Lab Documentation

Student Handout

Stoichiometry---Determination of Percent by Mass of $NaHCO_3$ in Alka Seltzer Tablets

I. *Introduction*

Alka Seltzer is an over-the-counter antacid and pain relief medication that is taken by dissolving it in water before ingesting. Alka Seltzer is an effervescent tablet that contains aspirin (acetylsalicylic acid), citric acid, and $NaHCO_3$. As soon as the tablet dissolves in water, an acid-base reaction involving sodium bicarbonate takes place. The generation of carbon dioxide from the acid-base reaction causes the bubbling. The release of carbon dioxide into the atmosphere results in a total weight loss after the reaction. With the weight loss, one should be able to calculate the amount of sodium bicarbonate reacted, and determine the percent by mass of $NaHCO_3$ contained in Alka Seltzer tablets. According to the balanced chemical equation, it takes one mole of $NaHCO_3$ to produce one mole of CO_2. In other words, the moles of $NaHCO_3$ reacted equals the moles of CO_2 produced. Therefore,

mass of $NaHCO_3$ reacted =

(mass of CO_2 generated / M.W. of CO_2) × M.W. of $NaHCO_3$

percent by mass of the reacted $NaHCO_3$ in a tablet =

(mass of $NaHCO_3$ reacted in a tablet / mass of a tablet) × 100 %

II. Materials and Equipment

- 8 (or more) Alka Seltzer Tablets (Bayer Corporation)
- Vinegar (acetic acid ca. 4.5 %), 150 mL
- Clear plastic cup (9 cm depth, ca. 230 mL) or a 250 mL beaker
- Electronic balance (±0.01g)
- Graduated cylinder (50 ±0.5 mL). To improve the results for the early runs one might use a 10 mL graduated cylinder.

III. Experimental Procedure

- add 35 mL of water to a clear plastic cup
- weigh and record the total weight of the cup with water in it
- weigh and record the weight of an Alka Seltzer tablet
- drop the tablet into the cup, carefully swirl the cup to ensure complete dissolution of the tablet
- weigh and record the weight of the cup containing water and the dissolved substances when the bubbling ceases
- wash and rinse the cup with water
- calculate the mass of carbon dioxide generated
- calculate the mass of $NaHCO_3$ reacted
- calculate the percent by mass of the reacted $NaHCO_3$ in the tablet
- repeat the experiments with 5 mL vinegar + 30 mL water, 10 mL vinegar + 25 mL water, 15 mL vinegar + 20 mL water, 20 mL vinegar + 15 mL water, 25 mL vinegar + 10 mL, 30 mL vinegar + 5 mL water, and 35 mL vinegar instead of 35 mL of water
- Plot the calculated % by mass of the reacted $NaHCO_3$ in a tablet versus the volume of vinegar used

IV. Safety and Hazards

One should not eat or taste the vinegar and Alka Seltzer tablets supplied by the instructor, even though they are edible. Eye protection is needed for potential eye hazards from the spattering of the reaction mixture. All solutions can be diluted with water and disposed of down the sink after the experiment.

V. Table of Data

Experiment No.	Run #1	Run #2	Run #3	Run #4	Run #5	Run #6	Run #7	Run #8
Volume of Vinegar (mL)	0	5	10	15	20	25	30	35
Volume of Water (mL)	35	30	25	20	15	10	5	0

Weight of cup with liquid (g)								
Weight of Alka Seltzer tablet (g)								
Weight of cup with all substances (g)								
Weight loss (mass of CO_2) (g)								
Calculated mass of $NaHCO_3$ reacted (g)								
Calculated % by mass of the reacted $NaHCO_3$ in a tablet								

VI. Plot of the percent by mass of the reacted $NaHCO_3$ in a tablet versus the volume of vinegar used

Use *Microsoft Excel* to plot the percent by mass of the reacted $NaHCO_3$ in a tablet versus the volume of vinegar used.

VII. Questions

1. Write the chemical equation corresponding to the reaction that causes the bubbling when an Alka Seltzer tablet is dropped into water.
2. How do you determine the amount of carbon dioxide generated in the reaction?
3. How do you determine the amount of $NaHCO_3$ consumed in the reaction?
4. How do you completely neutralize the $NaHCO_3$ in the reaction?
5. How do you determine the percent by mass of $NaHCO_3$ in an Alka Seltzer tablet?
6. How do you interpret the graph obtained in terms of the concepts of limiting reactant?
7. How does the dissolving of CO_2 in the reaction solution and the evaporation of water affect the result of the analysis, respectively?

Notes for the Teacher

I. Background

This experiment gives students experience with a simple chemical reaction involving materials used in everyday life. In the process of solving a real problem, students get the opportunity to verify the concepts of stoichiometry learned in a general chemistry class. In this laboratory, student should run the reaction, measure the amount of the product, calculate the amount of reactant consumed according to the mole-mass relationship, plot the experimental data, and finally, correlate the graph obtained to the behavior of limiting reactant in the reaction.

