Empirical Gas Laws (Part 3): The Ideal Gas Law

Determination of the Universal Gas Constant, R

In this experiment, you will generate and collect a sample of hydrogen gas over water by the reaction of magnesium with hydrochloric acid.

Using the Ideal Gas Law (PV=nRT) you will find values for the pressure (P), volume (V), number of moles of the gas (n), and the temperature (T) in order to determine the gas constant (R). Because there will be water vapor present in your sample, you will make a correction to the measured pressure and then compare your result for R to the literature value.

In this experiment, you will:

- Determine a value for the Universal Gas Constant, R. (Part 3 of Empirical Gas Laws)

Safety Precautions

Wear your goggles at all times. Hydrochloric acid is corrosive. Avoid spills and contact with your skin and clothing. If HCl comes in contact with your skin, inform your teacher and flush the acid with large quantities of water.

Note: If you are doing Part 3 to determine the value of the Universal Gas Constant, R in the same period as Parts 1 and 2, you should get Part 3 started first.

EXPERIMENTAL PROCEDURE **(WORK IN PAIRS)**

1. Put on goggles. Keep them on during the entire experiment.

2. Obtain a piece of magnesium ribbon that weighs no more than 0.08 grams. **Record the mass obtained** (use significant figures!). Record this value in your data table (see report sheets). Loosely roll it into a ball or coil it.

   Encase the magnesium in a piece of copper mesh. Why do you think this might be helpful?

3. Fill the 800-mL beaker with approximately 200-mL of tap water.

4. Fill the 100-mL graduated cylinder with tap water. Using parafilm, a one-hole stopper, or the palm of your hand, cover the top and invert the cylinder into the beaker of water. You will end up with an inverted cylinder full of water. Remove the parafilm or stopper if you used one. Rest the cylinder on the bottom of the beaker. Try not to introduce any air bubbles in your inverted cylinder (see Figure 1).

5. Place the magnesium (in its copper cage) into the graduated cylinder. Make sure the magnesium is captured in the cylinder.

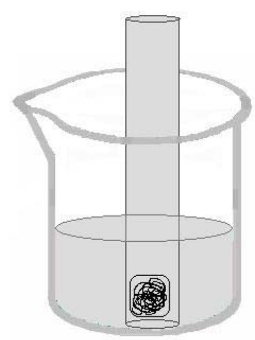

Figure 1: Gas collection in an inverted cylinder full of water. A ball of magnesium ribbon is enclosed in a copper cage and placed inside the cylinder.

6. Add about 25-mL of 6M HCl into the beaker. Use a thistle tube to deliver the HCl to the bottom of the beaker. This will facilitate the reaction with magnesium.

7. The acid should begin to react with your magnesium immediately. Record your observations (how can you tell there is a reaction?) As it reacts, the magnesium might move up the graduated cylinder. If this happens, GENTLY tip your cylinder back and forth to bring the magnesium back down.

* *

This reaction may take a while, so if you are doing Parts 1 and 2 of Empirical Gas Laws, then start it and come back.

* *

8. When the reaction is complete (the magnesium is no longer visible) tap the side of the cylinder to release any trapped bubbles. Allow the cylinder to sit for two minutes. In the meantime, **record the atmospheric pressure** for today (ask your instructor).

Atmospheric pressure today: _________________ mbar (use the BC Weather Station website).

If 1 bar = 750 mmHg (not 760), the atmospheric pressure today is **_____________ mm Hg.**

Enter these values into the data table.

9. After allowing the beaker to rest, record the temperature in the beaker in your data table.

10. Lift the graduated cylinder until the levels of water inside and outside of the cylinder are the same. This sets the pressure inside the cylinder to atmospheric pressure. **Record the volume of gases** in the cylinder in your data table. (How many significant figures should be recorded?)

Make sure you have recorded all necessary variables to calculate R (see Calculations section). Put the hydrochloric acid from your experiment into a designated waste container. Clean the lab area.

