EXPERIMENT 6: Ideal Gas Constant & Molar Volume Hydrogen

INTRODUCTION

"Ideal Gases"

The pressure, volume, moles, and temperature relationships expressed by the Ideal Gas Equation are based on two assumptions.

The first assumption is that the particles (usually atoms or ions) of a substance in the gaseous state occupy no volume. Remember that the volume occupied by a gas is its container's volume, not the sum of the volumes of the individual particles that make up the gas. Thus, the assumption is that the volume of a gas is empty space, and that none of that empty space is taken up by particles.

The second assumption is that the particles of a substance in the gaseous state are not attracted to each other.

When a gas behaves in accordance with the above assumptions, it is behaving ideally—this is the behavior of an ideal gas. It is behaving according to the Ideal Gas Equation, which indicates that the ratio of P•V to n•T is constant:

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2} \qquad \text{OR} \qquad \frac{P \bullet V}{n \bullet T} = \text{constant}$$

That constant is the Boltzman Constant (or ideal gas constant), R. Thus,

$$\frac{P \bullet V}{N \bullet T} = R \qquad R = \frac{0.08206 \text{ L atm}}{\text{K mole}}$$

OR

$$R = \frac{62.37 \text{ L torr}}{\text{K mole}}$$

"Real Gases"

In reality, the particles of a gas do occupy some volume and they are attracted to each other. Thus the actual behavior, and therefore the values obtained in measurements of a so-called "real gas", deviate from the behavior, or theoretical values, predicted for an "ideal gas" under the same conditions.

EXPERIMENT SUMMARY:

When zinc is added to an aqueous solution of hydrochloric acid the following reaction occurs:

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

You will weigh a sample of Zn and react it with excess HCl solution. The H_2 gas produced in the reaction will be collected "over water". You will calculate an experimental value for R using the measured pressure, volume, temperature, and moles of H_2 gas. You will also calculate an experimental molar volume of H_2 scaled to conditions of standard temperature and pressure.

PROCEDURE

CAUTION:

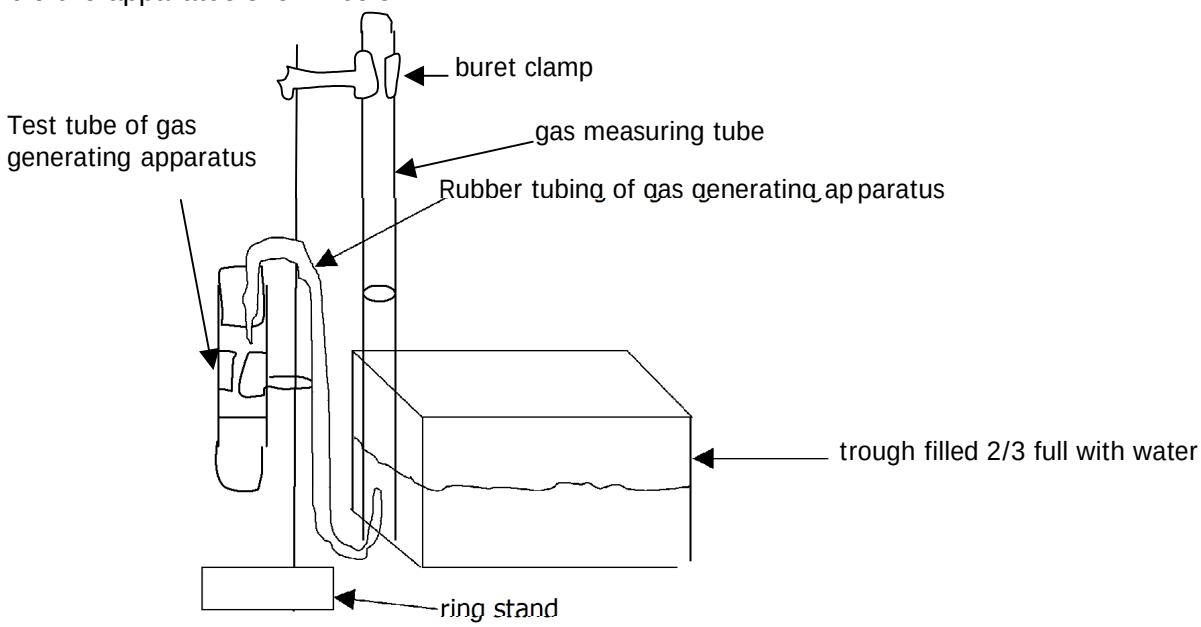
HYDROGEN is FLAMMABLE Be sure that no one is working with open flames in the lab.