II. Materials

All materials used (Alka Seltzer tablets, vinegar, and cocktail cups) are household materials that can be purchased from drug stores or supermarkets.

III. Teaching Tips

1. Since the quantity of vinegar is not required in the calculation, the content of acetic acid in vinegar is not crucial. However, vinegar with a lower concentration will result in a later switch of the limiting reactant

from the acid (H^+) to $NaHCO_3$ and vice versa.

2. To improve the results for the early runs one might use a 10 mL graduated cylinder for the measurement of vinegar.

3. The spattering of reaction mixture resulting from the bubbling of CO_2 during the reaction may cause an extra weight loss. Therefore, the use of a tall type cup (or beaker) with volume around 250 mL is suggested.

4. The cup containing reaction mixture is swirled during the experiment to ensure thorough mixing of the reaction mixture and complete release of the gas product (CO_2).

5. For a 10 min reaction period, there is a 35~70 mg of weight decrease in the blank vinegar-water solution depending on the temperature and the humidity in the room. The quantity of CO_2 dissolved in 35 mL of reaction solution is approximately 46 mg (*1*). While the evaporation of water leads to too large a value of percent by mass of $NaHCO_3$, the dissolving of CO_2 in solution will affect the result in the opposite way. Therefore, the combination of the two errors should only give a minimal effect on both the shape of the curve in the graph and the percent by mass of the $NaHCO_3$.

6. Since HCl solutions have been used in the analysis of $NaHCO_3$ in Alka Seltzer tablets (*1*), it is interesting to use HCl solution instead of vinegar in this experiment. However, the instructor should carefully decide the concentration of the HCl solution to be used. The use of HCl solution with too high a concentration will result in a very early switch of the limiting reactant from the acid to $NaHCO_3$. The analysis of $NaHCO_3$ in the tablet may not be affected by the high concentration of HCl solution, but the goal of observing the actions of limiting reactant will not be achieved. HCl solution with concentration ranging from 0.3 to 0.5 M is considered to be appropriate in this experiment.

7. Citric acid is one of the components of the Alka Seltzer tablet. Unlike HCl and acetic acid, citric acid is a triprotic acid. It is interesting to use citric acid in the analysis instead of vinegar. However, the buffer capacity of citric acid is considered to be an important factor on the resulting percent by mass of $NaHCO_3$. Since there will be a large amount of solid dissolving in water, it is important to make sure all of the tablet is completely dissolved.

8. The reaction mixture can be diluted with water and disposed of down the sink.

IV. Answers to the Questions

1. $HCO_3^-{}_{(aq)}$ + $H^+{}_{(aq)}$ $\rightarrow$ $H_2O_{(l)}$ + $CO_{2\,(g)}$

2. Since the gas product (CO_2) is released into the atmosphere, the weight loss of the reaction mixture after the reaction is the amount of CO_2 generated in the reaction.

3. According to the balanced chemical equation, it takes one mole of $NaHCO_3$ to produce one mole of CO_2. Therefore,

   mass of $NaHCO_3$ reacted =

   (mass of CO_2 generated / M.W. of CO_2) $\times$ M.W. of $NaHCO_3$

4. Excess acid is required to consume all the $NaHCO_3$ contained in Alka Seltzer tablets.

5. percent by mass of $NaHCO_3$ in a tablet =

   (mass of $NaHCO_3$ contained in a tablet / mass of a tablet) $\times$ 100 %

6. When $NaHCO_3$ is in excess, the acid (H^+) in the reaction is the limiting reactant. As the amount of vinegar is increased, more sodium bicarbonate will react and more CO_2 will be produced. On the other hand, when the acid is in excess, sodium bicarbonate becomes the limiting reactant. Since the amount of sodium bicarbonate in a tablet is fixed, the amount of CO_2 generated remains constant regardless of the quantity of vinegar added.

7. The dissolving of CO_2 in reaction solution will lead to too small a value of percent by mass of $NaHCO_3$ in Alka Seltzer tablets. The evaporation of water will lead to too large a value of percent by mass of $NaHCO_3$ in Alka Seltzer tablets. The evaporation of water may be corrected by subtracting the weight loss of a blank solution from the weight loss of the reaction. The quantity of dissolved CO_2 can be estimated by the information used in published articles: 10 mL 6M HCl solution absorbs about 3.0×10^{-4} mol of CO_2 (*2*). This value should be added to the weight loss obtained.

V. References:

1. Peck, L.; Irgolic, K. and O'Connor, R. *J. Chem. Educ.* **1980**, *57*, 517.

2. Dudek, E. *J. Chem. Educ.* **1991**, *68*, 948.