Experiment 13

The Ideal Gas Law and Stoichiometry

Pre-lab Assignment

- Read the lab thoroughly.
- Answer the pre-lab questions that appear at the end of this lab exercise.

Purpose

Use the Ideal Gas Law and a balanced reaction to determine how much gas will be produced to inflate a life preserver.

Background

Chemists need to know how much product they make. In previous labs you have learned to balance chemical reactions, and use stoichiometry to find the limiting reactant and percent yield of a product. Now you will relate the Ideal gas law (PV= nRT) to a chemical reaction.

Recall that P is pressure in atmospheres, V is volume in Liters, n is moles of **GAS**, R is the gas law constant 0.08206 $\frac{L\ atm}{K\ mol}$, and T is temperature in Kelvins.

For most reactions that happen on Earth under normal atmospheric pressures and temperatures gases behave ideally. At lower temperatures and higher pressures the conditions may alter the kinetic molecular theory postulates and how gas particles behave. For lab today the gas will be assumed to behave ideally and follow the kinetic molecular theory of gases.

Today you will design a prototype of a life preserver by measuring how much sodium bicarbonate as a limiting reactant combines with excess acid to produce carbon dioxide gas and inflate a plastic baggie.

Procedure:

Safety: Be sure to wear your safety goggles.
Hydrochloric acid can cause chemical burns and skin irritation. If you came in contact with the hydrochloric acid, be sure to wash it off your skin immediately with a large amount of water.

Waste: Extra hydrochloric acid should be placed in the waste container in the fume hood. All waste can be disposed of in the sink.

Equipment

- Gallon size plastic baggie with seal tight closure
- 3.0 M Hydrochloric acid (HCl)
- 50 mL graduated cylinder
- 100 or 150 mL beaker
- Weigh boat
- Sodium bicarbonate ($NaHCO_3$)

1. Record the temperature and barometric pressure using the barometer on the weighing room wall.

2. Place a weighing boat on the balance.

3. Tare the balance to read 0.00 g.

4. Using a scoopula measure ________ g of sodium bicarbonate ($NaHCO_3$) into the weighing boat. Make sure to clean up any spills with the brushes.

   NOTE THIS VALUE IS CALCULATED BY YOU IN YOUR PRELAB QUESTION FIVE.

5. Calculate the <u>exact</u> mass of the sodium bicarbonate you obtained and record it in the data table.

6. Place the weighing boat holding the sodium bicarbonate on the bench.

7. Obtain 60 mL beaker of 3.0 M hydrochloric acid (HCl) and **<u>carefully</u>** pour all the acid into a 150 mL Erlenmeyer flask. (*Rinse with cold water if acid comes into contact with skin)*

8. Obtain a 1 gallon seal tight plastic baggie.

9. Carefully and slowly pour the sodium bicarbonate into the baggie to make sure it is all on the bottom of the bag. (Avoid spilling)

10. When all of the sodium bicarbonate has been added, tap the side of the bag to make sure the powder is all at the bottom of the bag. Then roll it up many times from the bottom of the bag to trap the solid in a separate layer of the bag.

11. While one partner holds the rolled part of the bag tightly the other lab partner will pour the Hydrochloric Acid into the remaining portion of the plastic baggie.

12. Once the two reactants are in the baggie, close the seal on the bag tightly to make sure the gas does not escape the bag.

13. Consult your instructor to check your setup before proceeding to step 14.

14. Once the baggie is firmly fastened, the other partner should stop holding the baking soda portion of the bag to release all of the acid and let the reaction begin. A vigorous shake will help to initiate the reaction.

15. While the baggie inflates, keep checking the seal on the baggie to make sure no gas escapes. Help the solid and liquid mix if necessary to produce the maximum amount of gas for the reaction to go to completion.

16. When the reaction stops (*no more bubbles*), check with your instructor to see if your prototype passes the test. If your design was not successful your instructor may have you try again.

17. If your bag did not pop you will be asked to weight the contents again to see how good your percent yield of gas was.

18. At the end of lab rinse the bag out with water and return to the lab counter for reuse in other lab sections. Using a paper towel, carefully wipe off any liquid and make sure to clean your lab station and wash your hands.

