Gas Stoichiometry

Background

Active metals such as zinc and magnesium will react with acids to produce hydrogen gas.

$$Zn_{(s)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2\,(aq)} + H_{2\,(g)}$$

$$Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$$

If the volume, temperature, and pressure of the gas are known, the number of moles can be calculated using the ideal gas law. From the moles of hydrogen gas the moles of metal can be calculated via stoichiometry and the chemical equations shown above.

The reaction will take place and the hydrogen gas will be collected in a gas measuring tube or eudiometer. This is a long, tubular container with calibrations that allow the volume of gas collected to be read to the nearest 0.1 mL.

Obtaining the pressure of the hydrogen gas is a little complicated. The barometric pressure in the lab can be obtained by the instructor. The eudiometer is inverted in a beaker of water and contains hydrogen gas above acid solution. The barometric pressure is the pressure on the surface of the water in the beaker. This pressure is counterbalanced by the pressures in the column of the eudiometer.

- The solution above the level of liquid in the beaker has a pressure contribution that must be determined and subtracted from the barometric pressure to obtain the pressure of the gas collected inside the eudiometer. This pressure contribution can be obtained by measuring the height of the acid column in centimeters from the level of the water in the beaker to the bottom of the meniscus in the eudiometer. This can be converted to mm Hg by multiplying by the factor 0.772 mm Hg/cm of acid solution.

- By subtracting the pressure contribution of the acid in the column from the barometric pressure, you have determined the pressure of the gas in the tube, but the gas you collected is a mixture of hydrogen and water vapor. There is a table of water vapor pressures at different temperatures at the end of the procedure.

- Subtracting the water vapor pressure from the pressure of the gas in the tube leaves behind only the hydrogen gas itself. This is the pressure that will be used to calculate the moles of hydrogen gas.

For the sample data you are asked to calculate the percent error. The error is the difference between the theoretical and experimental values. The percent error is calculated by dividing the error by the theoretical value and multiplying that fraction by 100.

Equipment

From the stockroom:
- 100 mL eudiometer
- buret clamp
- digital thermometer
- meter stick

From the common drawer
- ring stand

From your drawer:
- large beaker (at least 400 mL)
- wash bottle

Procedure

Part I–Determination of the Mass of Zinc

We will do this as a "dry lab" to practice the calculations. Refer to the Report Form.

Part II–Determination of the Mass of a Piece of Magnesium

1. Obtain an unknown from your instructor and record its number.
2. Make a cage around the piece of magnesium using fine copper wire. This cage must be tight enough so that the magnesium can't fall out when it has reacted and become small. If it is too tight, the reaction will be very slow. Leave a tail of copper wire about six inches long.
3. Pour approximately 20 mL of dilute (6 M) hydrochloric acid into a clean 100 mL eudiometer. This does not need to be measured accurately nor does the exact volume need to be known.
4. Carefully and slowly fill the rest of the eudiometer with a beaker so as to avoid mixing of the water and the acid.
5. Insert the copper cage containing your magnesium sample in the eudiometer so that the cage is ~ 4" from the stopper (when it is upside down) holding the copper tail in your fingers until you secure it into place by squeezing it between the glass surface and the one–hole rubber stopper. DO NOT try to thread the wire through the hole, and DO NOT let go of the copper tail until you are sure the cage is secured! When inserting the rubber stopper, let the excess water come out through the hole. Make sure no air is trapped in the tube as it will later be measured as hydrogen gas causing error. Make sure the hole in the stopper also is filled with water by using your deionized water bottle.

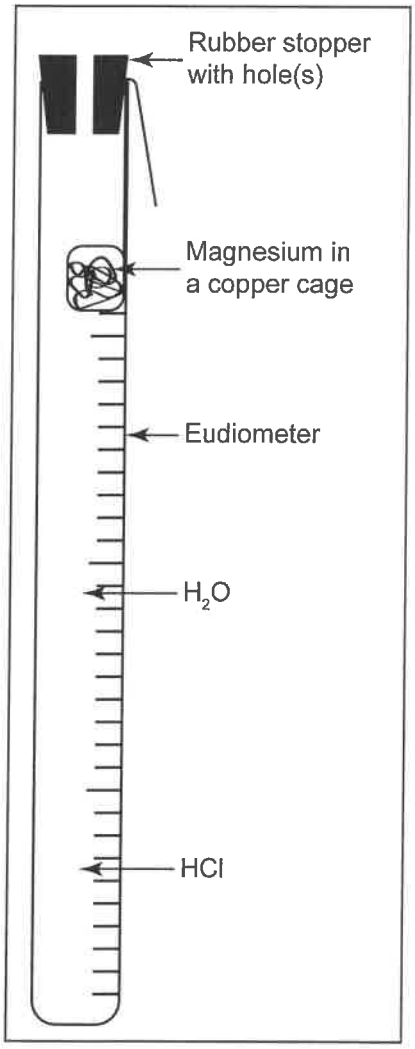

Figure 1–Eudiometer

6. Cover the hole in the stopper with your index finger and invert the eudiometer in a large beaker around two-thirds filled with water. DO NOT release your finger until the stopper is submerged in the water. Clamp the eudiometer to a ring stand using a buret clamp taking care to make sure the stopper stays submerged. The acid solution, being denser than the water, flows down the eudiometer and reacts with the magnesium producing hydrogen gas.

