Investigating a Gas-Forming Reaction

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Purpose of the Experiment

- To use the ideal gas law and stoichiometry to calculate the amount of reactants needed to produce a specific volume of gaseous product.
- To practice making measurements and reporting them correctly.

Background Required:
Complete the online prelab assignment for "Investigating a Gas Forming Reaction" BEFORE the start of the lab session. You will work in pairs for this experiment.

Background Information:
We use balanced equations and the principles of stoichiometry to calculate quantities of reactants and products that are consumed or produced as part of chemical reactions. If one of the products of a reaction is a gas, we can use stoichiometry and the ideal gas law to calculate the volume of gas that will be produced for given quantities of reactants at laboratory conditions of temperature and pressure. These types of calculation are critical in real-life applications such as the reaction systems used to generate nitrogen gas to fill a car air bag. In the lab today, we will use a common acid-base reaction with gas evolution to fill a plastic bag with carbon dioxide. Your first task will be to calculate how much sodium bicarbonate and acetic acid solution will be needed to produce enough carbon dioxide gas to fill a 1 pint or 1 quart Ziploc plastic bag. After you have completed the calculations, you will test your accuracy by performing the reaction and observing the results.

The first step is to write the balanced chemical equation (with states) for the reaction that occurs when solid sodium bicarbonate and acetic acid are mixed. Do this in the indicated space in your Data Table.

From Avogadro's law, we know that the volume of a gas is directly proportional to the number of moles of a gas when temperature and pressure are held constant. The ideal gas law allows us to convert between volume and number of moles of a gas in order to determine how many moles of a gaseous product would be needed to fill a specific volume (at laboratory conditions):

$$PV = nRT$$

Where: P is atmospheric pressure in the lab in atm
V is the desired volume in L
n is the number of moles of the gaseous product
R is the gas constant, 0.0821 L· atm/mol· K
T is the temperature of the lab in K

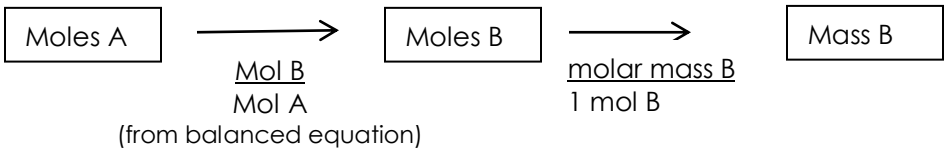
We can re-arrange the equation to solve for n, the number of moles: $n = PV/RT$

The equation is simple, but we will need to do several unit conversions to get our laboratory values for volume, temperature and pressure into the correct units for the ideal gas equation.

Our desired volumes today are the volumes of a 1 pint and 1 quart Ziploc bag, minus the volume of the liquid reaction mixture (20 mL in the pint bag and 45 mL in the quart bag). You will need to convert these volumes to L, using the conversion factors given in the Table 1 at the end of the lab procedure, and subtract the volumes for the reaction mixture.

Next, we will use our thermometers and the lab barometer to measure T and P in the lab. The temperature and pressure units will need to be converted to atm and K, using the conversion factors in Table 1.

After all of the measurements are in the correct units, we can easily calculate the number of moles of carbon dioxide needed to fill the Ziploc bags. We can then calculate the quantities of reactants needed to produce this much carbon dioxide using our usual solution map:



Be aware, there is another other unit conversion that will be necessary for the acetic acid.

Equipment:

Vinegar (5% acetic acid solution)	Baking soda (sodium bicarbonate)
1 pint and 1 quart Ziploc baggies	twist ties
pH paper	

Safety: Always wear your safety goggles while in the lab room. Do not dispose of anything in the drain unless specifically directed to by your instructor.

Procedure 1: Preparation and calculations

1. Obtain either a 1 pint or a 1 quart Ziploc baggie based on the size assigned by your instructor.
2. Calculate how many liters your size Ziploc baggie holds, and then subtract either 20 mL or 45 mL to account for the volume occupied by the side products and the water in the vinegar solution. Show your work in the Data Table and record your final answer in **L**.
3. Use your thermometer to measure the room temperature in Celsius. Be careful not to touch the bulb with your hand! Record the temperature **in Kelvin** in the data section.
4. Use the barometer hanging on the wall to determine the atmospheric pressure in cm Hg. Convert to atm (show your work), and write your final answer **in atm** in the Data Table.
5. Use the ideal gas equation to calculate the number of moles of carbon dioxide gas that would be needed to fill your Ziploc baggie. Show your work and write your answer in the Data Table.
6. Determine the number of grams of sodium bicarbonate required to produce this quantity of carbon dioxide. Show your work and write your answer in the Data Table.
7. Calculate the number of milliliters of vinegar required to fully react with the sodium bicarbonate. HINT: The vinegar is 5% w/v acetic acid, meaning 5 g of acetic acid per 100 mL of solution. Show your work and write your answer in the Data Table.

Procedure 2: Performing the experiment

8. Once your calculations are completed, measure the desired volume of vinegar in a graduated cylinder. You should get within +/- 1 mL of your calculated volume.
9. Next, using a piece of weighing paper, measure the desired mass of sodium bicarbonate using the top loading balance. You should get within +/- 0.1 g of your calculated mass.
10. Place the sodium bicarbonate into the bottom corner of your Ziploc bag and use your twist tie to hold it in place.
11. Carefully pour the vinegar solution into the other bottom corner. The two reactants should not be mixing yet.
12. Press out as much air as you can before zipping the baggie closed.
13. Remove the twist tie, and shake gently to completely mix the reactants.
14. Wait for the reaction to subside.
15. Carefully open your Ziploc baggie and determine the pH of the solution. Record this in the data section.
16. Record your observations of the reaction in the Data Table
17. Pour the reaction mixture into the labeled waste container in the hood.

Table 1. Conversion Factors	
1 L = 1.057 qt	K = °C + 273
1 L = 2.114 pt	5% w/v means 5 g/100 mL
760 mm Hg = 1 atm	

Data, Calculations and Discussion

Record all data in the indicated spaces in the Data Table. Complete all calculations on the table and answer the discussion questions with your partner before leaving. Staple and turn in only the Data and Discussion Questions on the due date.

Name_____ **Partner**_____ **Section #**_____

Data and Calculations (Show set-up for all conversions)	**Values (units)**
Calculated volume of carbon dioxide gas based on baggie size: (convert bag volume to L and subtract volume of reaction mixture)	
Laboratory Temperature in K	
Laboratory pressure in atm	
Number of moles of carbon dioxide gas needed to fill baggie at laboratory temperature and pressure: (n = PV/RT)	
Grams of sodium bicarbonate needed to produce desired amount of carbon dioxide gas: (mol CO_2 → mol $NaHCO_3$ →mass $NaHCO_3$)	
Number of mL of vinegar solution needed to produce desired amount of carbon dioxide gas: (mol CO_2 → mol acetic acid → mass acetic acid → mL acetic acid)	
pH of solution after reaction	
Observations during and after reaction:	

Discussion Questions:

1. On a typical California summer day (cool 68.0 °F morning, very warm afternoon), the students in the morning lab used 5% more acetic acid in their quart-sized bag than the students in the afternoon lab. What was the temperature of the lab in °F in the afternoon? Assume the barometric pressure was the same (1.00 atm) all day.

2. What does the pH value of the reaction mixture after the reaction tell you about how well you performed the experiment?

3. If the correct amount of acetic acid was measured into the bag, but the student added twice as much sodium bicarbonate than they should have, would the Ziploc bag be likely to burst? Explain your answer.