# Alka Seltzer Fizzing—Determination of Percent by Mass of $NaHCO_3$ in Alka Seltzer Tablets

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## An Undergraduate General Chemistry Experiment

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### Background

Stoichiometry, a fundamental concept in general chemistry, is the study of quantitative aspects of chemical formulas and chemical reactions. Stoichiometry includes writing and balancing chemical equations, stoichiometric coefficients, molar ratios of reactants and products, limiting reactants, theoretical yields, and percent yields. One can predict quantities of substances consumed or produced by examining the amounts of substances involved in a chemical reaction.

To apply the principles of the topics taught in lectures, experiments on stoichiometry are commonly seen in general chemistry laboratory manuals (*1–5*). A number of experiments involving the stoichiometric aspects of reactions of carbonates (or bicarbonates) have also been published (*6–10*). Carbonates and bicarbonates can be differentiated by measuring the temperature, pressure, and the volume of $CO_2$ evolved from the reaction with HCl (*7*). Metals in the carbonates can be identified by the method of simple weight loss, gravimetric analysis, eudiometry, and titration (*8*). The chemical equation of the reaction can be deduced when heating the sodium bicarbonate (*9*). The percent by mass of sodium bicarbonate in Alka Seltzer tablets can be determined by the method of eudiometry (*10*).

In the experiment described in this article, an alternative to the work of Peck et al. (*10*), students analyze the content of $NaHCO_3$ in an Alka Seltzer tablet by a rather simple method (measuring the weight loss) utilizing a common household material (vinegar). By incrementally increasing the amount of the acid (vinegar) used in each run of the reaction, students observe the effect of the limiting reactant.

Instead of laboratory chemicals, this experiment utilizes household materials that are inexpensive and readily available. It poses no health hazard and produces no hazardous waste. It not only focuses on the experimental application of the principles of stoichiometry discussed in lectures, but also gives students an opportunity to develop laboratory skills. During the past two years, this experiment has been successfully performed in our general chemistry laboratory courses by approximately 120 students.

### Rationale for the Experiment

Alka Seltzer is an over-the-counter antacid and pain-relief medication that is dissolved in water before it is ingested. It is an effervescent tablet that contains aspirin (acetylsalicylic acid), citric acid, and sodium bicarbonate. The use of Alka Seltzer tablets in science activities has been described in many articles of this *Journal* (e.g., *10–13*).

As the tablet dissolves in water, sodium bicarbonate undergoes the acid–base reaction with the acids (citric and acetylsalicylic) contained in the tablet (eq 1).

$$HCO_3^-(aq) + H^+(aq) \rightarrow H_2O(\ell) + CO_2(g) \qquad (1)$$

The gas product, carbon dioxide, causes the bubbling. This reaction is similar to the carbon dioxide ($CO_2$) generation that occurs by mixing sodium bicarbonate (or carbonates) with vinegar (or acids). The release of carbon dioxide into the atmosphere results in a weight loss after the reaction. According to the mole–mass relationship, the quantity of sodium bicarbonate that reacted can be calculated using the weight loss. Here, students are encouraged to determine the percent by mass of sodium bicarbonate in an Alka Seltzer tablet by carrying out this simple acid–base reaction.

The packaging indicates that each Alka Seltzer tablet contains 325 mg of aspirin (acetylsalicylic acid), 1000 mg of citric acid, and 1916 mg of sodium bicarbonate. The acids originally contained in a tablet give only 17.4 mmol of $H^+$, which is not enough to neutralize all of the sodium bicarbonate (22.8 mmol). If students start by dissolving the tablet in pure water, the sodium bicarbonate is in excess, and the acid ($H^+$) is the limiting reactant. Only a limited amount of $NaHCO_3$ can be reacted. When the tablet is dissolved in a vinegar–water solution, the amount of acid ($H^+$) increases and more $NaHCO_3$ reacts, increasing the production of $CO_2$. With increasing amounts of vinegar in the vinegar–water solution, even more $CO_2$ is generated. Eventually, the acid ($H^+$) will be in excess, and the $NaHCO_3$ contained in the Alka Seltzer tablet becomes the limiting reactant. Since the amount of $NaHCO_3$ in an Alka Seltzer tablet is fixed, no additional $CO_2$ will be generated with increasing amounts of vinegar. The calculated percent by mass of the reacted $NaHCO_3$ in a tablet is plotted against the amount of vinegar used in the vinegar–water solution to produce in a graph similar to Figure 1. The construction and interpretation of the graph should further help students to understand the concept of the limiting reactant.

