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Percent Yield of Hydrogen Gas From Magnesium and HCl

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 according to equation 1.

$$Mg\ (s) + 2\ HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g) \qquad \textit{Equation 1}$$

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 so 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 ***dry*** hydrogen gas is calculated from Dalton's Law of Partial Pressures according to equation 2.

$$P_{total} = P_{H2(g)} + P_{H2O(g)} \qquad \textit{Equation 2}$$

The total pressure (P_{total}) is the total pressure in the eudiometer, which we have made equal to the atmospheric pressure. The water vapor pressure ($P_{H2O(g)}$) is the pressure exerted by water vapor that has evaporated into the eudiometer. This value may be found in Table 1. The pressure of hydrogen ($P_{H2(g)}$) may be determined by rearranging equation 2 and calculating the value.

The volume of hydrogen gas collected can then be converted to a standard temperature and pressure (STP) with the combined gas law, equation 3.

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \qquad Equation\ 3$$

This calculation 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 chemical equation. The percent yield can then be calculated using equation 4.

$$\%\ yield = \frac{exprimental\ volume}{theoretical\ volume}\ x\ 100\ \% \qquad Equation\ 4$$

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Table 1. Vapor Pressure of Liquid Water between 15.0°C and 29.9°C

Temp. (°C)	Vapor Pres. (torr)	Temp. (°C)	Vapor Pres. (torr)	Temp. (°C)	Vapor Pres. (torr)
15.0	12.833	20.0	17.552	25.0	23.756
15.1	12.915	20.1	17.660	25.1	23.898
15.2	12.997	20.2	17.769	25.2	24.040
15.3	13.080	20.3	17.879	25.3	24.184
15.4	13.164	20.4	17.989	25.4	24.328
15.5	13.247	20.5	18.100	25.5	24.472
15.6	13.332	20.6	18.211	25.6	24.618
15.7	13.417	20.7	18.323	25.7	24.764
15.8	13.502	20.8	18.436	25.8	24.911
15.9	13.588	20.9	18.549	25.9	25.059
16.0	13.674	21.0	18.663	26.0	25.208
16.1	13.761	21.1	18.777	26.1	25.357
16.2	13.848	21.2	18.892	26.2	25.507
16.3	13.936	21.3	19.008	26.3	25.658
16.4	14.024	21.4	19.124	26.4	25.810
16.5	14.113	21.5	19.241	26.5	25.963
16.6	14.202	21.6	19.359	26.6	26.116
16.7	14.292	21.7	19.477	26.7	26.270
16.8	14.382	21.8	19.596	26.8	26.425
16.9	14.473	21.9	19.715	26.9	26.581
17.0	14.564	22.0	19.835	27.0	26.738
17.1	14.656	22.1	19.956	27.1	26.895
17.2	14.748	22.2	20.078	27.2	27.053
17.3	14.841	22.3	20.200	27.3	27.213
17.4	14.934	22.4	20.322	27.4	27.372
17.5	15.028	22.5	20.446	27.5	27.533
17.6	15.123	22.6	20.570	27.6	27.695
17.7	15.218	22.7	20.695	27.7	27.857
17.8	15.313	22.8	20.820	27.8	28.020
17.9	15.409	22.9	20.946	27.9	28.185
18.0	15.505	23.0	21.073	28.0	28.350
18.1	15.603	23.1	21.201	28.1	28.515
18.2	15.700	23.2	21.329	28.2	28.682
18.3	15.798	23.3	21.458	28.3	28.850
18.4	15.897	23.4	21.587	28.4	29.018
18.5	15.996	23.5	21.717	28.5	29.187
18.6	16.096	23.6	21.848	28.6	29.357
18.7	16.196	23.7	21.980	28.7	29.528
18.8	16.297	23.8	22.112	28.8	29.700
18.9	16.399	23.9	22.245	28.9	29.873
19.0	16.501	24.0	22.379	29.0	30.047
19.1	16.603	24.1	22.513	29.1	30.221
19.2	16.706	24.2	22.648	29.2	30.397
19.3	16.810	24.3	22.784	29.3	30.573
19.4	16.914	24.4	22.921	29.4	30.750
19.5	17.019	24.5	23.058	29.5	30.929
19.6	17.124	24.6	23.196	29.6	31.108
19.7	17.231	24.7	23.335	29.7	31.288
19.8	17.337	24.8	23.475	29.8	31.469
19.9	17.444	24.9	23.615	29.9	31.651

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Experimental Procedure

You will do two determinations using this same procedure. Between determinations you should rinse the eudiometer with three 10 mL portions of distilled water. There is no need to dry the eudiometer.

