Target Gas Law Lab

The Ideal Gas Law Applications

Introduction

Many chemical reactions involve gaseous reactants or products. This lab requires students to combine what has been learned about stoichiometry and balanced chemical equations with what has been learned about the ideal gas law ($PV = nRT$) to precisely predict the volume of gas that will be produced during a chemical reaction. Students will be graded not by the teacher, but by the gas itself!

Concepts

- Ideal gas law
- Molar volume
- Stoichiometry

Materials

For each student group

Hydrochloric acid solution, HCl, 6 M, 60 mL
Zinc metal sheet or strip, 2–3 g piece (different mass for each group)
Water, tap
Beaker, 100-mL
Flask, Erlenmeyer, 250-mL
Gas collecting setup
Grading scale printed on acetate sheet
Graduated cylinder, 1-L
Magnet, neodymium disc
Paper clip, large, plastic coated
Paper towel
Plastic wrap to cover graduated cylinder
Rubber stopper, 1-hole to fit flask
Tape, transparent
Thermometer, digital

To be shared

Balance, electronic, 0.01-g precision
Computer with Internet access

For teacher preparation

Butane safety lighter
Clamps, universal extension (1 per lab station)
Clamp holders (1 per lab station)
Flasks, 500-mL, 3
Scissors, heavy duty
Support stands (1 per lab station)
Rubber stoppers, solid, to fit flasks, 3
Tubing, glass, to fit 1-hole rubber stoppers (1 piece per gas collection setup)
Tubing, plastic, for gas delivery
Tubing, rubber, for water overflow

Safety Precautions

Hydrochloric acid solution is toxic by ingestion or inhalation and severely corrosive to skin and eyes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Set up a gas delivery system for each lab station according to Figure 1. Fill the troughs with water to above the platform. *Note:* The graduated cylinder and Erlenmeyer flask will be put in place by the students after they have completed their calculations.
2. Cut zinc sheet or strips into 2–3 g pieces. Each piece should be slightly different.
3. Dispense enough 6 M HCl solution into several large flasks for student access. Stopper and label each flask.

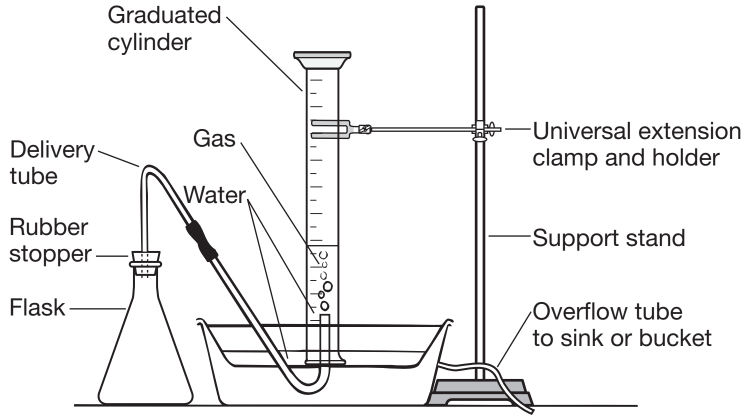

Figure 1.

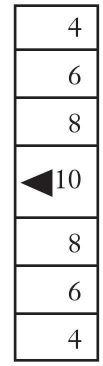

Figure 2.

4. Make and print the grading scales on a piece of acetate overhead transparency sheet and cut enough scales for each student group (see Figure 2).

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The excess hydrochloric acid solution may be neutralized according to Flinn Suggested Disposal Method #24b.

Tips

- This lab is best conducted after students have had some experience with stoichiometry, balanced chemical equations, and the ideal gas law.
- More than one student lab group may share a gas delivery system. The reaction goes rather quickly, so as soon as one group has its results, the next group may get ready.
- For step 17 of the student *Procedure*, remove the graduated cylinder from the trough, allowing any water left to drain into the trough. Turn the cylinder right-side up and bring a lit butane safety lighter to the mouth of the cylinder. The hydrogen gas will react with a loud "pop"!

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions

Sample Data and Answers to Post-Lab Questions *(Student data and answers will vary.)*

Calculations Table

a. °C → K	*25 °C → 298 K*
b. in → torr	*29.9 in → 760 torr*
c. Balanced equation	$Zn + 2HCl \rightarrow ZnCl_2 + H_2$
d. g Zn → mol Zn → mol H_2	*(2.35 g/65.409 m/g)(mol H_2/mol Zn) → 0.0359 mol H_2*
e. PV = nRT (R = 62.4 L·torr/mol·K)	*760 torr·V = (0.359 moles)(62.4 Lztorr/mol·K)(298 K)* *V = 0.879 L*
f. answer to e (1.09)	*0.879(1.09) = 0.958 L*
g. L → mL (Final answer!)	*958 mL*

1. What was the purpose of the paper clip?

   The purpose of the paper clip was to provide a way to hold the zinc in place in the stoppered flask without starting the reaction.

