EXPERIMENT

THE IDEAL GAS CONSTANT AND THE MOLAR VOLUME OF HYDROGEN

OBJECTIVES:

In this experiment you will determine both, the numerical value of the ideal gas constant R using the ideal gas law and the molar volume of hydrogen gas at STP.

INTRODUCTION:

The pressure, volume and temperature relationships investigated by Boyle ($V \alpha 1/P$) , Charles ($V \alpha T$) and Avogadro ($V \alpha n$) are based on the assumption that gas molecules have no volume of their own and do not attract one another. However, **real gas** molecules are finite in size and exhibit finite mutual attractive forces. In precise measurements with **real gases**, corrections are needed to make the gas law equations valid. A gas that strictly obeys Boyle's, Charles and Avogadro's relations is called an **ideal gas**.

The above three gas relations may be expressed through a single relationship:

$$V \alpha \frac{T \cdot n}{P}$$

Thus $P V \alpha n T$, and we can write: $P V = n R T$

The ideal gas constant, R, is the proportionality constant.

EXPERIMENT SUMMARY:

H_2 gas liberated by the reaction of an accurately measured mass of Zn (s) with an excess of HCl (aq), will be collected by the displacement of water. A balanced equation is needed to relate the quantity of H_2 gas liberated to the mass of Zn (s) reacted.

$$Zn\ (s) + 2\ HCl\ (aq) \rightarrow ZnCl_2\ (aq) + H_2\ (g)$$

You will calculate the ideal gas constant, R, using the ideal gas equation and the experimental values of pressure, volume, temperature and number of moles of H_2 gas.

Calculation of the molar volume (volume of one mole) of H_2 gas at STP conditions [temperature of 0° C (273 K) and pressure of 1 atm (760 torr)] will also be done].

CAUTION:

1) H_2 gas is flammable. You are not to use any burners during this experiment. Make sure no students in the lab are using burners. No open flames!! In the presence of an open flame, H_2 gas reacts EXPLOSIVELY with O_2 (g) present in the air.

2) Use caution when handling Dil HCl (6 M) and report any spills. HCl can affect the body if inhaled, swallowed or brought in contact with the eyes or skin. If Dil HCl (6 M) gets in contact with your skin or clothing, immediately rinse the affected area with large amounts of water.

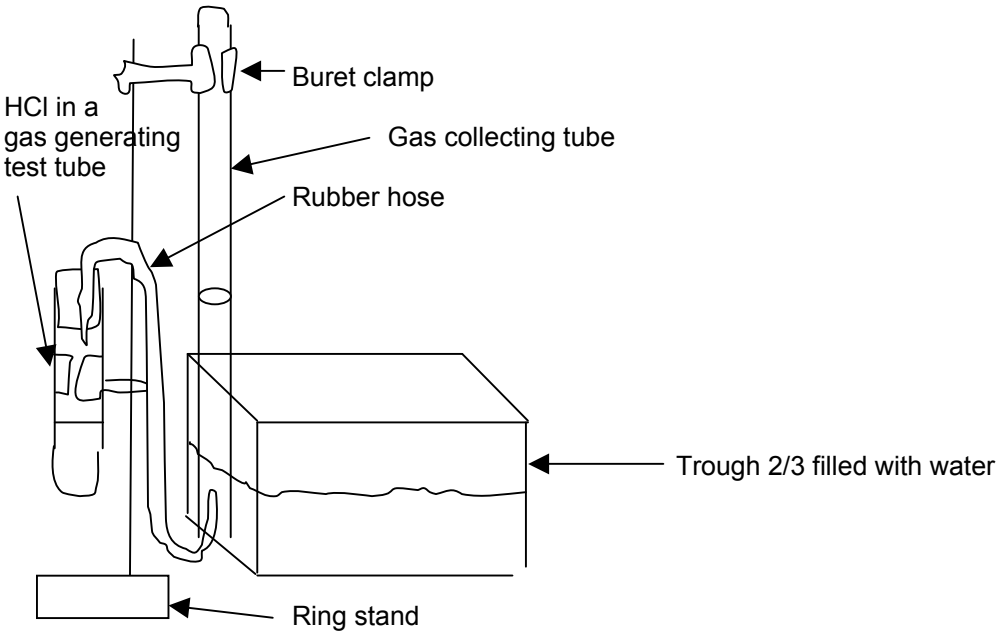
PROCEDURE

A) Check out from the stockroom the following:

- A gas generating apparatus (which consists of a 6-inch test tube fitted with a rubber stopper and a rubber hose) .
- A 12-inch plastic ruler.
- A gas measuring tube (which has a capacity of 100 ml).

Note: All of the above checked out equipment should be returned to the stockroom at the end of the lab period.

B) Assemble the apparatus shown in the figure below as follows



1) SETTING -UP THE GAS GENERATING APPARATUS

a) Add about 9 ml of Dil HCl (6 M) into the 6-inch gas generating test tube.
b) Clamp the tube to a ring stand .

2) SETTING -UP THE GAS MEASURING APPARATUS:

a) Fill the trough about two-thirds with water.
b) Fill the gas measuring tube completely with water . Use a wash bottle to adjust the water level to the uppermost rim. There should be no air bubbles present.
c) Cover well the mouth of the gas measuring tube with the palm of your hand.
d) While the mouth of the gas measuring tube being sealed with your hand, carefully invert the gas measuring tube so that its mouth is pointing downward.
e) Submerge the mouth of the tube into the water in the trough. Now unseal the mouth of the tube, but keep it submerged. Make sure no air bubbles appear in the gas collecting tube.
f) Use a buret clamp to secure the gas measuring tube to the ring stand.
g) Place the end of the rubber hose connected to the rubber stopper under the mouth of the inverted gas measuring tube.
h) Ask your instructor to approve your apparatus and initial your report before continuing.

