Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Period \_\_\_\_

**THE STANDARD MOLAR VOLUME OF A GAS LAB**

Both solids and gases are often handled in the same experiment. The mass of a solid can easily be determined using a balance. However, it is more difficult to find the mass of a gas. Chemists measure gas volume and use this value to calculate the number of moles, and furthermore the mass of the gas. Therefore, it is necessary for the chemist to know the quantitative relationship between the volume of a gas and the number of moles of the gas. *Avogadro's hypothesis* explains this relationship and states that *equal volumes of gases under the same temperature and pressure conditions contain an equal number* of *molecules.* This is the basis behind the standard molar volume of a gas. In other words, the volume occupied by one mole of any gas at standard temperature and pressure equals 22.400 liters.

**Purpose:**

1. Experimentally determine the volume of H2 gas collected from a reaction between HCl and Mg.
2. Use the volume of H2 to determine the moles of H2 collected
3. Compare the results to Avogadro’s hypothesis at STP, the standard molar volume of a gas

**Background Knowledge:**

1. Write a balanced chemical equation for the reaction between hydrochloric acid and magnesium metal. (Hint: This is a single replacement reaction that produces H2 gas.)
2. Write the equation for Dalton’s Law of Partial Pressures for gases collected over water.
3. What must be true about the water levels inside and outside the gas collection container in order for Dalton’s Law to apply?
4. What is the *theoretical* standard molar volume of a gas? (Hint: This is the volume of one mole of any gas at STP.)
5. What are the conditions of STP? Temperature \_\_\_\_\_\_\_\_\_\_\_\_ Pressure \_\_\_\_\_\_\_\_\_\_\_\_

**Materials:**

* 10 mL graduated cylinder
* tall cylinder filled with water
* 400 mL beaker
* 50 mL eudiometer
* 6.0 M HCl
* Balance
* Barometer
* Metric ruler
* Mg ribbon
* Rubber stopper with 1 hole
* Ruler
* Scissors
* Sink filled with tap water
* String
* Thermometer

***Safety:***

***6.0 M HCl can cause mild burns and irritate your lungs and eyes. Handle with extreme caution, and avoid contact and inhalation. Rinse spills with plenty of water and baking soda and/or soap.***

**Procedure:**

1. Fill the sink with tap water and allow it to come to room temperature (about 2 minutes)
2. Fill a 400 mL beaker with tap water from the sink and allow it to come to room temperature
3. Find the room temperature and record this value in your data table
4. Find the water temperature and record this value in your data table
5. Record the barometric pressure (provided by your instructor)
6. Obtain a 2.5 cm piece of magnesium ribbon. Find the mass of your magnesium ribbon and record this value in your data table
7. Obtain a piece of string approximately 10 cm long. Tie the string around the magnesium ribbon and fold the Mg to a size that will fit inside the eudiometer tube.
8. *SLOWLY* pour about 10 mL of 6.0 M HCl into the eudiometer tube.
9. Tilt the eudiometer slightly and fill it completely to the top with tap water from the beaker. Pour the water slowly down the side of the tube so the water and acid mix as little as possible.
10. With the eudiometer completely full of water, insert the string tied to the magnesium ribbon about 3 to 4 cm into the tube. With the string against the side of the tube and partially hanging out, insert a 1-hole rubber stopper. The stopper should force water and all air bubbles out of the tube and should hold the string suspending the magnesium in place.
11. Make sure there is no air in the hole of the stopper. Place your finger over the hole in the stopper and invert the stoppered end of the tube in the sink of water. Once submerged, remove your finger and hold the eudiometer so it remains suspended in the water.
12. Watch the acid slowly diffuse downward (this looks sort of “trippy”). The reaction will begin when the acid reaches the magnesium metal.
13. When the magnesium has reacted completely and evolution of gas has ceased, tap the side of the eudiometer tube with your finger to dislodge any bubbles.
14. Cover the hole in the stopper with your finger and transfer the tube to a large cylinder that is almost filled with water at room temperature. Raise and lower the tube until the level of the liquid inside the tube is the same as the level of the water outside the tube. This permits you to use Dalton’s Law of Partial Pressure to relate the pressures of the collected gases to atmospheric pressure.
15. Using the scale on the eudiometer tube, record the volume of gas collected to the nearest 0.1 mL. Remember, this is the volume of BOTH hydrogen gas and water vapor combined.
16. Empty the contents of the tube in the sink and carefully rinse with tap water.
17. Wipe down the counter tops at your lab station.

**Data Table:**

|  |  |
| --- | --- |
| Room Temperature (convert to Kelvin) | **K** |
| Water Temperature (convert to Kelvin) | **K** |
| Record the Water Vapor Pressure (PH2O) at this water temperature (convert to atm)  Use the chart on the back page | **atm** |
| Barometric pressure (Patm) (convert to atm) | **atm** |
| Mass of Mg | **grams** |
| Volume of gas collected (convert to L) | **L** |

**Observations:**

In complete sentences, list any qualitative observations you made during the lab. Include any physical properties of the chemicals or evidence of a chemical reaction taking place.

**Data Analysis:**

**SHOW ALL WORK AND ROUND TO THE PROPER NUMBER OF SIGNIFICANT FIGURES. FOR FULL CREDIT YOU MUST INCLUDE THE FORMULA IN WORDS, SUBSTITUTION AND A BOXED ANSWER WITH UNITS.**

1. Use the stoichiometry mole highway to determine the number of moles of H2 gas collected in your eudiometer tube. (Hint: Start with grams of Mg 🡪 moles Mg 🡪 moles H2)
2. Use Dalton’s Law of Partial Pressures to find the partial pressure of *dry* hydrogen gas. (PH2 = Patm - PH2O)
3. The Combined Gas Law unites Boyle’s Law and Charles’ Law into one convenient equation. The combined gas law shows that:

**P1V1 = P2V2**

**T1 T2**

Use the combined gas law to find the volume of H2 gas at STP according to your *experimental* data. (Hint: For initial pressure use the dry pressure of H2 (calculation #2), for initial volume use the volume of H2 from your data table, for initial temperature use the air temperature. For final conditions use standard pressure and standard temperature. Solve for V2.)

1. Calculate your *experimental* standard molar volume. Divide your *experimental* volume of H2 gas by *experimental* moles of H2 gas. (Hint: calculation #3/calculation #1)
2. Find your percent error in experimentally calculating the standard molar volume of a gas. (Hint: Your *experimental* value is calculation #4. Your *theoretical* value is written in your background knowledge.)

% error = l(experimental – theoretical)l/ theoretical X 100

**Discussion Questions:**

1. Why does the acid slowly diffuse downward when the eudiometer tube is inverted into the sink full of water?
2. Which TWO gases were collected in the eudiometer?
3. At the end of this reaction, if the water in the tube were evaporated, which salt product would remain? (Hint: look at your balanced equation)

**Conclusion and Evaluation**

This is the most important part of your lab report. It must be at least two paragraphs.

Paragraph 1:

* Begin with a topic sentence that refers to the purpose of your lab
* Then state the significant data (use a # from your data analysis) -- summarize the results
* Next refer to your background information and explain why that happened and/or tell what you infer from the data -- What does the data tell you?
* End this paragraph with a concluding sentence that tells what you learned.

Paragraph 2:

Was your data consistent with your expectations and/or known data? Discuss possible errors by providing a couple of reasons why you think your experimental standard molar volume of a gas was different than Avogadro’s hypothesis. Be very specific to your lab experience. Provide specific recommendations that would improve your result.

