Reaction of Magnesium with Hydrochloric Acid

Your Name: 
Date: 
Partner(s): 

Objectives:
React magnesium metal with hydrochloric acid, collecting the hydrogen over water. Calculate the grams of hydrogen produced and compare this with the theoretical yield of hydrogen, as determined by stoichiometric calculations based on the original mass of magnesium. Report the percent yield of hydrogen gas.

Introduction:
The reaction of magnesium metal with concentrated hydrochloric acid produces hydrogen gas, in a “single-displacement” reaction, due to the fact that magnesium is more chemically active than hydrogen. The more active an element, the more inclined it is to react with other elements and to displace less active elements in chemical compounds. Thus, the magnesium metal displaces the hydrogen from hydrochloric acid, creating magnesium chloride and leaving the hydrogen on its own to form hydrogen gas, which bubbles out of the solution.

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

We will collect the hydrogen gas in an inverted graduated tube (often called a eudiometer). As long as the magnesium reacts completely and none of the gas escapes, we expect a stoichiometric amount of hydrogen gas to be formed, allowing us to compare the expected or “theoretical” mass of hydrogen formed, to the actual mass of hydrogen formed, and to calculate the percent yield of hydrogen for our experiment.

<table>
<thead>
<tr>
<th>Equipment Needed:</th>
<th>Chemicals Needed:</th>
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</thead>
<tbody>
<tr>
<td>Alcohol thermometer</td>
<td>Distilled water (appx. 150 mL)</td>
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<tr>
<td>Beakers (100 mL, 2000 mL)</td>
<td>Hydrochloric acid (Concentrated, 12 M)</td>
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<tr>
<td>Laboratory balance</td>
<td>Magnesium ribbon</td>
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<tr>
<td>Eudiometer (50 mL)</td>
<td>Tap water</td>
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<tr>
<td>Nichrome or copper wire</td>
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<td>Buret clamp</td>
<td></td>
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<tr>
<td>Rubber stopper (one-holed, No. 00)</td>
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<tr>
<td>Glass pipette (10 mL, graduated)</td>
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<tr>
<td>Steel wool</td>
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<tr>
<td>Forceps</td>
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</tbody>
</table>
Procedure:

Initial Preparations and Data

In your data table, record the current atmospheric pressure from the laboratory barometer (as demonstrated by your instructor).

Fill a 2000 mL beaker (or large pail) almost full, about 2 cm from the top, with tap water.

Obtain a pre-cut strip of magnesium metal and use steel wool to scrub off any oxide coating on both sides of the strip. After removing the oxide coating, accurately record the mass of the magnesium in your data table. You must have between 0.040 g and 0.045 g of metal after the oxide coating has been removed. Try to handle the magnesium as little as possible with your hands after you have removed the oxide coating.

Assembly of Apparatus

Roll the magnesium strip into a coil and wrap it in a nichrome or copper wire cage as demonstrated by your instructor. Set this assembly aside for use later in the experiment.

Obtain a clean, dry 50 mL gas collection tube (eudiometer), which is a graduated tube open at one end and closed at the other. Using a 10 mL graduated glass pipette, carefully add 8-10 mL of 12 M hydrochloric acid (which has been colored with food coloring) into the eudiometer. Hold the eudiometer at a 45° angle and very carefully and slowly fill the eudiometer with distilled water without mixing the acid and water. While adding the water, carefully rotate the eudiometer to make sure that any acid on the sides is washed to the bottom. The eudiometer should be filled to the point that the water is almost overflowing.

Insert the handle of the wire cage containing the magnesium through the hole of a number 00 one-holed rubber stopper as demonstrated by your instructor. Insert the wire cage into the open end of the eudiometer and seal it with the stopper. (Push the stopper straight into the eudiometer until it cannot be pushed any further and no more water bubbles out of the eudiometer when pushing on the stopper.)

Reaction of Mg and HCl; Collection of Hydrogen Gas

Keeping your index finger tightly over the hole in the stopper, invert the eudiometer into the 2000 mL beaker or large pail of water on your laboratory table. Remove your finger from the hole in the stopper and clamp the eudiometer to a buret clamp supported by a ringstand making sure that the stoppered end of the eudiometer remains submerged in the water in the beaker.

At this point you should be able to see the acid layer swirling down through the water layer toward the wire cage containing the magnesium metal. The reaction is complete when no more bubbling is seen around the magnesium metal. At this point, lightly tap the eudiometer to dislodge any bubbles that remain around the metal.

After the reaction is complete, raise or lower the eudiometer so that the meniscus of the water inside the eudiometer is even with the water level in the beaker or pail, making sure that the stoppered end of the eudiometer still remains submerged in the water in the beaker.

