

Name:

Period:

Seat#:

Required Sections: (Refer to R-15 for guidelines and requirements. Make note of any specific changes given by your teacher in class.)

Prelab: Prelab Questions, Purpose, Materials, Reagent Table, Procedures, and set up Data Tables before you get to class.

During Lab: Data section – Fill out your data table that is already set up from the prelab.

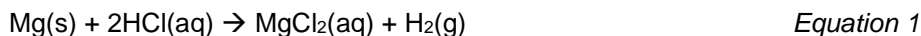
Post-lab: Calculation section, Post-Lab Questions, Post-Lab Two Pager done on separate Worksheet.

Introduction

Airbags have been required safety features on new cars since the 1980s and are credited with saving thousands of lives over that time. Airbags contain a compound that decomposes to give nitrogen gas upon impact from a collision. How much nitrogen gas must be generated to fill an airbag? The amount of gas needed to fill any size container can be calculated if we know the molar volume of the gas.

Avogadro's law states that equal volumes of gases contain equal numbers of molecules under the same conditions of temperature and pressure. It follows, therefore, that all gas samples containing the same number of molecules will occupy the same volume if the temperature and pressure are kept constant. The volume occupied by one mole of gas is called the *molar volume*. In this experiment we will measure the molar volume of hydrogen gas at standard temperature and pressure (STP, equal to 273 K and 1atm).

The reaction of magnesium metal with hydrochloric acid (Equation 1) provides a convenient means of generating small-scale quantities of hydrogen in the lab.



If the reaction is carried out with excess hydrochloric acid, the volume of hydrogen gas obtained will depend on the number of moles of magnesium as well as on the pressure and temperature. The molar volume of hydrogen can be calculated if we measure the volume occupied by a sample containing a known number of moles of hydrogen. Since the volume will be measured under laboratory conditions of temperature and pressure, the measured volume must be corrected to STP conditions before calculating the molar volume.

The relationship among the four gas variables – pressure (P), volume (V), temperature (T), and the number of moles (n) – is expressed in the ideal gas law (Equation 2), where R is a constant called the universal gas constant.

$$PV = nRT \quad \text{Equation 2}$$

The ideal gas law reduces to Equation 3, the combined gas law, if the number of moles of gas is constant. The combined gas law can be used to calculate the volume (V₂) of a gas at STP (T₂ and P₂) from the volume (V₁) measured under any other set of laboratory conditions (T₁ and P₁). In using either the ideal gas law or the combined gas law, remember that temperature must always be expressed in units of kelvins (K) on the absolute temperature scale.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{Equation 3}$$

Hydrogen gas will be collected by the displacement of water in an inverted eudiometer tube using the apparatus shown in Figure 1. The total pressure of the gas in the cylinder will be equal to the barometric (air) pressure. However, the gas in the cylinder will not be pure hydrogen. The gas will also contain water vapor due to the evaporation of the water molecules over which it is being collected. According to Dalton's Law, the total pressure of the gas will be equal to the partial pressure of hydrogen plus the partial pressure of water vapor (Equation 4). The vapor pressure of water depends only on the temperature (see Table 1).

$$P_{\text{total}} = P_{\text{H}_2} + P_{\text{H}_2\text{O}} \quad \text{Equation 4}$$

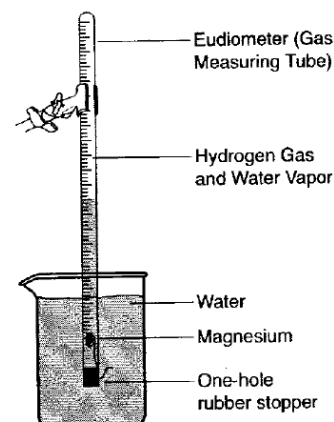


Figure 1

Dougherty Valley HS Chemistry - AP Gas Laws – Molar Volume of a Gas

Table 1. Vapor Pressure of Water at Different Temperatures

Temperature, °C	P_{H_2O} , mmHg	Temperature, °C	P_{H_2O} , mmHg
16 °C	13.6	22 °C	19.8
17 °C	14.5	23 °C	21.1
18 °C	15.5	24 °C	22.4
19 °C	16.5	25 °C	23.8
20 °C	17.5	26 °C	25.2
21 °C	18.7	27 °C	26.7