19. Pour any excess acid into the waste container and rinse the beaker that had the dilute acid in lab sink.

Report Sheets

Name: ________________________

Lab Section _______

Write Down Your Equation and Calculations from the Pre-Lab:

1. Balanced Chemical reaction for the reaction of sodium bicarbonate and hydrochloric acid (*pre-lab question 1)*

2. Amount of sodium bicarbonate in grams that you will need to fill a 1 gallon baggie with gas after the completion of the reaction. *(Pre-lab question 5)*

3. What is one safety rule you should follow when using acids?

Instructor Signature/Approval ____

4. Record the conditions in the laboratory:

   Mass of $NaHCO_3$ used _________________ g

Temperature = _______________°C ___________________K

(note: *at thermal equilibrium room temperature = CO_2 gas temperature*)

Pressure

Barometer reading = __________________ mm Hg = _______________atm

Convert atmospheric pressure from barometer in mm Hg to atmospheres (atm) *1atm = 760 mm Hg*

(note: CO_2 gas pressure = barometric pressure of room)

5. Calculate the **Actual number of CO_2 gas moles** in the bag using the IDEAL GAS LAW

   PV= nRT

Assume: P = atmospheric pressure at sea level from barometer in atm
R = 0.08206 $\frac{L\ x\ atm}{K\ x\ mol}$
T = measured temperature of the room in K = gas temp.
V = volume of inflated bag = volume of gas in L *(assume 1 gallon)*

Actual moles of CO_2 gas= ________________________

calculate the **actual yield (mass) of the CO_2 gas** from the actual number of gas moles and the molar mass of CO_2

Actual yield (mass) of CO_2 gas = ___________________grams

6. **Refer to the** balanced chemical equation for the reaction inside the plastic bag from the **PRELAB** .

calculate the **theoretical yield in grams of CO_2** gas produced from <u>your</u> starting mass of sodium bicarbonate limiting reactant.

(perform a *<u>mass-mass</u> stoichiometry problem for the reaction*)

Theoretical yield CO_2 in grams = ___________________________

calculate the **Percent Yield CO_2** for the reaction

% Yield = Actual Yield ____ *x* 100

Theoretical Yield

% Yield CO_2 = _____________________________

Post Lab Questions:

1. Using the combined gas law, calculate the volume the CO_2 gas would occupy in mL at *STP* starting with your experimental data.

Hint: V_1 = measured volume of the gas in the inflated balloon

1.b Does the volume of the gas increase or decrease? Explain

2. Calculate the density of the CO_2 gas in g/L at *STP* using its molar mass and molar volume at *STP*. (*note: V_m @ STP = 22.4 L / mol)*

3. Calculate the density in g/L of the CO_2 gas from <u>your</u> actual gas mass data and the gas volume calculated in question 1. (*d = m / v)*

4. Compare the two density numbers by performing a % error analysis.

Measured density value = # from question 3

Accepted density value = # from question 2

% error = $\dfrac{\text{measured value} - \text{accepted value}}{\text{accepted value}}$ *x* 100

5. From the same balanced chemical equation for this lab perform the following mass-mole stoichiometry problem.

If you start out using 10.0 grams of $NaHCO_3$ and use an excess of HCl, how many moles of CO_2 can form?

6. Using the number of moles of carbon dioxide that you calculated in question 5, use the ideal gas law to calculate the volume this gas will occupy at standard conditions of 1 atmosphere and 25 °C.

7. What could account for less than 100 % yield of CO_2 from your chemical reaction?

8. What did you learn from this experiment?

Name ___________________________

Pre-Lab Assignment for The Ideal Gas Law and Stoichiometry

Note: You will need to calculate how much material you need for the lab in advance. Make sure you allow enough time to do this before coming to lab and to consult with your instructor if needed.

1. Write a BALANCE reaction for sodium bicarbonate reacting with hydrochloric acid to produce water, carbon dioxide, and sodium chloride.

2. How many liters are in a 1.0 gallon container? *Hint: Look at your conversion factors sheet from the Dimensional Analysis unit.*

3. Rearrange the Ideal Gas Law Equation to solve for moles of gas.

4. Using the number of liters of gas in one gallon as your volume (question 2) pressure as 1.01 atm, ambient lab temperature of 296 K, and the gas constant R= 0.08206 $\frac{L\ atm}{K\ mol}$, find moles of gas.

5. Convert moles of gas in Question 4 to grams of sodium bicarbonate using your balance chemical equation (question 1) . Molar Mass of sodium bicarbonate is 84.018 g/mol.