EXPERIMENT

The Reaction of Magnesium with Hydrochloric Acid; The Molar Volume of Hydrogen

PURPOSE

In this experiment you will determine the volume of the hydrogen gas which is produced when a sample of magnesium reacts with hydrochloric acid. The volume of the hydrogen gas produced will be measured at room temperature and pressure. The data you obtain will enable you to answer the question - ***How many liters of dry hydrogen gas at room temperature and pressure can be produced per mole of magnesium metal?*** We will use this to determine the molar volume of hydrogen gas at STP.

MATERIALS AND EQUIPMENT

Materials

400-600 mL beaker	ring stand
Thermometer	buret clamp
Ruler	one-hole stopper to fit eudiometer
Gas measuring (eudiometer) tube (100 mL)	12 M Hydrochloric Acid (HCl)
Magnesium ribbon (~80 mg)	

DISCUSSION

Given the equation for the reaction:

$$Mg_{(s)} + 2\,HCl_{(aq)} \rightarrow H_{2(g)} + MgCl_{2(aq)} \quad (1)$$

Net ionic equation:

$$Mg_{(s)} + 2\,H^{+}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)} \quad (2)$$

we can calculate the moles of magnesium reacted and measure the volume of H_2 gas collected at room temperature. The hydrogen pressure (dry hydrogen) in the eudiometer tube is then calculated. The volume of hydrogen gas collected (at room temperature) is converted the volume the gas would occupy at standard temperature and pressure (STP) conditions. By dividing the volume of H_2 at STP by the moles of magnesium reacted (moles H_2 produced) we obtain the experimental molar volume of H_2. This is compared to the theoretical molar volume of 22.4_{14} l/mol.

PROCEDURE

SAFETY **HCl solution are corrosive and irritating to the eyes and skin. If you spill it on yourself, rinse the affected area with cool water. The reaction of Mg and HCl solutions *must* be carried out in the fume hood. *Wear gloves and goggles!***

WASTE DISPOSAL **HCl solutions should be neutralize with bicarbonate solution and discarded. Left over of solid Mg should be placed in the trash. Any unreacted solutions need to be placed in a toxic waste container.**

1. Obtain a 100 mL[1] gas eudiometer tube, a piece of magnesium ribbon (~80 mg) and a piece of copper wire (~20 cm) from the equipment cart.

2. Clean the surface of the magnesium by rubbing it with a small piece of sand paper (or emery cloth) until the surface is shiny and free of dull or dark streaks. Do not touch the Mg ribbon before massing with your bare hands!
3. Mass the ~80 mg magnesium ribbon on the analytical balance (± 0.1 mg).
4. Prepare the Mg ribbon for reaction - after massing fold and crumple the magnesium into a pea-sized lump (1/4 " dia.) and wrap it around with your copper wire like a ball of yarn on string, so that the Mg remains compacted, but leave ~2" (~5 cm) of copper wire straight.
5. Take your eudiometer tube to the fume hood. Obtain ~ 5 mL of concentrated HCl. [Caution: If you get any of the acid on your hands go wash it off IMMEDIATELY!] Incline (tilt) your eudiometer tube slightly and add the conc. HCl. Take the eudiometer tube with the acid back to your bench and using your buret clamp, clamp the eudiometer tube open side up with bottom touching lab bench.
6. Using your plastic (squeeze) bottle of distilled H_2O, **slowly** add distilled water by running it down the inside wall of your eudiometer tube (this will minimize premixing of the HCl and water until thee tube is inverted for gas collection). By this method, carefully layer about 10-15 mL of distilled water over the conc. HCl, **avoid mixing**. Now you can increase the rate of addition of water and fill the eudiometer tube completely to the top.
7. Form a small hook with the end of the straight portion of the copper wire with Mg ribbon. Then insert the Mg into the eudiometer tube and **hook it** over the tube opening with the metal hook you made so that the copper wrapped Mg extends down ~2" from the narrow end of the stopper (Figure 1a). **[Be careful not to drop the assembly into the eudiometer tube!]** Put the #00 one-hole rubber stopper in place over the opening of the eudiometer tube. Water bead should form at the top of the one-hole rubber stopper. If not add more water with your squeeze bottle.
8. Add 300-400 mL of water into your 600 mL beaker (water reservoir).
9. Holding your finger firmly over the hole in the rubber stopper **invert** the tube into the 600 mL beaker containing the 300-400 mL water. Release your finger when the eudiometer tube is under the surface of the water in the beaker. Clamp the eudiometer tube in the buret clamp, so that the end of the tube is ~2" under the surface of the water (Figure 1b).

[1] If a 50 mL eudiometer tube is used, the mass of magnesium ribbon used should be reduced to ~ 40 mg.

10. Bubbling of H_2 gas will begin as soon as HC1 reaches the Mg and will continue until all the HCl and Mg has reacted. Keep your eye on the reaction. If any small pieces of Mg floats to the surface make sure it remains in the solution, which must also be reacted, and does **not** stick to the wall (tap the tube) of the eudiometer tube. When the bubbling has ceased, wait about five minutes and **read** the volume of H_2 produced from the tube graduations (mL). Record the temperature of the water in the beaker.
11. Determine the height of the water column (mm H_2O) inside the eudiometer tube above the water level in the beaker. This can be done by measuring the height of the water column (from the bench top) in mm inside (eudiometer) and outside (beaker). Record all data in your notebook.
12. Remove the eudiometer tube from the water and pour the acid solution it contains down the sink. Repeat the experiment to obtain a second trial. Once finished Rinse the tube with water.