### Experimental Procedure

Students obtain 8 (or more) Alka Seltzer tablets (Bayer Corporation), vinegar (acetic acid ca. 4.5%), a 250-mL beaker (or clear plastic cup), and a 50-mL (or 10-mL) graduated cylinder from the instructors. An electronic balance (±0.01 g)

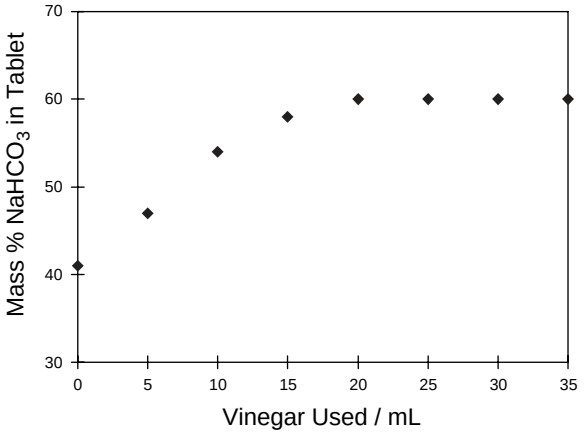


Figure 1. Percent by mass of the reacted $NaHCO_3$ in a tablet versus the volume of vinegar used in the reaction solution.

**Table 1. Typical Data for the Analysis**

| Run No. | Vol/mL | | Mass/g | | | | $NaHCO_3$ Reacted | |
|---|---|---|---|---|---|---|---|---|
| | Vinegar | Water | Cup with Liquid | Alka Seltzer Tablet | Cup with All Substances | Loss[a] (Mass of $CO_2$) | Mass/g | %[b] |
| 1 | 0 | 35 | 40.92 | 3.20 | 43.44 | 0.68 | 1.30 | 41 |
| 2 | 5 | 30 | 40.86 | 3.24 | 43.30 | 0.80 | 1.53 | 47 |
| 3 | 10 | 25 | 40.92 | 3.26 | 43.26 | 0.92 | 1.76 | 54 |
| 4 | 15 | 20 | 41.06 | 3.26 | 43.33 | 0.99 | 1.89 | 58 |
| 5 | 20 | 15 | 41.43 | 3.25 | 43.66 | 1.02 | 1.95 | 60 |
| 6 | 25 | 10 | 41.25 | 3.24 | 43.48 | 1.01 | 1.93 | 60 |
| 7 | 30 | 5 | 41.28 | 3.20 | 43.47 | 1.01 | 1.93 | 60 |
| 8 | 35 | 0 | 41.39 | 3.24 | 43.61 | 1.02 | 1.95 | 60 |

[a]Mass of cup with liquid plus mass of Alka Seltzer tablet minus mass of cup with all substances (after reaction).

