationship can be leveraged to find the molar volume of a gas. This lab explores the use of this relationship to find the moles of hydrogen gas from a reaction between magnesium metal and hydrochloric acid.

Materials

- Eye protection
- 2 - 3 cm of magnesium metal
- 10 mL of 6 M HCl
- Gas burette
- String
- 500 mL beaker
- 300 mL of tap water
- Barometer
- Thermometer
- String
- Balance
- Stopper

Procedure:

Please refer to the lab sheet "Standard Molar Volume of H_2 Lab"

Observations:

Mass of magnesium metal (g)	0.041
Ambient Temperature (K)	296.65
Atmospheric Pressure(kPa)	100.6
Volume of H_2 gas(mL)	43.2
Temperature of water in the beaker(K)	298.15
Volume of HCl (mL)	17.1

Table 1.1

Analysis:

1. Balance the equation.

$$Mg_{(s)} + HCl_{(aq)} \rightarrow H_{2(g)}$$
$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + MgCl_{2(aq)}$$

2. Determine the vapour pressure of water at room temperature

   From the chart of vapour pressures of water at various temperatures, the vapour pressure of water at 23.5 °C is about 2.89 kPa.

3. Subtract the vapour pressure of water from the atmospheric pressure. This is the pressure of hydrogen gas.

   $$P_a - P_v = P_H$$
   $$100.6 - 2.89 = 97.71$$
   $$P_H = 97.71\ kPa$$
   The pressure of hydrogen gas is 97.71 kPa.

4. Convert the volume of the gas collected to STP. Use room temperature for T1 for hydrogen gas.

   With the combined gas law, $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, the volume of the gas can be calculated as follows:
   $$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$
   $$\frac{(97.71)(43.2\times10^{-3})}{296.65} = \frac{(101.3)V_2}{273.15}$$
   $$V_2 = \frac{(97.71)(43.2\times10^{-3})(273.15)}{296.65(101.3)}$$
   $$V_2 = 38.3681\ \times 10^{-3}\ L\ =\ 38.3681\ mL$$
   The volume of gas at STP is 38.3681 mL.

5. Determine the number of moles of hydrogen gas formed using the balanced equation and the stoichiometry between Mg and H_2.

   The balanced equation is $Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2(g)} + MgCl_{2(aq)}$, and the number of moles of H can be found as follows:
   $$n\ =\ \frac{m}{M}$$
   $$n\ =\ \frac{0.041}{24.305}$$
   $$n\ = 0.00169\ mol\ of\ Mg$$

   $$\frac{n_{Mg}}{n_{Mg}} = \frac{n_{H_2}}{n_{H_2}}$$
   $$\frac{0.00169}{1} = \frac{n_{H_2}}{1}$$
   $$n_H = 0.00169\ mol\ of\ H_2$$

   Therefore, 0.00169 mol of H_2 is formed in this reaction.

6. Calculate the standard volume of hydrogen if there was one mole of H_2 produced. (This is using your results from #4 and #5)

The standard volume of hydrogen if one mole of H_2 is produced can be calculated as follows:

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$
$$\frac{V_1}{1} = \frac{43.2\times10^{-3}}{0.00169}$$
$$V = 25.562\ L$$

If one mole of H_2 was produced, there would be 25.562 L produced.

7. Compare your answer to the literature value of 22.4 L at STP by finding the percent difference.

$$\%difference = |\frac{22.4 - V_H}{22.4}| \times 100\%$$
$$\%difference = |\frac{22.4 - 25.562}{22.4}| \times 100\%$$
$$\%difference = |\frac{22.4 - 25.562}{22.4}| \times 100\%$$
$$\%difference = 0.1412 \times 100\%$$
$$\%difference = 14.12\%$$

There is a 14.12% difference from the literature value of 22.4 L at STP.

8. Explain why the partial pressure of hydrogen is determined by the subtraction of the vapour pressure of water from the atmospheric pressure.

By Dalton's Law of Partial Pressures, the total pressure of a gaseous solution is the sum of the pressures of the constituent gases if they took up the same volume as the total volume. In this experiment, HCl, water, and magnesium were in the test tube. As such, HCl and water will contribute vapour pressure in the tube. Therefore, any value for pressure calculated will also include this vapour pressure. So, to determine the partial pressure of hydrogen gas, this vapour pressure can be subtracted from the total pressure, as explained by Dalton's Law of Partial Pressures.

9. Why is the solution left for 5 minutes before the temperature of the water in the beaker is taken?

Leaving the solution for 5 minutes ensures that as much of the HCl can react with the Mg to produce H_2 gas. After 5 minutes, it is reasonable to assume that almost all of the HCl reacted with Mg and the H_2 gas collected is the most H_2 that can be collected. If the temperature of the water in the beaker was to be recorded immediately after the reaction seemed to have settled, the temperature recorded would be lower than the real temperature as the volume, and thereby temperature, of the H_2 gas could be increased.

Conclusion

This experiment explored the relationships between pressure, volume, moles, and the temperature of hydrogen gas in the reaction between magnesium and hydrochloric acid. It was found that 0.00169 mol of H_2 was produced in the reaction between 0.041 g of Mg and

17.1 mL of 6M HCl. Moreover, the molar volume of H_2 was found to be 24.562L, a 14.12% difference from the molar volume of 22.4 L. This difference can be explained through the three largest sources of error in this experiment: all of the HCl may not have reacted with all of the Mg, the ambient temperature may not have been the same temperature at which the reaction took place, and the reaction may not have occurred at the exact pressure read by the barometer. All of the HCl not reacting with the Mg would lead to a lower volume of H_2 gas produced than would have been produced in a complete reaction. The differences between the ambient temperature and atmospheric pressure and the temperature and pressure at which the reaction occurred can contribute to higher or lower molar volumes of H_2 calculated.