The sum of the pressure of the H_2 inside the tube (mm Hg), plus the equivalent in mm Hg of the height of the water remaining in the tube above the surface of the water in the beaker, plus the vapor pressure (mm Hg) of the water at the temperature of the water in the tube (assume it is the same as T in beaker water) must equal the atmospheric pressure pressing down on the surface of the water outside the tube (Figure lc).

$$\mathbf{P_{atm}\ (torr) = P_{H_2}\ (torr) + P_{H_2O}\ (vapor) + P\ (h\ column\ H_2O,\ torr)} \quad (3)$$

The vapor pressure of water at the temperature measured can be found in the back of your laboratory procedure manual, or in the "Handbook of Chemistry and Physics" "CRC". The pressure of the column of water in torr (mm Hg) will be equal to the mm H_2O divided by 13.59, a correction obtained by multiplying the height of the water column by the ratio of the density of water to that of mercury.

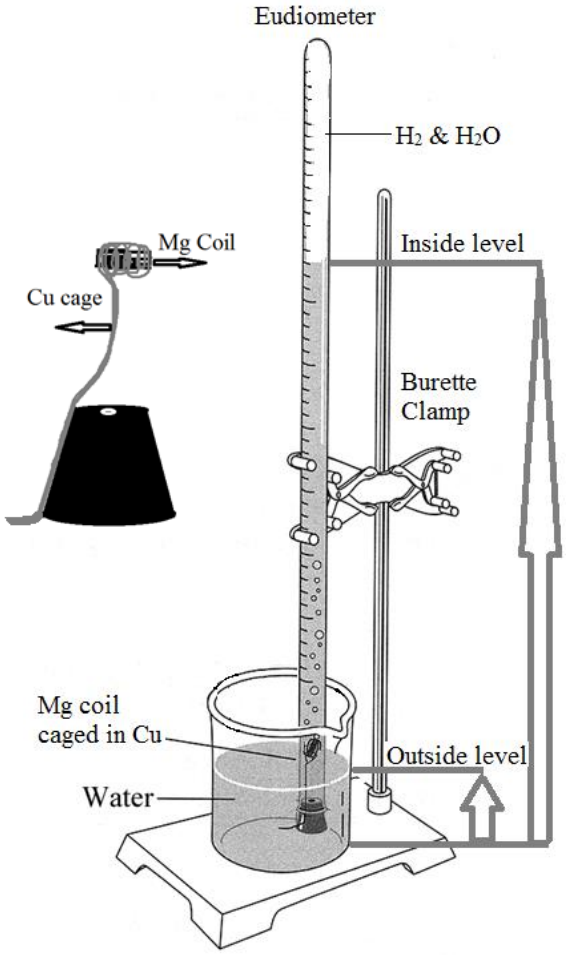

Figure1

The appropriate volume of concentrated (12 M HCl is added to the buret, and water is then layered on top of it until the buret is completely filled, as in Figure 1a. Inversion of the buret in a beaker partly filled with water starts the reaction (1b), which continues until all of the metal is gone and the buret is nearly full of hydrogen gas, as shown in 1c.

Name: _____ Date: _____

Partners Name: _____ Lab Section: _____

		Trial 1	Trial 2	Trial 3
1a.	Mass of magnesium ribbon	_____	_____	_____
b.	Moles of magnesium ribbon	_____	_____	_____
c.	Moles of H_2 (theoretical)	_____	_____	_____

{Show calculations for 1b & c below}

2a.	Volume of H_2 (in mL)	_____	_____	_____
b.	Volume of H_2 (in Liters)	_____	_____	_____
3a.	Temperature of H_2 (˚C)	_____	_____	_____
b.	Temperature of H_2 (K)	_____	_____	_____
4a.	Atmospheric Pressure (torr) (Temperature correction = - torr)	_____	_____	_____
b.	Vapor Pressure of H_2O (at expt'l T)	_____	_____	_____
c.	Water level in beaker (outside level) measured from desk top (mm H_2O)	_____	_____	_____
d.	Water level in eudiometer (inside level) measured from desk top (mm H_2O)	_____	_____	_____
e.	Calculated height of H_2O in eudiometer (This is equal to 4d –4c)	_____	_____	_____
f.	Equivalent height of water (in mm Hg) [multiply h(H_2O) by 1/13.59]	_____	_____	_____
g.	Pressure of H_2 in eudiometer tube (torr) [Hint: Dalton's Law of Partial Pressures]	_____	_____	_____
5a.	Volume of dry H_2 at STP [Hint: Use Combined Gas Law]	_____	_____	_____
b.	Molar Volume of H_2	_____	_____	_____

{Show one calculation for each part 4f, 4g, 5a, and 5b}

	Trial 1	Trial 2	Trial 3
6. Determine *the* percent error in V/n	_____	_____	_____
[V/n(theory) = 22.4_{14} l/ml] Average Value		_____	

(Show error calculation below)

Post Laboratory Questions.

1. What volume of hydrogen gas, at standard conditions (STP), can be liberated by the reaction of sulfuric acid with 0.0270 g Al?
   (a) Write a balanced equation for the reaction.
   (b) Determine the volume of H_2 liberated.

2. A 1.733 g sample of a certain metal reacts with hydrochloric acid to liberate 380.0 mL of H_2, when collected over water at 20.0 ˚C and 720.0 torr pressure.
   (a) Write a balanced **net ionic** equation for the reaction, assuming that the metal forms an M^{2+} ion in solution.
   (b) Determine the identity of the Metal.

3. Calculate the maximum mass of calcium metal that should be used in this experiment with a 50-mL eudiometer tube for gas collection. Assume that the H_2 gas generated occupies 45.0 mL at standard conditions.