2. Complete the following "If/then" hypothesis.

   "If the zinc had been accidentally weighed with the paper clip on it, then the calculated volume of hydrogen gas would be *too high* because *the moles of zinc would be too high and there is a 1:1 ratio of moles Zn to moles H_2.*"

3. Why bother with the whole magnet setup; why not just drop the zinc in and stopper the flask?

   If the zinc was dropped in and then the flask was stoppered, some of the hydrogen gas produced may have been lost.

4. Why would starting with a 5.00 g piece of zinc not have worked out?

   Five grams of zinc would produce more than 1000 mL of H_2—more than the capacity of the graduated cylinder.

5. There was air in the flask at the beginning of the experiment. That means that what bubbled across into the graduated cylinder was not pure hydrogen. Explain why this doesn't matter.

   According to the ideal gas law, a given number of molecules of any gas occupy the same volume under the same conditions of temperature and pressure.

6. Charlie repeats the experiment using a 1.25-g strip of zinc. The pressure he got from the Web site was 29.73 inches Hg and the temperature he recorded was 23.9 °C. What volume in milliliters of H_2 should be produced? Show all your calculations.

   Moles H_2 = 1.25 g Zn (1 mole/65.409 g Zn)(1 mole H_2/1 mole Zn) = 0.019 moles H_2

   V = 0.019 moles H_2 (62.4 L·torr/mol·K)(297 K)/755 torr = 0.469 L(1.09) = 0 .511L (1000 mL/L) = 511 mL H_2

7. What happened when a flame was brought to the mouth of the graduated cylinder in step 17? Write a balanced equation for this reaction.

   A combustion reaction occurs as the hydrogen gas "explodes" with a loud pop.

   $2H_2 + O_2 \rightarrow 2H_2O$

8. Bonus: Charlie repeats the experiment a third time using a 0.78-g strip of *aluminum*. The pressure he got from the Web site was 30.13 inches Hg and the temperature he recorded was 21.9 °C. What volume in liters of H_2 should be produced? Show all your calculations.

   $2Al + 6HCl \rightarrow 2AlCl_3 + 3H_2$

   Moles H_2 = 0.78 g Al (1 mole/26.98 g Al)(3 moles H_2 / 2 moles Al) = 0.043 moles H_2

   V = 0.043 moles H_2 (62.4 L·torr/mol·K)(295 K)/765 torr = 1.04 L(1.09) = 1.14 L H_2

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Target Gas Law Lab* activity, presented by Bob Becker, is available in *The Ideal Gas Law Applications* and in *Bob Becker Target Labs*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Target Gas Law Lab* are available from Flinn Scientific, Inc.

Catalog No.	Description
H0033	Hydrochloric Acid Solution, 6 M, 500 mL
Z0024	Zinc, Strips, Pkg/10
AP8334	Pneumatic Trough
GP9090	Cylinder, 1000-mL
AP5666	Neodymium Magnet
AP1038	Clamp, Extension, Universal
AP8219	Clamp Holder

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Target Gas Law Lab Worksheet

Many chemical reactions involve gaseous reactants or products. The volumes of gases that react or are produced depend entirely on the moles of the gas, and of course on the pressure and temperature as well. This lab requires you to combine what you learned about stoichiometry and balanced chemical equations with what you have learned about the ideal gas law (PV = nRT) to precisely predict the volume of gas that will be produced during a chemical reaction. You will be graded not by the teacher, but by the gas itself!

Safety Precautions

Hydrochloric acid solution is toxic by ingestion or inhalation; severely corrosive to skin and eyes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines.

Procedure

1. Fill the 1000 mL graduated cylinder with tap water. Fill it to the very top and then some!
2. Here comes the tricky part: Place a piece of plastic wrap over the top, making sure not to trap any large bubbles of air. Then holding the plastic wrap in place around the neck of the cylinder, carefully flip the cylinder over into the trough so the top of the cylinder with the plastic wrap is under the water. If air does get in, you can just take off the plastic wrap and start this step again. Once the cylinder is completely inverted into the tank, you can remove the plastic wrap.
3. Carefully move the cylinder so that its opening is over the hole in the platform. Secure the cylinder to the support stand with the universal clamp.
4. Obtain a piece of zinc metal and weigh it. Record the mass. __________
5. Bend the zinc into a half circle and slide a small paper clip down the center (see Figure 1).
6. Go to the Web site: http://weather.unisys.com and enter in the local zip code. Record the latest local pressure (use "in" not "mb"). __________
7. Go to the dispensing station and fill small beaker with 50–60 mL of 6 M HCl. Take this back to your lab station and pour it into the Erlenmeyer flask.
8. Carefully hold the zinc (w/paper clip) inside the neck of the flask as shown in Figure 2—do not drop it into the flask! Use a small magnet on the outside of the flask to "grab" the zinc/paper clip and hold it there.
9. Slowly lower the magnet to lower the zinc down about 2 cm into the flask as shown in Figure 3. Do not let the zinc come in contact with the HCl at the bottom of the flask!
10. Use a thermometer to take the temperature of the water in the trough. ________
11. Take the stopper that is connected by the delivery tube to the gas collecting trough and insert it securely into the flask (see Figure 3).
12. Before proceeding any further, you must do some calculations.