1. Fill an 1000 mL beaker with about 800 mL of distilled water (or a 600 mL beaker with about 400 mL of distilled water). Allow the beaker of water 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.

2. Obtain a length (approximately 2.5 cm) of magnesium ribbon. With steel wool or sand paper, buff the magnesium ribbon until it is shiny. Determine its mass on a balance to the 0.001 g. If the balance near your work space does not measure to 0.001 g, go to a balance that will measure with this precision. Your magnesium should have a mass no larger than 0.0450 g.

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

4. Obtain a eudiometer and a one-hole stopper. Always carry a eudiometer in a vertical position. Temporarily attach the eudiometer to the buret clamp and test the stopper to make sure it fits well.

5. Measure out 10 mL of 6 M hydrochloric acid in a graduated cylinder and pour it into your eudiometer.

6. Remove the eudiometer from the buret clamp, hold it on a slant, and add enough water to the eudiometer to fill it completely. Add the water carefully, try to mix the water and the acid as little as possible. You want a layer of HCl at the bottom of the eudiometer and water on top. Reattach the eudiometer to the buret clamp, open end up.

7. 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 one-hole rubber stopper into the eudiometer so the thread is held firmly against the edge and water squirts out the hole in the stopper.

8. Place your thumb securely over the hole. Take 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 eudiometer is *about 5 cm below the surface of the water in the beaker*. The acid will flow down the eudiometer and react with the magnesium.

9. When the reaction has stopped, 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 the 0.1 ^{o}C, add 273.2 when converting to Kelvin.

10. Securely 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

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leveling tank. This means that the pressure of the gas in the eudiometer is now equal to the atmospheric pressure. Read the volume of gas in the eudiometer and record it in your Data Table.

11. Record the barometric pressure from the barometer in the lab room. Pay carefully attention to the units on the barometer.
12. Repeat the experiment with a second sample of magnesium.

Safety

Be careful of hydrochloric acid. It can cause burns and irritation to eyes and nose. Be certain to wear safety goggles at all times during the experiment. If any hydrochloric acid gets on your skin, rinse it off immediately to avoid a serious burn and inform your instructor. If you spill a significant amount of hydrochloric acid anywhere in the laboratory, immediately ask your instructor for help properly cleaning up the spill by neutralizing it with sodium bicarbonate before wiping it up.

Disposal

The aqueous solution in the eudiometer may be poured in the sink and rinsed down with water.

Clean-up

Clean all glassware and return shared equipment. Wipe down your work surfaces with a damp sponge or paper towel.

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Data and Results

	Trial 1	Trial 2
Mass of Mg ribbon		
Temperature of gas (^{o}C)		
Temperature of gas (K)		
Volume of gas (mL)		
Water vapor pressure (torr)		
Atmospheric Pressure (include units)		
Atmospheric Pressure (torr)		

1. Calculate the theoretical volume of hydrogen gas that you should produce based on your mass of magnesium metal for each trial. For full credit, show all calculations set-up. Report your value with correct significant figures and units.

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2. Calculate the pressure of dry hydrogen gas produced in this experiment for each trial using equation 2. For full credit, show all calculations set-up. Report your value with correct significant figures and units.

3. Calculate the experimental volume of hydrogen gas at STP for each trial using equation 3. For full credit, show all calculations set-up. Report your value with correct significant figures and units.

4. Calculate the % yield of hydrogen gas for each trial using equation 4. For full credit, show all calculations set-up. Report your value with correct significant figures and units.

5. A student performed this experiment and noted a little unreacted magnesium ribbon after obtaining the volume of gas produced. How will this affect the % yield the student calculates?

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PRESTUDY

1. Nitrogen gas is collected over water in a eudiometer. The volume of the nitrogen gas is 125 mL, the atmospheric pressure is 763 mm Hg, the water temperature is 24 ^{o}C, and the water level inside the eudiometer is the same as the level of water in the beaker.

    a. (2) Calculate the pressure of the dry nitrogen gas. For full credit, show all calculations set-up. Report your value with correct significant figures and units.

    b. (4) Calculate the volume of the nitrogen gas at STP. For full credit, show all calculations set-up. Report your value with correct significant figures and units.

2. (4) If a 1.75 g sample of lead(II) oxide is decomposed, what volume of oxygen gas will be produced at STP? For full credit, show all calculations set-up. Report your value with correct significant figures and units.