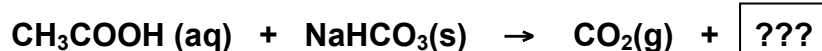


# Experiment: Stoichiometric Analysis of an Antacid<sup>1</sup>

## Introduction

In this lab, you will use the concept of stoichiometry to solve two sequential problems. First, you will try to determine the products of a certain reaction (below), choosing between three possibilities. Then, you'll use your results of this first part to determine the amount of sodium bicarbonate in a common household substance.



You've probably seen this reaction in elementary school -- add a few drops of red food coloring, and you have the classic "volcano reaction." Or, you can perform it easily in your kitchen by mixing vinegar (dilute acetic acid) and baking soda (sodium bicarbonate). The most noticeable sign of the reaction is vigorous bubbling, a result of very rapid carbon dioxide generation.

Gaseous carbon dioxide is one of the products, as you can see with your own eyes. (You can prove the gas to be carbon dioxide by collecting it in a flask, and inserting a burning match into the flask. The flame will be immediately extinguished.) Aside from carbon dioxide, what else is produced by the reaction?

A chemist approaching this problem would most likely form some hypotheses about the other products, and then design experiments to evaluate which hypothesis is best supported by experimental evidence. For this experiment, we'll supply three possible reactions, shown below. Notice that they are all balanced equations.

- A.  $\text{CH}_3\text{COOH (aq)} + \text{NaHCO}_3\text{(s)} \rightarrow 2 \text{CO}_2\text{(g)} + \text{CH}_2\text{O(aq)} + \text{Na}^+\text{(aq)} + 3\text{H}^+\text{(aq)}$
- B.  $\text{CH}_3\text{COOH (aq)} + \text{NaHCO}_3\text{(s)} \rightarrow \text{CO}_2\text{(g)} + \text{H}_2\text{O(l)} + \text{CH}_3\text{COO}^-\text{Na}^+\text{(aq)}$
- C.  $\text{CH}_3\text{COOH (aq)} + 2 \text{NaHCO}_3\text{(s)} \rightarrow \text{CO}_2\text{(g)} + \text{Na}_2\text{CO}_3\text{(aq)} + \text{H}_2\text{O(l)} + 2 \text{CH}_2\text{O(aq)}$

**Your job is to determine which of these three possibilities is correct**, using some simple laboratory measurements. Focus on the differences between the three proposals: Reactions A and C produce formaldehyde (CH<sub>2</sub>O), but Reaction B doesn't. The products of Reaction A are acidic (H<sup>+</sup> is produced); those of B and C are basic (CH<sub>3</sub>COO<sup>-</sup>Na<sup>+</sup> and Na<sub>2</sub>CO<sub>3</sub> are produced). These things could be tested, but an even simpler method would be to take advantage of the different amounts of carbon dioxide produced, relative to sodium bicarbonate:

In Reaction A, 1 mole NaHCO<sub>3</sub> produces 2 moles CO<sub>2</sub>

In Reaction B, 1 mole NaHCO<sub>3</sub> produces 1 mole CO<sub>2</sub>

In Reaction C, 2 mole NaHCO<sub>3</sub> produces 1 mole CO<sub>2</sub>

You will measure the ratio of moles NaHCO<sub>3</sub> used to moles of CO<sub>2</sub> produced, and if it is approximately 1:2, you may conclude that Reaction A is correct; if the ratio is around 1:1, you can bet that Reaction B is correct, and if it's about 2:1, you should choose Reaction C.

<sup>1</sup> Used with permission from Seattle Central Community College, 2011

Keep in mind that your results may not give you exact whole number mole-to-mole ratios because of basic experimental errors. Your results may be off by as much as 20% for this experiment, but you will still be able to choose between the three reactions (A, B, or C) with a fair amount of confidence if you work carefully and collect good data.

Determining the moles of  $\text{NaHCO}_3$  is easy: Use the measured mass you scoop out of the container to use. (The other reactant, acetic acid will be used in excess, so its exact amount will have no relationship to the amount of carbon dioxide generated.)

Determining the moles of  $\text{CO}_2$  is less straightforward; it's not so simple to collect and measure the mass of a gaseous substance, as you can imagine. In each of the three reactions above, carbon dioxide is the only gas, and all other reactants and product are liquids, solids, or aqueous. As the reaction occurs, carbon dioxide will bubble out of the reaction solution and escape into the laboratory.

