

## Reaction of Magnesium with Hydrochloric Acid (Gas Laws)

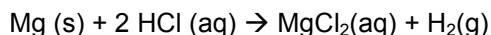
Your Name:	Date:
Partner(s) Names:	

### 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 calculated based on the original mass of magnesium using stoichiometry. 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. Magnesium is more active than hydrogen (see the “Activity Series” Appendix of our Lab Manual). Thus, the more active magnesium metal displaces the hydrogen from hydrochloric acid, creating magnesium chloride and leaving the less active hydrogen on its own to form hydrogen gas, which bubbles out of the solution.



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.

<b>Equipment Needed:</b> Alcohol thermometer 100-mL beaker 4000 mL or larger (or large graduated cyl.) Laboratory balance Eudiometer (50 mL or 100 mL) Nichrome or copper wire Buret clamp Rubber stopper (one-holed, No. 00) Glass pipette or cylinder (10 mL, graduated) Steel wool Forceps	<b>Chemicals Needed:</b> Distilled water (appx. 150 mL) Hydrochloric acid (Concentrated, 12 <u>M</u> ) Magnesium ribbon Tap water
<b>Safety Note:</b> The hydrochloric acid in this lab is extremely concentrated and must be handled with care. Please wear your safety goggles at all times while anyone is working with chemicals or equipment.	

## Procedure:

### Initial Preparations and Data

In your data table, record the current atmospheric pressure from the laboratory barometer. (Ask your instructor for help reading this instrument.)

Fill a 2000-mL beaker (or large pail) almost full, about 2 cm from the top, with cold 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 0.075 g and 0.085 g of metal after the oxide coating has been removed. (Check with instructor about this amount; it depends on what glassware we are using.) To avoid depositing oils from your fingers onto the metal, use tongs or forceps to handle the magnesium 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 (or 100-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 or graduated cylinder, carefully add 8-10 mL of 12 M hydrochloric acid (which has been colored with food coloring) into the eudiometer. Holding the eudiometer at a 45° angle, very carefully and slowly fill the eudiometer with distilled water without mixing the acid and water. (This is contrary to the rule about adding acid to water, and we're intentionally creating two layers here, so that the acid will stay relatively concentrated at the bottom of the eudiometer.) 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 and tightly into the eudiometer. Add water if necessary to eliminate any bubbles from the eudiometer.)

### 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 ring stand 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, where the reaction will occur. 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. This equalizes the pressures inside and outside of the tube. 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 in your data table.

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. Hydrogen gas was collected over water in a eudiometer at 26 °C when the atmospheric pressure was 726 mm Hg. What was the pressure of the hydrogen gas?
2. Why is it necessary to clean the magnesium strip before reacting it with hydrochloric acid?
3. 3.15 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 this magnesium?
4. 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 46.3 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,  $R=0.0821 \text{ l-atm/K-mol}$ )?

## Data and Calculations

Using Table 1, find the vapor pressure of water at the temperature of your reaction and record this pressure in your data table.

**Table 1 - Vapor Pressure of Water at Various Temperatures**

Temperature (°C)	19	20	21	22	23	24	25	26
Pressure (mmHg)	16.48	17.54	18.65	19.83	21.07	22.38	23.76	25.21

The idea now is to determine your percent yield of hydrogen for the experiment. First, you will use the mass of magnesium (your limiting reactant) to calculate the theoretical yield of hydrogen gas. This theoretical yield is the mass of hydrogen that could have been produced from the magnesium. Second, you will calculate the actual yield of hydrogen gas. Because we didn't measure the mass of the hydrogen gas collected, we need to calculate it from some of the other data that we collected. First, because some water vapor (also a gas) has inevitably joined the hydrogen gas in the eudiometer, we need to make a correction using the pressures to calculate the partial pressure of hydrogen in the tube. We'll use that later in the ideal gas law to calculate the moles of hydrogen in the eudiometer.

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## Data Table

	<u>Trial 1</u>	<u>Trial 2</u>	<u>Trial 3</u>
Atmospheric pressure	_____	_____	_____
Mass of Mg metal	_____	_____	_____
Volume of 12 M HCl	_____	_____	_____
Volume of H <sub>2</sub> gas	_____	_____	_____
Water temperature	_____	_____	_____
Partial pressure of water vapor (from Table 1)	_____	_____	_____

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## Calculations

(Please draw a box around each answer.)

### Theoretical Yield of Hydrogen Gas

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.

Write the balanced equation for the reaction between magnesium metal and hydrochloric acid. For each trial, use the mass of magnesium and the balanced equation to calculate the theoretical mass of hydrogen that could be produced from the magnesium.

### Actual Yield of Hydrogen Gas

Using your pressure, temperature, and volume data, you will calculate the mass of hydrogen gas formed in the reaction. This is done in three steps: (1) pressure of  $H_2$  using Dalton's Law, (2) moles using the ideal gas law, and (3) grams using molar mass, as outlined on page 4.

#### (1) Pressure of Hydrogen Gas

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. Using the measured atmospheric pressure and the partial pressure of water vapor (determined from temperature) in your data table, calculate the pressure of hydrogen gas for each trial. (Note: This is not a  $PV=nRT$  calculation. That one is on the next page.)

**Actual Yield of Hydrogen Gas (continued)****(2) 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. You calculated the pressure of hydrogen gas on the previous page.

**(3) Calculation of Mass of Hydrogen Collected (Actual Yield)**

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

**Percent Yield of Hydrogen Gas**

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.

**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 yield) be erroneously high, erroneously low, or be unaffected by the bubble of air? Explain.
  
2. The amount of hydrochloric acid added to the reaction was more than enough to consume all of the magnesium. Therefore, the magnesium is the limiting reactant. How many milliliters of 12 M hydrochloric acid solution necessary to consume 0.080 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 yield) erroneously high, erroneously low, or be unaffected by not adding enough HCl? Explain.