EXPERIMENT 17

Percent Yield of Hydrogen Gas From Magnesium and Hydrochloric Acid

INTRODUCTION

For chemical reactions involving gases, gas volume measurements provide a convenient means of determining stoichiometric relationships. A gaseous product is collected in a long, thin graduated glass tube, called a eudiometer, by displacement of a liquid, usually water. Magnesium reacts with hydrochloric acid, producing hydrogen gas:

\[
\text{Mg (s)} + 2\text{HCl (aq)} \rightarrow \text{MgCl}_2 (aq) + \text{H}_2 (g)
\]

When the magnesium reacts with the acid, the evolved hydrogen gas is collected by water displacement and its volume measured. The temperature of the gas is taken to be the same as the temperature of the water it is in contact with because, given a sufficient amount of time, the two will reach thermal equilibrium. The level of water in the eudiometer is adjusted to that it is equal to the level of water outside the eudiometer. This insures that the pressure in the eudiometer is equal to the prevailing atmospheric pressure. The pressure of the dry hydrogen gas is calculated from Dalton's Law of Partial Pressures:

\[
P_{\text{total}} = P_{\text{H}_2} + P_{\text{H}_2\text{O}(g)}
\]

so

\[
P_{\text{H}_2} = P_{\text{total}} - P_{\text{H}_2\text{O}(g)}
\]

where \(P_{\text{total}}\) (the pressure in the eudiometer) is atmospheric pressure, and \(P_{\text{H}_2\text{O}(g)}\) (the water vapor pressure) is the pressure exerted by water vapor that has evaporated into the eudiometer. The volume of hydrogen gas collected can then be converted to standard temperature and pressure (STP) with the combined gas law:

\[
\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}
\]

This will give you the experimental volume of hydrogen gas collected at STP. The theoretical volume of hydrogen gas collected at STP can be calculated from the known mass of magnesium that was reacted and the balanced equation. The percent yield is then:

\[
\% \text{ Yield} = \frac{\text{experimental volume}}{\text{theoretical volume}} \times 100\%
\]
PROCEDURE

1. Students will work in pairs for this experiment. Except for the laboratory handout, remove all books, purses, and such items from the laboratory bench top, and placed them in the storage area by the front door. For laboratory experiments you should be wearing closed-toe shoes. Tie back long hair, and do not wear long, dangling jewelry or clothes with loose and baggy sleeves. Open you lab locker. Put on your safety goggles, your lab coat, and gloves.

2. Fill an 800-mL beaker with about 500 mL of water (or a 600-mL beaker with about 400 mL of water) and allow it to sit on the base of a ring stand so that the temperature of the water may adjust to room temperature. Place a double buret clamp on the ring stand well above the beaker.

3. Obtain a length of magnesium ribbon from the cart. If the ribbon is dull, place the magnesium ribbon on one of the cutting mats and sand it with a piece of sand paper until it is shiny. Do not sand the metal while it is on the black lab bench, the lab bench will scratch. Determine its mass on an analytical balance that reads four places past the decimal point, and record its mass in your Data Table. Your magnesium should have a mass no larger than 0.0450 g.

4. From the balanced equation and the your mass of magnesium metal, calculate the volume of hydrogen gas you should theoretically produce at STP in today’s reaction. Record this in your Data Table as Volume of Hydrogen Gas at STP, Theoretical.

5. Roll the magnesium ribbon into a loose coil. Obtain a piece of thread 25 cm in length from the back counter, and tie it to one end of the magnesium ribbon in such a way that all the loops of coil are tied together.

6. Obtain a eudiometer from the cart. Always carry a eudiometer in a vertical position. The eudiometer will contain water and be plugged with a solid rubber stopper to keep dust out. Remove and set aside the solid rubber stopper until the end of the lab period. Empty out the water into your sink, and temporarily attach the eudiometer to the buret clamp, open end up.

7. Measure out 10 mL of hydrochloric acid in a graduated cylinder and pour it into your eudiometer.

   CAUTION: Hydrochloric acid is corrosive and can cause severe burns.

   Remove the eudiometer from the buret clamp, hold it on a slight slant, and add enough water to the eudiometer to fill it completely. Try to mix the water and the acid as little as possible. Reattach the eudiometer to the buret clamp, open end up.

