

Chemistry 1215 Experiment #12 Determination of the Atomic Weight of a Metal

Objective

In this experiment you will determine the atomic weight of a metal by measuring the amount of hydrogen gas it produces when it dissolves in acid. You will use the atomic weight to identify the metal, then calculate the percent error of your determination.

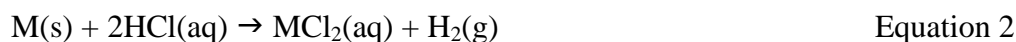
Introduction

Numerous years of experimentation with gases by numerous scientists revealed that there are four variables that must be known in order to characterize the physical state of the gas. These four variables are pressure, P; temperature, T; volume, V and the amount of gas, usually in moles, n. The ideal gas law describes the relationship between these variables for an ideal gas (Equation 1). An ideal gas is a hypothetical gas in which the molecules don't occupy volume and there is no interaction between gas molecules. No gas is ideal, however, at low temperatures and pressures, the ideal gas equation is a close approximation and thus is very useful.

$$PV = nRT \qquad \text{Equation 1}$$

In equation 1, the quantity R is a constant often called the gas constant. The value of R depends on the units for the variables in the equation, however, the two most common values are 0.0821 L·atm/mol·K or 8.314 J/mol·K. Note that the ideal gas law requires that temperatures be measured in Kelvin, K.

In this experiment you will react a known mass of an unknown metal with aqueous hydrochloric acid according to Equation 2, where M stands for the unknown metal.



The hydrogen gas produced by this reaction will be collected by downward displacement of the dilute acid in a eudiometer tube (see Figure 1) and the volume of the gas will be determined from the scale on the side of the tube. Since the hydrogen gas is collected over water, water vapor is inherently present. Because the collected hydrogen gas contains water vapor you must account for water vapor pressure in all your calculations. The pressure exerted by the wet gas is given by Dalton's Law of partial pressures as shown in Equation 3.

$$P_{\text{total}} = P_{H_2} + P_{H_2O} \qquad \text{Equation 3}$$

Calculations

Water vapor is not created by the reaction in Equation 2. Therefore the water vapor pressure must be subtracted from the total pressure in order to get the pressure of the dry hydrogen gas (Equation 4).

$$P_{H_2} = P_{\text{total}} - P_{H_2O}$$

Equation 4

The values for vapor pressure of water at various temperatures are given in Table 1. The total pressure, P_{total} is the pressure exerted by the wet hydrogen gas on the column of water inside the eudiometer tube. After the gas inside the eudiometer tube has equilibrated with the solution, and if the level of water inside the tube is equal to the level of water outside the tube, P_{total} is equal to the atmospheric pressure.

Once the pressure of hydrogen gas is known, the number of moles of H_2 gas produced can be calculated using the Ideal Gas equation, Equation 1. The volume is read from the graduations on the eudiometer tube and the temperature of the gas will be equal to the temperature of the water.

According to the stoichiometry of Equation 2, the number of moles of metal is equal to the number of moles of H_2 gas produced by the reaction as calculated above. The atomic mass of the metal can then be calculated by dividing the mass of metal used by the number of moles of metal. The experiment will be done twice and the average value will be calculated. The average atomic mass is then compared to the weights on the Periodic Table and the identity of the metal is determined. To help you determine the correct metal, remember the stoichiometry of equation 2 and the charge of the metal cation produced. Finally, once the metal has been identified, calculate a percent error for your experimental atomic mass (Equation 5).

% Error = [(experimental value – literature value)/literature value] x 100% (Equation 5)

Table 1

Temperature, °C	Water vapor pressure, Torr	Temperature, °C	Water vapor pressure, Torr
19	16.477	27	26.739
20	17.535	28	28.349
21	18.650	29	30.043
22	19.827	30	31.824
23	21.068	31	33.695
24	22.377	32	35.663
25	23.756	33	37.729
26	25.209	34	39.898

Safety

Hydrochloric acid, HCl is toxic and corrosive. Avoid getting it on your clothes and wash your hands after skin contact.