HYDROCHLORIC ACID SOLUTION: POISON! DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED. If Dil HCl (6 M) gets in contact with your skin or clothing, immediately rinse the affected area with large amounts of water.

A. Check out the following items from the Stockroom :

- gas generating apparatus (a 6-inch test tube fitted with a rubber stopper and rubber tubing)
- 12-inch plastic ruler
- 100 mL gas measuring tube

B. Assemble the apparatus shown below



1. Setting up the gas generating apparatus:
   a. Add about 9 mL of Dil (6 M) HCl (bottle #2 at your bench) solution to the 6-inch gas generating test tube.
   b. Clamp the tube to a ring stand .
2. Setting up the gas measuring tube
   a. Fill the trough about two-thirds with water.
   b. Fill the gas measuring tube completely with water. There should be no air bubbles present.
   c. Cover well the mouth of the gas measuring tube with the palm of your hand, then turn the tube upside down and submerge the mouth of the tube in the water in the trough.
   d. Remove your hand from the mouth of the tube, but keep the tube submerged. Make sure no air bubbles appear in the gas collecting tube.
   e. Use a buret clamp to secure the gas measuring tube to the ring stand.

f. Submerge the end of the rubber tubing from the gas generating apparatus up underneath and into the mouth of the inverted gas collecting tube.
g. Before continuing, ask your instructor to check and approve your apparatus.

C. Reaction of Zn and HCl

1. Get a small weighing boat from your instructor. Tare the weighing boat on the analytical balance. Weigh accurately between 0.2000 and 0.2300 grams of granular zinc into the weighing boat. Record the mass on your Report Sheet.

2. Carefully (without spilling) add the zinc to the HCl solution in the gas generating test tube. Then quickly stopper the test tube with the rubber stopper of the gas generating apparatus (minimize the loss of the H_2 gas). The system should be air tight.

3. Return the weighing boat to your instructor when finished with the experiment.)

4. When all of the zinc has reacted and there is no further evolution of H_2, collect the following data and record it on your Report Sheet.

   a. Determine the volume of H_2 gas evolved by reading the volume in mL on the gas measuring tube.
   b. Measure the temperature of the water in the trough by using the thermometer. (We will assume that the temperature of the H_2 is the same as that of the water in the trough.)
   c. Measure the height, in cm, of the column of water in the gas measuring tube using the ruler. (Measure the distance from the top of the liquid water in the trough to the top of the liquid water in the gas measuring tube.)
   d. Find the barometer in the laboratory and read the atmospheric pressure, in inches Hg at which the experiment was conducted.
   e. Using the table below determine the vapor pressure of water at the temperature you measured in step b.

Table: Vapor Pressure of Water at different temperatures.

Temperature (°C)	Vapor Pressure (mm Hg)	Temperature (°C)	Vapor Pressure (mm Hg)
16	13.6	23	21.1
17	14.5	24	22.4
18	15.5	25	23.8
19	16.5	26	25.2
20	17.5	27	26.7
21	18.6	28	28.3
22	19.8		

DISPOSAL: Dispose of the reaction mixture in the test tube by pouring it in the sink and rinsing it down the drain with lots of water.