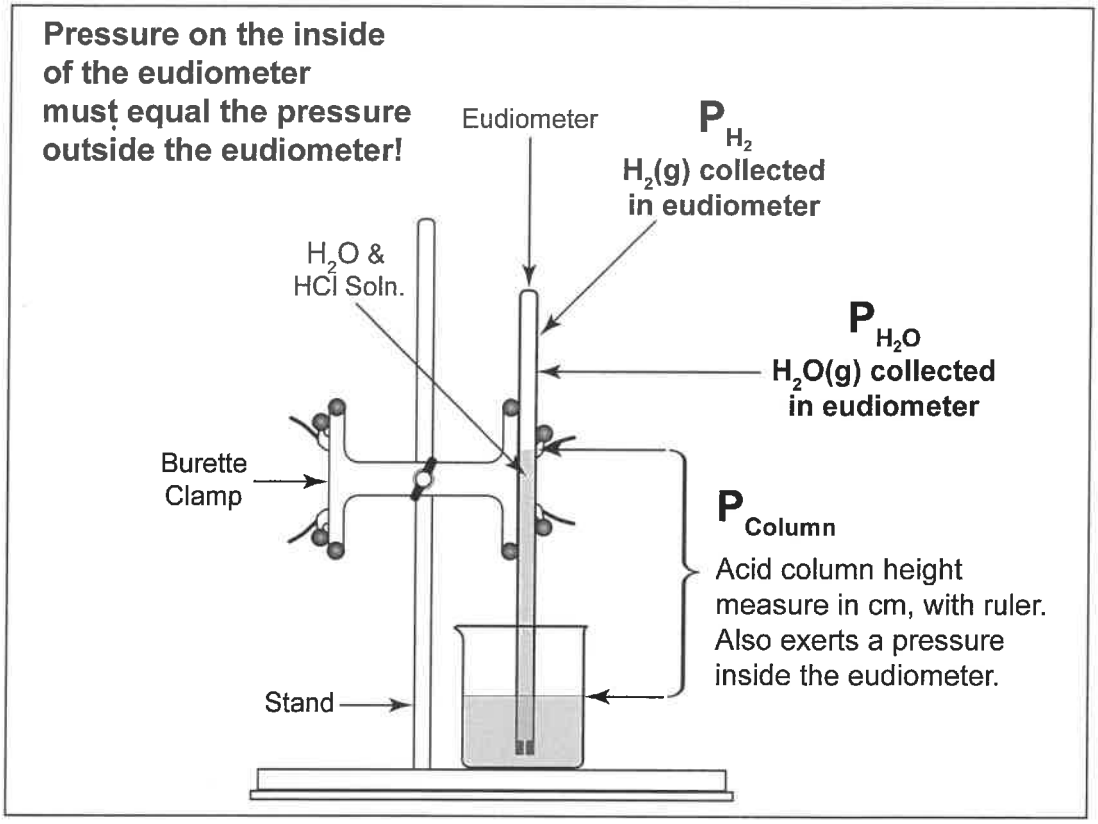

Figure 2

7. After complete reaction of the magnesium, let the apparatus cool, as the reaction is mildly exothermic. Free any hydrogen bubbles adhering the sides of the tube or copper wire by tapping the apparatus.

8. Read and record to the nearest 0.1 mL the volume of gas liberated. Adjust the height of the eudiometer if necessary to get a good reading, but MAKE SURE the stopper stays submerged. Once you have read the volume, DO NOT change the height of the eudiometer until all remaining measurements are taken.

9. Without changing the position of the eudiometer, place a meter stick on the bench top, and measure the height of the liquid in the eudiometer to the nearest 0.1 cm recording your measurement in your report form.

10. Measure and record the height of the liquid in the beaker to the nearest 0.1 cm, and record it in your report form. Calculate the difference in liquid levels between the two liquids showing your calculation on your report form. Use the difference in liquid levels to calculate the pressure contribution of the acid in the column by using the conversion factor 0.772 mmHg/cm. Show all calculations on the calculations page.

11. Measure and record the temperature of the gas by taking the room temperature reading from your digital thermometer.

12. Find the aqueous vapor pressure at the temperature you measured in the table of aqueous vapor pressures provided, and record this value in your report form.

13. Obtain the barometric pressure in the lab and record it. Convert the barometric pressure from inches of mercury to mm of mercury showing your calculations on the calculations page.

14. Calculate the pressure of hydrogen alone considering the pressure contributions of the atmosphere, the water vapor, and the pressure in the acid column. Convert the pressure of hydrogen to mm Hg. Show all calculations on the calculations page.

15. Use the ideal gas law to calculate the moles of hydrogen. Show your calculation on the calculations page.

16. From the moles of hydrogen and the balanced chemical reaction calculate the moles and then the mass of magnesium. Show your calculations on the calculations page.

17. The solutions in the eudiometer and in the beaker should be disposed of by pouring them into the neutralizing bucket in the hood sink to neutralize the acid.

18. Return the piece of copper wire to your instructor for recycling (please do not leave in the sink.)