Objectives

In this experiment, you will

- Determine the molar volume of one mole of hydrogen gas at standard temperature and pressure (STP).
- Hydrogen will be generated by the reaction of a known mass of magnesium with excess hydrochloric acid in an inverted eudiometer tube filled with water.
- The volume of hydrogen collected by water displacement will be measured and corrected for differences in temperature and pressure in order to calculate the molar volume of hydrogen at STP.

Prelab Questions (Part of your Prelab Assignment)

Reaction of 0.028 g of magnesium with excess hydrochloric acid generated 31.0 mL of hydrogen gas. The gas was collected by water displacement in a water bath 22°C. The barometric pressure in the lab that day was 746 mmHg.

- 1) Use Dalton's law and the vapor pressure of water at 22°C (Table 1) to calculate the partial pressure of hydrogen gas in the gas collecting tube.
- 2) Use the combined gas law to calculate the "corrected" volume of hydrogen at STP.
Hint: Watch your units for temperature and pressure!
- 3) What is the theoretical number of moles of hydrogen that can be produced from 0.028 g of Mg?
Hint: Refer to Equation 1 for the balanced equation for the reaction.
- 4) Divide the corrected volume of hydrogen by the theoretical number of moles of hydrogen to calculate the molar volume (in L/mol) of hydrogen at STP.

Materials

Chemicals

- Copper wire, Cu, 18-gauge, 10cm long
- * Hydrochloric acid, HCl, 2 M, 15 mL
- * Magnesium ribbon, Mg, 2.5 cm pieces x2
- Distilled water

Equipment

- 600mL beaker
- Graduated cylinder, 25 mL
- Eudiometer tube, 50 mL
- One-hole rubber stopper, size 1 or 2
- Scale
- Funnel

- Thermometer
- Barometer
- Scissors or wire cutter
- Metric ruler
- One tall 1000mL graduated cylinder for equalizing the pressure, class will share.



SAFETY PRECAUTIONS

DANGER: *Hydrochloric acid is a corrosive liquid. Avoid contact with eyes and skin and clean up all spills immediately. Magnesium metal is a flammable solid. Keep away from flames and other sources of ignition. Wear chemical splash goggles. Wash hands thoroughly with soap and water before leaving the laboratory.*

Dougherty Valley HS Chemistry - AP Gas Laws – Molar Volume of a Gas

Procedure

- 1) Fill a 600 mL beaker about $\frac{3}{4}$ full with water
- 2) Obtain or cut a 2.5 cm piece of magnesium ribbon. Do not exceed 2.5 cm
- 3) Record the mass of magnesium ribbon using the scale.
- 4) Obtain a piece of copper wire about 10cm long. Twist and fold one end of the copper wire around a pencil to make a small “cage” into which the magnesium ribbon may be inserted. See Figure 2.
- 5) Firmly place the 2.5 cm piece of magnesium into the copper-wire cage.
- 6) Insert the straight end of the copper wire into a one-hole rubber stopper so that the cage end containing the magnesium is about 2.5 cm below the bottom of the stopper (see Figure 1). Hook the end of the copper wire around the top of the stopper to hold the cage in place.
- 7) Obtain about 15mL of 2 M hydrochloric acid in a 25 mL graduated cylinder.
- 8) Carefully and slowly pour the acid into the eudiometer tube.
- 9) While holding the eudiometer tube in a tipped position, slowly and carefully fill the eudiometer tube with distilled water from a wash bottle or a beaker. Work slowly to avoid mixing the acid and water layers at this time. Fill the eudiometer tube all the way to the top so that no air remains in the tube.
- 10) Insert the magnesium-copper-wire-stopper assembly into the eudiometer tube. The magnesium piece should be above the 10mL line on the eudiometer tube (see Figure1)
- 11) Place your finger over the hole of the rubber stopper, invert the eudiometer tube, and carefully lower the stoppered end of the eudiometer tube into the 600 mL beaker containing water.
- 12) Record any evidence of a chemical reaction in the data table.
- 13) If the magnesium metal “escapes” its copper cage, gently shake the eudiometer tube up and down to work the magnesium back up into the acidic solution.
- 14) Allow the apparatus to stand for 5 minutes after the magnesium has completely reacted. Gently tap the sides of the eudiometer tube to dislodge any gas bubbles that may have become attached to the sides.
- 15) Gently move the eudiometer tube up or down in the tall container water bath until the water level inside the eudiometer tube is the same as the water level in the beaker. This is done to equalize the pressure with the surrounding air (barometric pressure). *Note:* Be careful to make sure that the stoppered end of the eudiometer tube remains submerged in the water.
- 16) When the water levels inside and outside the tube are the same, measure and record the exact volume of hydrogen gas in the eudiometer tube.
- 17) Measure and record the temperature of the water bath in the beaker. Using a barometer, measure and record the barometric pressure in the lab.
- 18) Remove the eudiometer tube from the water bath and discard the water in the beaker down the drain.
- 19) Clean and rinse the eudiometer tube with distilled water. Repeat the entire procedure to obtain a second set of data. Record as Trial 2 in the data table.