Procedure

1. Obtain a 50 mL eudiometer tube. The eudiometer tube looks like a large test tube with lines marking the volume in 0.1 mL increments. You will also need a rubber stopper, a piece of copper wire, and a 2 L beaker or a 2 L soda bottle with the neck cut off. Make sure that the eudiometer tube is clean and free of grease. If the stopper assembly is not already prepared, prepare one according to Figure 2. Make sure that the loop on the copper wire is 3-4 cm above the stopper.

2. Obtain a piece of metal. Carefully remove the oxide film on the metal by rubbing its surface with steel wool or sand paper. After cleaning the metal, handle it with tweezers or forceps to avoid reaction with or contamination by the skin oils on your fingers. Weigh the piece of metal to the nearest 0.001 grams. Record the mass. The sample weight should be between 0.030 and 0.037 g.
3. Clamp the eudiometer tube to a ring stand. Using a funnel, pour 9 to 10 mL of 6 M HCl into the tube. Fill the remaining volume of the tube with room temperature distilled water. Add the water slowly pouring it down the sides of the tube to avoid too much mixing with the acid. The tube must be filled completely with solution.
4. Using tweezers, secure the metal strip on the loop of the copper wire attached to the rubber stopper. Insert the stopper assembly into the tube. Loosely press the stopper into the tube taking care not to trap any bubbles underneath the stopper. Note that you must invert the tube and if the stopper is too loose it will leak or even fall out of the tube.
5. Pour room temperature water into the plastic soda bottle until it is approximately 2/3 full. Remove the eudiometer tube from the clamp, place your finger over the stopper and invert the tube. Immerse the stoppered end of the eudiometer tube into the water in the bottle (see Figure 1). Take care not to lose any liquid from the tube. If you do, you must repeat steps 1-4 above.

Remove your finger from the stopper and clamp the tube in a vertical position with the stopper about 3-4 cm from the bottom of the beaker. The acid in the tube is more dense than the water so it will flow down the tube until it reaches the metal. Once the metal contacts the acid it will begin to dissolve and produce hydrogen gas which will bubble to the top of the tube. You may observe a stream of acid coming out of the tube at this point but that is okay, the contents of the tube are being displaced by the gas.

6. When all of the metal has reacted and no more bubbles are being formed, allow the tube to cool to room temperature. Tap the tube to remove any bubbles adhering to the sides of the tube. Without taking the tube out of the water, remove the stopper from the bottom of the tube with crucible tongs. Raise or lower the eudiometer tube to equalize the water level in the soda bottle and the tube. This equilibrates the gas pressure inside the tube with the atmospheric pressure.

If it is impossible to make the two water levels equal, use a ruler to measure the difference in millimeters. Convert the difference in millimeters of water to millimeters of mercury (Hg) by dividing by 13.6. (at room temperature, the density of water is 1.00 g/mL while that of mercury is 13.6 g/mL.) To obtain the wet gas pressure you need to subtract this calculated correction factor from the atmospheric pressure if the water level in the tube is above the water level in the soda bottle or add it to the atmospheric pressure if the level of the water in the tube is below that in the soda bottle. Convert to dry gas pressure by subtracting the vapor pressure of water.

Convert pressure in mm Hg to atmospheres by dividing mm Hg by 760 mmHg/1.0 atm.

7. Record the volume of the collected gas and measure and record the temperature of the water in the soda bottle. The temperature of the gas will be the same as that of the water.

8. Rinse the eudiometer tube and repeat the experiment with a second sample of metal and fresh water in the tube and the soda bottle.