8. Obtain a #000 one-hole rubber stopper from the back counter. Take your magnesium coil and lower it into the water of the eudiometer to a depth of about 5 cm. Have the thread attached to the coil hang over the lip and out of the eudiometer. Insert the #000 one-hole rubber stopper into the eudiometer so the thread is held firmly against the edge, and when water squirts out of the hole in the stopper, cover the hole firmly with your thumb.
9. Taking care that no air enters, remove the eudiometer from the buret clamp, invert it, and place its open end underwater in the beaker. Yes, your hand will get wet. Reclamp the eudiometer to the buret clamp so that the bottom of the stopper is about 2 cm above the bottom of the beaker, as shown below to the left. The acid will flow down the eudiometer and react with the magnesium.

10. When the reaction has stopped, the eudiometer will look like the picture below to the right. Tap the tube with your finger to dislodge any bubbles you see attached to the side of the eudiometer. Measure the temperature of the water in your beaker; this will be the temperature of the hydrogen gas in the eudiometer. Record this value in your Data Table. Because your thermometer reads to a tenth of a degree Celsius, add 273.2 when converting to Kelvin.

11. Place your finger over the hole in the stopper and remove the eudiometer from the beaker. Lower the eudiometer into the leveling tank and remove your finger. Raise or lower the eudiometer until the water level inside the eudiometer is the same as the water level in the leveling tank, as shown on the next page. This means that the pressure of the gas in the eudiometer is now equal to the atmospheric pressure. Read the volume of hydrogen gas in the eudiometer and record it in your Data Table.
12. The barometer is hanging on the wall next to the drying oven, with instructions on how to use it posted on the wall next to it. Read the barometer to obtain the current atmospheric pressure, and record this value in your Data Table. The water vapor pressure can be found from a chart on the wall next to the barometer. Record this value in your Data Table. You should now be able to calculate the pressure of your dry hydrogen gas. Because the barometer reads to a tenth of a torr, divide by 760.0 when converting to atmospheres.

13. You now have the volume of hydrogen gas collected at a known temperature and a known pressure. You should now be able to convert your volume of hydrogen gas to STP with the Char-Boyled Law. Record this in your Data Table as Volume of Hydrogen Gas at STP, Experimental.

14. Your percent yield of hydrogen gas can now be calculated from the Volume of Hydrogen Gas at STP, Experimental and the Volume of Hydrogen Gas at STP, Theoretical. Clean the eudiometer, dry the outside, fill it with deionized water, plug it with the original solid rubber stopper, and return it to the back counter.

15. Clean and wipe dry your laboratory work area and all apparatus. When you have completed your lab report have the instructor inspect your working area. Once your working area has been checked your lab report can then be turned in to the instructor.
**EXPERIMENT 17 LAB REPORT**

Name: ________________________________  Student Lab Score: ___________________
Date/Lab Start Time: ____________________  Lab Station Number: _______________

**DATA TABLE**

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Mass of Magnesium Metal</td>
<td>.</td>
<td>g</td>
</tr>
<tr>
<td>1 Volume of Hydrogen Gas at STP, Theoretical</td>
<td>.</td>
<td>L</td>
</tr>
<tr>
<td>Volume of Hydrogen Gas, Experimental</td>
<td>.</td>
<td>mL</td>
</tr>
<tr>
<td>2 Volume of Hydrogen Gas, Experimental</td>
<td>.</td>
<td>L</td>
</tr>
<tr>
<td>Temperature of Hydrogen Gas</td>
<td>.</td>
<td>°C</td>
</tr>
<tr>
<td>Atmospheric Pressure</td>
<td>.</td>
<td>torr</td>
</tr>
<tr>
<td>Water Vapor Pressure</td>
<td>.</td>
<td>torr</td>
</tr>
<tr>
<td>3 Pressure of Dry Hydrogen Gas</td>
<td>.</td>
<td>torr</td>
</tr>
<tr>
<td>4 Volume of Hydrogen Gas at STP, Experimental</td>
<td>.</td>
<td>L</td>
</tr>
<tr>
<td>5 Percent Yield of Hydrogen Gas</td>
<td>.</td>
<td>%</td>
</tr>
</tbody>
</table>

**CALCULATIONS**

1.
POSTLAB QUESTIONS

1. Nitrogen gas is collected over water in a eudiometer. The volume of the nitrogen gas is 45.5 mL, the atmospheric pressure is 756.0 mm Hg, the water temperature is 24.0°C, and the water level inside the eudiometer is the same as the level of water in the beaker.

(a) Calculate the pressure of the dry nitrogen gas. *Box your answer.*

(b) Calculate the volume of the nitrogen gas at STP. *Box your answer.*
2. If a 2.75 g sample of lead (II) oxide is decomposed, what volume of oxygen gas will be produced at STP? \textit{Box your answer.}