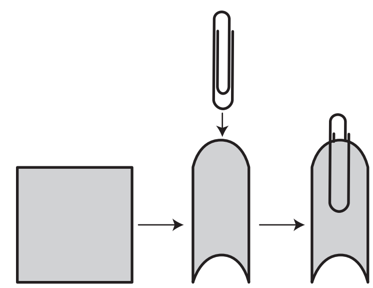

Figure 1.

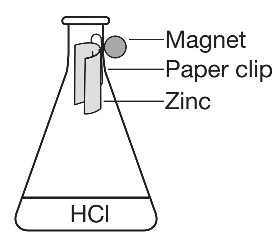

Figure 2.

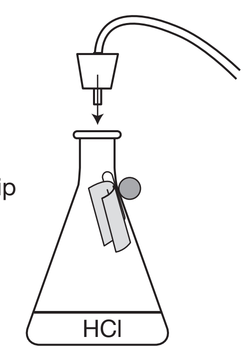

Figure 3.

Calculations *(Show your work and record answers in the Calculations Table below.)*

a. For the temperature recorded in step 10, convert degrees Celsius into Kelvins.

b. For the atmospheric pressure reported by the Web site in step 6, convert "in" into "torr" (1 in = 25.4 torr).

c. Consider the reaction that would occur between the zinc metal and the HCl solution. First, figure out what the products would be. *Hint:* Hydrogen is one product. Write a balanced equation for the reaction.

d. Use stoichiometry and the balanced equation to convert grams of Zn (from step 1) to moles Zn and then moles Zn to moles of hydrogen gas (H_2).

e. Put it all together. Use the calculated kelvin temperature, the corrected pressure and the moles of hydrogen gas produced to calculate the volume of hydrogen gas that should be produced. Your answer should include proper units!

f. A few pressure correction factors exist in this lab. Altogether, these factors total about a 9% difference in the final calculations. Multiply your answer from step e. by 1.09 and record.

g. The volume computed from PV = nRT above is in liters (L). Convert this volume into milliliters (mL). *Hint:* This just involves moving the decimal point. (Now, back to the procedure!)

13. Dry off the outside of the 1000 mL graduated cylinder.

14. Take the clear plastic grading scale and tape it in position on the graduated cylinder so that the center arrow is aligned with the volume (mL) of gas you calculated above (Remember, the graduate is upside-down). For example if you calculated the volume to be 342 mL, the grading scale should be positioned as shown in Figure 4. Make sure this is done accurately; your grade depends on it. After the reaction is finished, if the volume ends up in the "10" region, you will score a perfect 10 out of 10. If it ends up in one of the "8" regions, your score will be 8 out of 10. If it appears to be on the line between "8" and "10," your score will be 9 out of 10. The teacher makes the call on this!

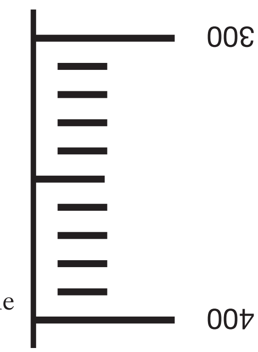

Figure 4.

15. At this point, call the instructor over to check out your setup. Then, when you are ready, pull the magnet away to allow the zinc (and paper clip) to fall down into the HCl.

16. The reaction will take a few minutes. During that time, record all your observations on the worksheet. Also, draw a NEAT diagram that shows the entire setup. Include the following labels on your diagram.

Bubbles of H_2 gas	Graduated cylinder	Volume prediction
Delivery tube	HCl	Water
Flask	Magnet	Zn
Gas collecting trough	Stopper	

17. When the reaction is finished, call the teacher over to record your grade! The teacher will also show you a fun way to dispose of the hydrogen you have produced!

Calculations Table

a. °C → K	
b. in → torr	
c. Balanced equation	
d. g Zn → mol Zn → mol H_2	
e. PV = nRT (R = 62.4 L·torr/mol·K)	
f. answer to e (1.09)	
g. L → mL (Final answer!)	

Observations *(from step 16)*

Diagram *(Include labels from step 16.)*

Post-Lab Questions

1. What was the purpose of the paper clip?

2. Complete the following "If/then" hypothesis.

   "If the zinc had been accidentally weighed with the paper clip on it, then the calculated volume of hydrogen gas would be (too high/too low/unchanged) because ____."

3. Why bother with the whole magnet setup; why not just drop the zinc in and stopper the flask?

4. Why would starting with a 5.00 g piece of zinc not have worked out?

5. There was air in the flask at the beginning of the experiment. That means that what bubbled across into the graduated cylinder was not pure hydrogen. Explain why this doesn't matter.

6. Charlie repeats the experiment using a 1.25-g strip of zinc. The pressure he got from the Web site was 29.73 inches Hg and the temperature he recorded was 23.9°C. What volume in milliliters of H_2 should be produced? Show all your calculations.

7. What happened when a flame was brought to the mouth of the graduated cylinder in step 17? Write a balanced equation for this reaction.

8. Bonus: Charlie repeats the experiment a third time using a 0.78-g strip of *aluminum*. The pressure he got from the Web site was 30.13 inches Hg and the temperature he recorded was 21.9°C. What volume in liters of H_2 should be produced? Show all your calculations.