[b]Percent by mass of the reacted $NaHCO_3$ in the tablet.

is used for all the weight measurements. Students run a number of reactions with various ratios of vinegar/water. The total volume of vinegar–water solution for each run is 35 mL. The volume of vinegar in the solutions is varied from 0 to 35 mL in 5-mL increments. Students start the experiment by measuring the mass of one tablet and the total mass of the 35-mL vinegar–water solution in the cup. The tablet is then dissolved in the vinegar–water solution. The cup containing the reaction mixture is carefully swirled to ensure complete dissolution of the tablet. The total mass of the reaction mixture in the cup is measured when the reaction (bubbling) stops. The procedure is repeated with all vinegar–water solutions, and the percent by mass of the reacted $NaHCO_3$ in a tablet is calculated for each run of the reaction. Finally, the graph of percent by mass of the reacted $NaHCO_3$ in a tablet versus the volume of vinegar used is constructed.

## Hazards

This activity uses inexpensive household chemicals and creates no hazardous waste. After the experiment, all the solutions can be diluted with water and disposed of down the sink. However, as a safety precaution, students should not eat or taste the materials (vinegar, Alka Seltzer tablet) used in the laboratory. Eye protection is needed for potential eye hazards from the spattering of the reaction mixture.

## Results and Discussion

### *Typical Student Data and Results*

Similar results were obtained by students. Data are presented in Table 1, and Figure 1 shows a typical plot obtained from the analysis. The percent by mass of the reacted sodium bicarbonate in the tablet initially increased with the amount of vinegar used and then reached a steady value. As shown in the figure, when less than 20 mL of vinegar was used, the acid was the limiting reactant. When the volume of vinegar was increased, more sodium bicarbonate reacted and more $CO_2$ was produced. Therefore, the percent by mass of the reacted sodium bicarbonate increased with increasing amounts of vinegar.

When the volume of vinegar exceeded 20 mL, sodium bicarbonate became the limiting reactant. The amount of $CO_2$ produced was exclusively proportional to the quantity of the sodium bicarbonate in the tablet. Since the content of sodium bicarbonate is fixed, the amount of the product ($CO_2$) remained unchanged regardless of the volume of vinegar used and the percent by mass of the reacted $NaHCO_3$ showed a constant value. The average of the horizontal set of data was reported as the percent by mass of $NaHCO_3$ in Alka Seltzer tablets.

Spattering of the reaction mixture, the dissolving of $CO_2$ in the reaction solution, and the evaporation of water are the major sources of inaccuracy and error. To simplify the calculations, certain assumptions were made. Spattering from the fizzing solution is avoided by using a relatively large container (a 250-mL beaker is big enough). Although the evaporation of water leads to too large a value of percent by mass of $NaHCO_3$, the dissolving of $CO_2$ in the solution will compensate for that. Although these two errors are not necessarily the same, in combination they should have only a minimal effect on the result. Based on these assumptions, the percent by mass of $NaHCO_3$ contained in a tablet as reported by students (58–62%) typically agreed with the labeled content within 5%.

Dilute HCl solution has been successfully used in the analysis of the sodium bicarbonate in Alka Seltzer tablets (*10*). One could use HCl solution in this procedure instead of vinegar. Comparison of the results obtained with strong acid (HCl) and with weak acid (vinegar) is interesting and can be studied in another experiment.

## Conclusions

This procedure is designed as a laboratory experiment for stoichiometry. It is appropriate for both high school chemistry and college general chemistry. The exercise is based on an example from everyday life. In contrast to unfamiliar laboratory chemicals, the analyte stimulates the interest of students

who are personally familiar with analgesics. All the students seemed to enjoy the experiment. Their responses to it include:

> I never thought chemistry could be so close to my life.
>
> I like the chemistry lab done in this way.
>
> What are we going to do next?
>
> This is the first time I don't hate chemistry lab so much.

This experiment should provide experiences that help students to comprehend the fundamental chemistry concepts involved. It also gives students an opportunity to gain skill in solving a problem. The entire experiment can be carried out and repeated, if necessary, in a typical three-hour educational laboratory. The data collected can be used as a laboratory assessment item for stoichiometry.

## W Supplemental Material

Student laboratory handouts and notes for the instructor are available as supplemental material in this issue of *JCE Online*.

## Literature Cited


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