D. CALCULATIONS

1. Pressure of liquid water in gas measuring tube.

   a. Convert the height of the water in the tube from cm H_2O to mm H_2O.

   b. Convert the height of the liquid water in the tube from mm H_20 to mm Hg. (13.6 mm H_2O = 1.00 mm Hg) This is the pressure of the liquid water in the tube

2. Calculate Pressure of H_2(g)

   a. Convert the barometric pressure (total pressure of tube contents) from inches of Hg to mm Hg. (1 in. = 2.54 cm)

   b. Calculate pressure of H_2 gas using Dalton's law of partial pressures which tells you that $P_{total} = \rho H_2O_{(l)} + \rho H_2O_{(g)} + \rho H_2(g)$

   c. Convert pressure of H_2 gas from mm Hg to atmospheres.

3. Moles H_2 (calculated from mass of Zn used)

   a. Balanced equation for reaction of Zn and HCl

   _____

   b. Calculate theoretical moles H_2 produced in the reaction. (molar mass Zn = 65.39 g/mole)

4. Convert temperature of H_2 from Celsius to Kelvin.

5. Convert volume H_2 from mL to L

6. Calculate Experimental Ideal Gas Constant, R, using experimental values for P, V, T and theoretical value for moles H_2)

7. Percent error in Ideal Gas Constant, R (theoretical value = 0.08205 L atm K^{-1} $mole^{-1}$)

8. Experimental volume (in liters) of H_2 scaled to STP (P = 1.0000 atm, T = 273.15 K) conditions.

9. Experimental molar volume of H_2 at STP

REPORT SHEET - EXPERIMENT 6 Name _____
last first

Instructor's initials _____

DATA

1. Mass of zinc _____
2. Volume of H_2 gas collected in the gas measuring tube. _____
3. Height of water column in the gas measuring tube. _____
4. Temperature of H_2 gas collected (temperature of water). _____
5. Barometric pressure (total pressure of gas measuring tube contents) _____
6. Vapor pressure of H_20 at temperature above. _____

CALCULATIONS:

1. Pressure of liquid water in gas measuring tube.

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QUESTIONS

1. Determine whether each of the errors listed below would make the value of the gas constant. Would it cause R to be Lower or Higher than it should be, or would the error have No Effect. Explain your conclusion.

   (Hint: Use complete set -up for the calculation of R to see the effect of each error.)

$$R = \frac{\text{VOLUME (L)} \bullet \text{PRESSURE (atm)}}{\text{TEMPERATURE (K)} \bullet \text{MOLE } H_2}$$

   a. Zinc contains contaminants that are insoluble in HCl solution. _____

   b. Zinc is contaminated with Al. _____

      Balanced equation for reaction of Al with HCl (aq)

      _____

   c. H_2 is soluble in water. _____

   d. By mistake you did not take into consideration the height of the water column inside the gas collecting tube, but assumed the pressure inside the gas collecting tube equaled the atmospheric pressure.

      _____

   e. Air bubbles are not expelled from the inverted gas collecting tube prior to the generation of H_2.

      _____

2. A 0.0677 g sample of magnesium metal reacted with excess hydrochloric acid solution to produce 69.9 mL of hydrogen gas. The gas was collected over water at 21.0° C. The levels of water inside and outside the gas collecting tube are identical (meaning that the pressure exerted by liquid water in the gas measuring tube is 0). The vapor pressure of water at 21.0°C is 18.6 torr and the atmospheric pressure is 755 torr. Calculate the experimental molar volume of hydrogen gas at STP.

Reaction Equation _____

3. A 0.188 g sample of unknown metal, M, produced 71.4 mL hydrogen gas when reac ted with an excess of $HCl_{(aq)}$.

$$M_{(s)} + 2\ HCl_{(aq)} \longrightarrow MCl_{2(aq)} + H_{2(g)}$$

The gas was collected over water at 23°C. The levels of liquid water inside and outside the gas measuring tube are identical (meaning that the pressure exerted by liquid water in the gas measuring tube is 0). The vapor pressure of water at 23°C is 21.1 mm Hg and the atmospheric pressure is 752 mm Hg. Calculate the molar mass of the unknown metal, M.
($R = 0.08205\ L\ atm\ K^{-1}\ mole^{-1}$ or $62.37\ L\ torr\ K^{-1}\ mole^{-1}$)