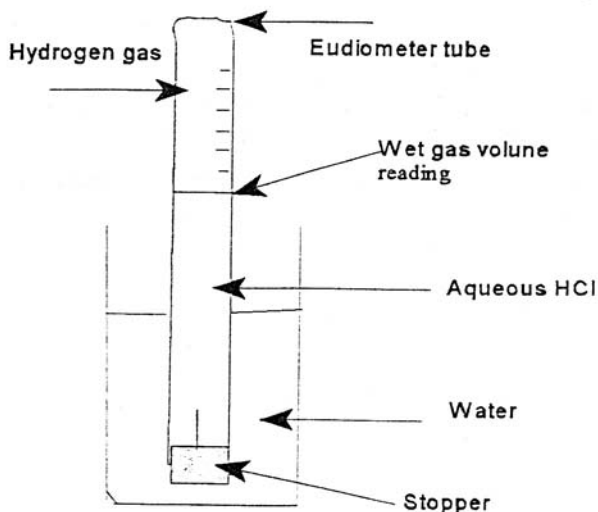


Figure 1. The experimental setup of the Eudiometer tube.

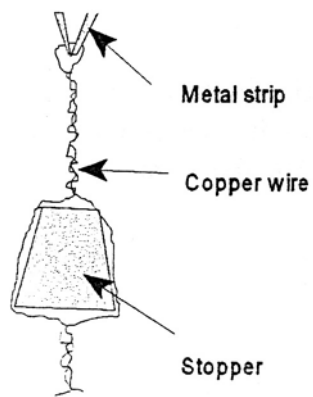


Figure 2. The setup of the stopper assembly

Data Table

	Experiment 1	Experiment 2
Atmospheric Pressure (mm Hg)	_____	_____
Mass of metal	_____	_____
Volume of gas in the eudiometer tube	_____	_____
Difference in water levels	_____	_____
Difference converted to mm Hg	_____	_____
Adjusted atmospheric pressure	_____	_____
Dry gas pressure in mm Hg	_____	_____
Convert mm Hg to atmospheres	_____	_____
Water temperature	_____	_____

Calculations

Use the ideal gas law to calculate the number of moles of hydrogen produced. Convert moles of hydrogen to moles of metal. From the mass of metal and the moles of metal, calculate the atomic weight of the metal. Determine the identity of the metal and calculate the percent error in your measurement.

Report

In your report include all calculations, a detailed discussion of the results including a statement of your calculated atomic weight and the identity of the metal. List any sources of experimental error and discuss how the errors may have affected your results.

Chemistry 1215, Experiment #11; Determination of the Atomic Weight of an Unknown Metal, **Pre-lab**

Name _____

1. Based on equation 2 in the introduction, to what group in the periodic table does the unknown metal probably belong? Explain your rationale.

2. Explain why it is necessary to consider water vapor pressure in calculating the atomic mass of the unknown metal. Would the calculated atomic mass be larger or smaller than the true value if water vapor pressure is ignored?

3. A 40.0 mg sample of a metal reacts with HCl according to the equation in the text. 24.4 mL of gas at 20.0 °C is collected by the downward displacement of aqueous acid as described in the lab protocol. If the atmospheric pressure is 780 mm Hg, what is the atomic weight of the metal?

4. A student allowed several air bubbles to enter his eudiometer tube. He ignored the error and proceeded with the experiment. What effect will this error have on his final result? Explain your rationale.

Chemistry 1215, Experiment #12; Determination of the Atomic Weight of an Unknown Metal, **Post-lab**

Name _____

1. A student who was measuring the atomic weight of a metal failed to thoroughly clean her metal ribbon leaving an oxide coat on the metal. Will the volume of hydrogen gas generated be lower or higher than the true value?
2. What volume will 5.00 g of helium gas occupy at 0.800 atmospheres and 25 °C?
3. Use Dalton's law of partial pressures to calculate the pressure of hydrogen gas collected over water if the ambient pressure is 710 mm Hg and the temperature is 25°C.
4. A student didn't equalize the water levels inside the eudiometer tube with that of his water bath. The water level inside the tube was 10 cm higher than the water level outside the tube. He ignored the difference and proceeded with his calculations. What effect will this error have on his calculated atomic mass? Explain your rationale.