3) GENERATING HYDROGEN GAS

a) Tare a weighing boat on the analytical balance. Weigh accurately between 0.2000- 0.2300g granulated zinc in the weighing boat. Record the mass on the report sheet. **Show the weighed sample of zinc to your instructor and get his or her initial on your report sheet.**

b) Carefully, add the zinc sample into the Dil HCl in the gas generating test tube. **Quickly**, stopper the test tube , with the rubber stopper connected to the hose, to minimize the loss of the evolving gas. The system should be air tight. H_2 gas will form in the test tube due to the reaction of zinc with HCl.

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

c) The H_2 gas evolved will displace the water in the inverted gas measuring tube.

d) When all zinc had reacted and there is no further evolution of H_2 gas, record the following measurements:

i) Determine the volume of H_2 gas released as indicated by the reading on the gas measuring tube.

ii) Determine the temperature of the water in the trough by using the thermometer.

iii) Determine the height of the water column in the gas measuring tube by measuring it with a millimeter ruler.

iv) Locate the barometer in the laboratory and read the atmospheric pressure at which the experiment was conducted.

v) Read the pressure of the water vapor from the table given below.

Table: Vapor pressure of water at different temperatures.

Temp,° C	**Vapor pressure in mm Hg**	**Temp,° C**	**Vapor pressure in mm Hg**
16	13.6	24	22.4
17	14.5	25	23.8
18	15.5	26	25.2
19	16.5	27	26.7
20	17.5	28	28.3
21	18.6		
22	19.8		
23	21.1		

DISPOSAL: Discard the contents of the reaction test tube in the sink with lots of water.

Lab Report
Experiment -THE IDEAL GAS CONSTANT AND THE MOLAR VOLUME OF HYDROGEN

Name _____
first **last**
Instructor's Initial_____

Instructor's approval of gas measuring tube filled with water with no air bubbles present

_____
(instructor's approval)

DATA:

1) Mass of zinc _____ g

Instructor's approval of the mass of zinc.

_____
(instructor's approval)

2) Volume of H_2 gas collected in the gas measuring tube. _____ ml

3) Height of water column in the gas measuring tube. _____cm

4) Temperature of H_2 gas collected (temperature of water). _____° C

5) Barometric pressure. _____inch Hg

Read the vapor pressure of water at the temperature of H_2 gas from the table on page 3.

_____ mm Hg

Write a balanced equation for the reaction of Zn(s) with HCl (aq).

_____

CALCULATIONS:

1) Convert the height of water column in the gas measuring tube into mmHg. The density of mercury is 13.6 g/ml.
Setup:

_____mm Hg

2) Convert the Barometric pressure into mmHg. *(1 inch =2.54 cm)*

_____mm Hg

3) Calculate the pressure of the dry H_2 (g) using Dalton's law of partial pressures.
Hint: $P_{atmospheric} = P_{dry\ hydrogen\ gas} + P_{water\ vapor} + P_{water\ column}$

Setup:

_____mm Hg

3) Calculate the number of moles of H_2 (g) from the mass of Zn(s).
Setup:

_____moles H_2

4) Calculate the ideal gas constant , R , in units of L.atm/mol.K
Setup:

_____L.atm/mol.K

5) Calculate % error in the experimentally determined value of the ideal gas constant, R.
Setup:

_____ %

6) Convert the volume (in liters) of H_2 gas collected , at lab condition of temperature and pressure, into STP condition . Hint: Use the combined gas law.
Setup:

_____ $L_{(STP)}$

7) Calculate the **experimental molar volume** of H_2 gas at STP.
(Hint: You need the volume of H_2 gas collected at STP in step 6 and the corresponding number of moles calculated in step 3 above.)
Setup:

_____ $L_{(STP)}$/mole

QUESTIONS

1) Determine whether each of the errors listed below would make the value of the gas constant, R:
a) Lower, b) Higher, or c) Cause no change.
(Hint: Follow a complete set -up for the calculation of R to see the effect of each error.)

a) Zn (s) contains contaminants that are insoluble in HCl solution.

a) _____

b) Zinc (s) is contaminated with Al (s).
(Hint; Write a balanced chemical equation for the reaction of Al(s) with HCl (aq).)

b) _____

c) H_2 gas is soluble in water .

c) _____

d) Suppose 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.

d) _____

e) If the air bubbles are not expelled from the inverted gas collecting tube prior to the generation of H_2 (g).

e) _____

2) A 0.0677 g sample of magnesium metal reacted with excess hydrochloric acid 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. The water vapor pressure at 21.0 ° C is 18.6 mm Hg and the atmospheric pressure is 755 mm Hg. Calculate the experimental molar volume of hydrogen gas at STP. (You must write a balanced chemical equation for the reaction)
Setup:

Answer_____

3) A 0.188 g sample of unknown metal,X (s), produced 71.4 ml of hydrogen gas when reacted with HCl according to the equation:

$$X\,(s) + 2\ HCl\ (aq) \longrightarrow XCl_2\ (aq) + H_2\ (g)$$

The gas was collected over water at 23 ° C. The levels of water inside and outside the gas collecting tube are identical. 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, X. (R =0.0821 L.atm/mol.K)
Setup:

Answer _____