Therefore, the mass of your reaction mixture after the reaction will be lighter due to the loss of carbon dioxide, and a simple subtraction tells you how much carbon dioxide was produced:

$$\text{Mass of CO}_2 = \left( \text{mass of reaction mixture before reaction} \right) - \left( \text{mass of reaction mixture after reaction} \right)$$

One small complication is that some of the  $\text{CO}_2$  produced will remain dissolved in the reaction mixture because carbon dioxide is somewhat soluble in water. This means that the mass you calculate by subtraction in the above equation is somewhat too low—i.e., you have not accounted for the carbon dioxide that goes into the water. You will account for this with a correction factor in your calculations.


Once you have chosen the correct reaction between acetic acid and sodium bicarbonate, you can use it to measure the amount of sodium bicarbonate in Alka-Seltzer tablets using a similar methodology. In this case, the mass of sodium bicarbonate will be an unknown. You can measure the amount of  $\text{CO}_2$  produced as you did before, and use the mole-to-mole ratio of the chosen reaction to calculate the number of moles and the mass of sodium bicarbonate which reacted. Finally, you will determine your experimental error by comparing your experimentally determined mass of sodium bicarbonate present with what the manufacturer reported on the package of Alka-Seltzer.

## Objectives

In this experiment, you will

- ✓ Determine the stoichiometry of a reaction experimentally.
- ✓ Weigh by difference a reaction mixture before and after the reaction in order to find the mass of a gas produced.
- ✓ Practice molar mass and mole ratio calculations.
- ✓ Calculate a percent error and determine how an inaccuracy in a specific measurement affects the outcome.

## Hazards

 Even though the reagents in this lab are fairly safe, please wear safety goggles and dispose of waste in the labeled waste container.

## Procedure

### Part A: Reaction Stoichiometry

Run the reactions in a clean and dry 250-mL beaker, with a large watch glass as a cover. The class supply of sodium bicarbonate must be kept in the hood. A beaker with 6 g of sodium bicarbonate is shown as an example. Refer to the sample, and pour out about the same amount for 6 g of sodium bicarbonate into a small beaker. This will be your personal supply for the experiment; you can always get more if needed, but **DO NOT BRING THE CLASS SUPPLY OF SODIUM BICARBONATE TO THE BALANCE AREA!** Clean up any sodium bicarbonate spills with paper towels and water, and dispose of excess down the drain with water.

Tare a watch glass, measure about 2 g of sodium bicarbonate ( $\text{NaHCO}_3$ ) and record the mass in the data table. Measure 50 mL of acetic acid into a graduated cylinder and pour this into a 250 mL beaker. Stack the watch glass on top of the beaker (with the sodium bicarbonate still in the watch glass). Re-zero a balance and carefully measure the mass of the whole stack altogether: beaker with acetic acid, plus watch glass and sodium bicarbonate on top. Record the mass in the data table.

Without spilling any of the sodium bicarbonate or reaction mixture, return to your work area, and initiate the reaction by carefully transferring all of the sodium bicarbonate from the watch glass into the acetic acid. (Note that the solution may overflow if you dump the sodium bicarbonate too quickly.) Put the watch glass back on top of the beaker and swirl the reaction mixture gently. After a few minutes, when the reaction is complete and no more bubbling is observed, weigh and record the total mass of the beaker, reaction mixture, and empty watch glass.

Pour the reaction mixture down the sink with plenty of water. Rinse the glassware thoroughly with water (no soap required) and dry completely. Never put a wet beaker onto a balance!

Repeat for at least one more trial. Do all the calculations for Part A.

**Get approval from your instructor before you proceed.**

### Part B: Analysis of an Antacid

Using your conclusion about which of the three reactions are correct from Part A, you can now measure the amount of sodium bicarbonate contained in Alka-Seltzer tablets.

Obtain one pack of two tablets from the lab staff. This will allow you to conduct two trials of the reaction. Record the mass of  $\text{NaHCO}_3$  indicated on the package on your Lab Report.

Use the same procedure as you used in Part A, replacing the sodium bicarbonate with the Alka-Seltzer tablet each time. Give the reaction at least 5 minutes to take place fully, and don't worry if there are small amounts of white solid in the reaction mixture after the reaction is complete.

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**Report**

## Stoichiometric Analysis of an Antacid

Name \_\_\_\_\_ Section \_\_\_\_\_

Lab Partner \_\_\_\_\_

**Data, Calculations, and Results****Part A: Reaction Stoichiometry**

	Trial 1	Trial 2	Average
Mass of NaHCO <sub>3</sub>			
Mass of beaker + acetic acid + NaHCO <sub>3</sub> + watch glass before reaction			
Mass of beaker + reaction mixture + watch glass after reaction			
Mass of CO <sub>2</sub> gas released			
Moles of CO <sub>2</sub> gas released			
Moles of CO <sub>2</sub> , corrected for amount dissolved* (see below)			
Moles of NaHCO <sub>3</sub> used			

NOTE: \*Calculate by adding 0.0040 moles to the "Moles of CO<sub>2</sub> gas released". This correction accounts for the amount of CO<sub>2</sub> that dissolves in 50 mL of aqueous solution.