In your data table, record the volume reading on the gas collection tube (being careful to take an accurate reading due to the inversion of the tube). Using an alcohol thermometer, measure the temperature of the water in the beaker and record it accurately in your data table.
Calculations

Using Table 11.1 (on the next page) find the vapor pressure of water at the temperature of your reaction and record this pressure in your data table.

Table 11.1 - Vapor Pressure of Water at Various Temperatures

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>23</th>
<th>24</th>
<th>25</th>
<th>26</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure (mmHg)</td>
<td>16.48</td>
<td>17.54</td>
<td>18.65</td>
<td>19.83</td>
<td>21.07</td>
<td>22.38</td>
<td>23.76</td>
<td>25.21</td>
</tr>
</tbody>
</table>

From your pressure, temperature, and volume data, calculate the mass of hydrogen gas formed in the reaction. Record the calculations and result in the data and calculations section.

Using the molar masses of magnesium and hydrogen, and the balanced equation for the reaction you have just observed, calculate the theoretical mass of hydrogen that could be formed, assuming that the magnesium was pure and was completely consumed by the hydrochloric acid. Determine the percent yield of hydrogen.

Repeat the experiment with a second piece of magnesium and an empty gas collection tube. Your instructor will specify the number of trials to be performed. Usually three trials is sufficient.

Pre-Lab Questions:

1. Write a brief, no more than one-half page, summary of the procedure for this experiment.
2. Hydrogen gas was collected over water in an eudiometer at 26 °C when the atmospheric pressure was 756 mm Hg. What was the pressure of the hydrogen gas?
3. Why is it necessary to clean the magnesium strip before reacting it with hydrochloric acid?
4. 3.94 g of magnesium metal was used to produce hydrogen gas. Write the balanced chemical equation for this reaction. How many moles of hydrogen gas would be produced by the complete reaction of the magnesium.
5. A student weighed .0367 g of magnesium to produce hydrogen gas collected over water at 24 °C and 746 mm Hg atmospheric pressure. If the volume of the collected gas was 36.3 mL, what is the value of the gas constant, R, determined by the student? Assume that the percent yield is 100%. What is the % error (when compared with the true value)?
Data: (Remember to write the units for each quantity.)

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
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</thead>
<tbody>
<tr>
<td>Atmospheric pressure</td>
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<tr>
<td>Mass of Mg metal</td>
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<tr>
<td>Volume of H₂ gas</td>
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<tr>
<td>Water temperature</td>
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<td></td>
<td></td>
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<tr>
<td>Partial pressure of water vapor (from Table 11.1)</td>
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</table>

Calculations: (Please draw a box around each answer.)

Theoretical Yield of Hydrogen Gas

For each trial, use the mass of magnesium and the balanced equation for the reaction to calculate the mass of hydrogen that could be produced.
Pressure of Hydrogen Gas

Using the atmospheric pressure and the partial pressure of water, determined from the temperature, to calculate the pressure of hydrogen gas for each trial. According to Dalton's Law of Partial Pressures, the total pressure of gas inside the tube will be the sum of the pressures of each gas in the tube. Assume that water and hydrogen are the only gases inside the tube.

Calculation of Moles of Hydrogen Gas Produced

For each trial, use the ideal gas law to determine the moles of hydrogen gas collected in your eudiometer. Look up the value of \( R \) (the ideal gas constant) in your textbook. Assume that the temperature of the hydrogen gas equals the temperature of the water over which you collected it.
Calculation of Mass of Hydrogen Collected (Actual Yield)

From the molar mass of hydrogen and the moles of hydrogen collected, calculate the mass of hydrogen produced from the magnesium for each trial.

Calculation of Percent Yield

The percent yield is the actual yield divided by the theoretical yield (times 100 to change the fraction into a percent. Calculate the percent yield for each trial.

Calculation of Average Percent Yield

Using the percent yield from each trial, calculate the average percent yield for your experiment.
Post-Lab Questions:

1. If an undetected bubble of air were trapped inside the gas collection tube, what would be its effect on the percent yield in your experiment? Would the actual yield, and thus the percent, increase, decrease, or be unaffected by the bubble of air? Explain.

2. In your reaction, the magnesium is necessarily the limiting reactant, so that it is completely consumed in the reaction. The amount of hydrochloric acid added to the reaction was more than enough to consume all of the magnesium. Calculate the exact amount of 12 M hydrochloric acid necessary to consume 0.040 grams of magnesium metal.

3. If you hadn’t added quite enough hydrochloric acid to consume all of the magnesium metal, what would be the effect of this error on the percent yield in your experiment? Would the actual yield, and thus the percent, increase, decrease, or be unaffected by not adding enough HCl? Explain.