Report Sheets

Empirical Gas Laws (Part 3) Name________________________

Lab Partner__________________ Section _______

Data/Calculations for Part 3

Create a data table to use for this experiment. Measurements are in bold. The rest of the entries are due to calculations (you will do several conversions). **<u>Don't forget units and significant figures.</u>**

Mass of magnesium (g)	
n= Moles of magnesium (mol)	
Volume of H_2 collected (mL)	
V= Volume of H_2 collected (L)	
Temperature (°C)	
T= Temperature (K)	
Atmospheric pressure (mbar or mb)*	
Vapor pressure of water – see Table 1 (mmHg)	
P= Pressure of H_2 collected (atm)	

*Use the Bellevue College weather station.
http://scidiv.bellevuecollege.edu

Results for Part 3

Calculated value for R (L·atm/mol·K)	
% error	

Report Sheets

Follow-up Questions for Part 3:

1. Write a balanced equation for the reaction between magnesium and hydrochloric acid. Include physical states.

2. Which was the limiting reactant, magnesium or hydrochloric acid? Explain how you know from visual inspection of the materials after the reaction is complete.

3. Why might the magnesium travel up the graduated cylinder as it reacts? (You may or may not have observed this yourself.)

4. Determine the values of n_{H2} (moles of H_2 produced) based on the moles of magnesium that reacted. Enter the value into the data table.

5. Convert the volume of gas to liters and the temperature to Kelvin. Enter the values into the data table.

Report Sheets

6. Determine the value of P_{H2} (pressure of hydrogen gas collected). Remember, **the total pressure inside the cylinder is the result of both hydrogen and water vapor, and equals the atmospheric pressure.** Use Table 1 to find the pressure due to the water vapor alone, then determine $P_{H2.}$

a) The pressure of the atmosphere (mm Hg):

b) The vapor pressure of water at the measured temperature (mm Hg):

Table 1. Vapor Pressure of Water from 10-30 °C[1]

t/ °C	P/mmHg	t/ °C	P/mm Hg
12	10.521	21	18.659
13	11.235	22	19.837
14	11.992	23	21.080
15	12.793	24	22.389
16	13.640	25	23.769
17	14.536	26	25.224
18	15.484	27	26.755
19	16.485	28	28.366
20	17.542	29	30.061

c) Use parts a and b above to find the pressure of hydrogen gas collected (mm Hg):

7. In thinking about significant figures, which measurement will limit the precision of your R value the most? Explain how many sig figs you will display for R based on this measurement.

8. Using the values obtained above, report a value for the gas constant, R. Remember to consider all measurements to determine the number of significant figures to report.

[1] Haar, L., Gallagher, J.S., and Kell, G.S., *NBS/NRC Steam Tables*, Hemisphere Publishing Corp., New York, 1984.

Report Sheets

9. Compare your value of R to the literature value (0.08206 Latm/molK). Calculate a percent error.

10. How would the ***experimental*** (your!) value of R be affected by the following conditions? State whether R would be artificially (incorrectly) high, artificially low, or neither and give a brief explanation.

Example: There was a very small air bubble (about 0.1 mL) inside the inverted graduated cylinder before you started the reaction.

*Answer: R = (P * V)/(n * T). Due to the bubble, V is larger than what it should be due to the formation of* H_2*. Therefore, R appears to be artificially high.*

a) There was a large amount of air (5 mL) inside the inverted graduated cylinder before you started the reaction.

b) A chunk of magnesium remained unreacted under the graduated cylinder.

c) The real temperature of the gas was higher than the measured temperature of the water over which the gas was collected.

d) The real air pressure inside the lab is lower than the measured atmospheric pressure you used in your calculation.

Pre-Lab Assignment:

Empirical Gas Laws (Part 3)

Name______________________

Section______

1) In part 1, you will use a graduated cylinder that can hold up to 100-mL of a gas. Hydrogen gas will be generated by the reaction of magnesium in hydrochloric acid:

$$Mg\ (s) + 2\ HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$$

Assuming HCl is in excess, does that put a constraint on the mass of magnesium that you will use in the experiment? Explain your answer without doing any calculations.

b) Calculate the maximum amount of magnesium (grams) that you should use in your experiment, given that you will use a 100-mL graduated cylinder to collect the hydrogen gas. (Hint: Use the ideal gas law. What is the value of R? What are reasonable values for P and T?)

c) Why should you wait a few minutes after the reaction to record the temperature of the gas?