Calculate (and show your work for at least trial #1) for the following:

1. The number of moles of CO<sub>2</sub> for Trial #1, 2, and 3.
2. The number of moles of CO<sub>2</sub>, corrected, for Trial #1, 2, and 3.
3. The number of moles of NaHCO<sub>3</sub> for Trial #1, 2, and 3.

4. Compare the calculated number of moles of  $\text{CO}_2$  and  $\text{NaHCO}_3$  in the table above. Which of the three possible reactions, A, B or C, is best supported by these results? Write out the balanced equation you chose, and **explain** your reasoning. (Note that results may not be exactly whole numbers.)

### Part B: Analysis of an Antacid

	Tablet 1	Tablet 2
Mass of beaker + acetic acid + tablet + watch glass before reaction		
Mass of beaker + reaction mixture + watch glass after reaction		
Mass of $\text{CO}_2$ gas released		
Moles of $\text{CO}_2$ gas released		
Moles of $\text{CO}_2$ , corrected for amount dissolved* (see note below)		
Moles of $\text{NaHCO}_3^{**}$ (see note below)		
Mass of $\text{NaHCO}_3$		
Average Mass of $\text{NaHCO}_3$ for two tablets		

\*Calculate by adding 0.0040 moles to the "Moles of  $\text{CO}_2$  gas released".

\*\*Use the balanced chemical equation from Part A for the mole-to-mole ratio to convert moles of  $\text{CO}_2$  (corrected) to moles of  $\text{NaHCO}_3$ .

Calculate the following (and show your work for at least trial #1):

1. The number of moles of  $\text{CO}_2$  gas released by the tablet.

2. The corrected moles of CO<sub>2</sub> released by the tablet.
3. Show the calculation for the moles of NaHCO<sub>3</sub>, using the mole ratio in the balanced chemical equation determined from Part A.
4. Show the calculation for the mass of NaHCO<sub>3</sub> for the tablet.
5. Show the calculation for the average mass of NaHCO<sub>3</sub> for the two tablets.
6. The mass of sodium bicarbonate in each tablet of Alka-Seltzer is reported as 1916 mg on the package (which we will call the “actual value”).

Using your experimental value for the average mass of NaHCO<sub>3</sub>, calculate the percent error. **Show your work.**

$$\% \text{ error} = \frac{|\text{actual value} - \text{experimental value}|}{\text{actual value}} \times 100\%$$

7. In Part B, suppose the tablet was mostly dissolved when some of your solution splashed out of the beaker as CO<sub>2</sub> continued to evolve. How would this affect the perceived mass of CO<sub>2</sub>? Would your final calculated mass of sodium bicarbonate in the tablet be **artificially high** or **artificially low** as a result of this splashing? **Choose one, and explain why.**

**Prelab**

## Stoichiometric Analysis of an Antacid

Name \_\_\_\_\_ Section \_\_\_\_\_

- 
1. When acetic acid and sodium bicarbonate react, why does total mass decrease?
  
  
  
  
  
  
  
  
  
  
  2. Suppose you are running a trial of the reaction in Part A. You use 2.80 g of  $\text{NaHCO}_3$ , and determine that 2.83 g of carbon dioxide are produced. Using these data and a periodic table, show calculations to:
    - a. Convert the mass of  $\text{NaHCO}_3$  to moles using the molar mass of  $\text{NaHCO}_3$ .
  
  
  
  
  
  
  
  
  
  
    - b. Convert the mass of  $\text{CO}_2$  to moles using the molar mass of  $\text{CO}_2$ .
  
  
  
  
  
  
  
  
  
  
    - c. Find the simplest ratio between the number of moles of  $\text{NaHCO}_3$  and  $\text{CO}_2$ .  
(Hint: Divide both numbers by the smaller of the two to get a ratio.)

The mole ratio of  $\text{NaHCO}_3$ :  $\text{CO}_2$  is \_\_\_\_:\_\_\_\_.

- d. Compare this ratio to the ratio of the coefficients for  $\text{NaHCO}_3$  and  $\text{CO}_2$  in the three balanced chemical equations (given on page 1). Which of the three possible reactions discussed is consistent with these results?

**WRITE THE EQUATION HERE.**

**NOTE:** The result in part C is not necessarily the correct answer. It is a hypothetical situation for practicing the calculations required in this lab. Do not use this actual result in the lab!