Figure 2.

Dougherty Valley HS Chemistry - AP Gas Laws – Molar Volume of a Gas

Data Table Remember, you need to make sure your data table has all required elements!
This is just to get you started on the right track.

	Trial 1	Trial 2
Length of Mg Ribbon		
Mass of Mg		
Evidence of Chemical Reaction		
Volume of "wet" H ₂ Gas		
Temperature of Water Bath		
Barometric Pressure		

Disposal and Cleanup

Your teacher will provide disposal and cleanup instructions.

Calculations

- Record any, and all, manipulation of numbers in your calculation section.
 - In addition to performing the numbered calculations below, be sure to construct a "Results Table" to summarize the results of the following calculations.
- Calculate the theoretical number of moles of hydrogen gas produced in Trials 1 and 2.
 - Use Table 1 in the *Introduction* section to find the vapor pressure of the water at the temperature of the water bath in this experiment. Calculate the partial pressure of hydrogen gas produced in Trials 1 and 2.
 - Use the combined gas law to convert the measured volume of hydrogen to the volume the gas would occupy at STP for Trials 1 and 2. *Hint:* Remember the units!
 - Divide the volume of hydrogen gas at STP by the theoretical number of moles of hydrogen to calculate the molar volume of hydrogen for Trials 1 and 2.
 - What is the average value of the molar volume of hydrogen? Look up the literature value of the molar volume of a gas in your textbook, or a reputable online source, and calculate the percent error in your experimental determination of the molar volume of hydrogen.
 - One mole of hydrogen gas has a mass of 2.02 g. Use your value of the molar volume of hydrogen to calculate the mass of one liter of hydrogen gas at STP. This is the density of hydrogen in g/L.
 - How does this experimental value of the density compare with the literature value? Consult your textbook, or a reputable online source, for the density of hydrogen.

Post Lab Questions

- In setting up this experiment, a student noticed that a bubble of air leaked into the eudiometer tube when it was inverted in the water bath.
 - What effect would this have on the measured volume of hydrogen gas?
 - Would the calculated molar volume of hydrogen be too high or too low as a result of this error? Explain.
- A student noticed that the magnesium ribbon appeared to be oxidized – the metal surface was black and dull rather than silver and shiny.
 - What effect would this error have on the measured volume of hydrogen gas?
 - Would the calculated molar volume of hydrogen be too high or too low as a result of this error? Explain.
- A student forgot to subtract out the partial pressure of the water vapor, and therefore did their calculations using "wet" gas instead of "dry" gas.
 - What effect would this have on the measured volume of hydrogen gas?
 - Would the calculated molar volume of hydrogen be too high or too low as a result of this error? Explain.