Fizzy Drinks: Stoichiometry You Can Taste W

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Background

Fizzies instant sparkling drink tablets, popular in the 1950s and 1960s, are now back on the market. When placed in water, these tablets bubble and fizz, forming an instant carbonated beverage. The fizzing is caused by released bubbles of carbon dioxide (CO_2) gas, which are formed as a result of a chemical reaction between two of the tablet's ingredients, citric acid ($H_3C_6H_5O_7$) and baking soda ($NaHCO_3$). The reaction is:

$$H_3C_6H_5O_7(aq) + 3NaHCO_3(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3H_2O(\ell) + 3CO_2(g)$$

In this Activity, students create their own Fizzie-style carbonated beverage. They find that using too much baking soda or too much citric acid ruins the taste. In the final steps, they use stoichiometry to calculate the correct mix of these two ingredients. An extended article on Fizzies is available (*1*).

Integrating the Activity into Your Curriculum

This activity can be used as an introduction to stoichiometry. It vividly illustrates to students why stoichiometry is important. It can be used for a general or advanced high school course, or an introductory college course. It can also serve as a concluding activity, as a means to test students on whether they have mastered the fundamentals of stoichiometry. However it is used, it is an activity that will teach stoichiometry in a fun way. A previous Classroom Activity also deals with stoichiometry and limiting reagents, using the reaction between baking soda and vinegar (*2*).

About the Activity

This activity requires tasting. It should *not* be done in the laboratory. Except for balances, no lab equipment should be used. Take balances out of the laboratory and clean them thoroughly before use. Food-grade citric acid and baking soda are necessary. These can be obtained from the grocery store or a pharmacist. Bulk citric acid is commonly sold in natural food stores. Canning products such as FruitFresh and EverFresh cannot be used as a replacement for citric acid, because these products contain sugar as their main ingredient.

Stoichiometry is a fundamental concept that beginning chemistry students should firmly grasp. However, many students fail to see the relevance of stoichiometry to everyday life. This activity enables them to see the practical benefits of stoichiometry when they use it to develop a product that they can immediately consume. As an introduction to this activity, Fizzies drink tablets can be demonstrated. They can be ordered from the Fizzies Web site, *http://www.fizzies.com*. WA video of a Fizzies tablet in water is available on *JCE* Online at *http://jchemed.chem.wisc.edu/Journal/issues/2000/Dec/abs1608A.html.*

Careful monitoring of the activity is essential. Students should be reminded that they are to taste only small amounts of the beverages in cups B, C, and D. Ingestion of excessive amounts of baking soda may be harmful. Read the warnings on a box of baking soda before performing this activity.

The correct stoichiometric amounts per 8-ounce (236.5 mL) serving are as follows: 0.45 g unsweetened powdered drink mix, 0.76 g citric acid, 1.00 g baking soda, 3.00 g powdered aspartame sweetener or 2 tablespoons sugar (approximately 50 g). Sugar should be made available for those who may be allergic to aspartame.

Answers to Questions

1. Citric acid and baking soda do not react unless they are in aqueous solution. In the solid powdered state, the reactants lack mobility, so few effective collisions occur and the reaction is slow. After dissolving in water, each molecule and ion is freed and can move about independently in solution. This allows a greater number of the molecules and ions to collide, producing the faster reaction.
2. Baking soda reacts with citric acid (or other acids) used as flavorings in the drink mix.
3. If too much citric acid is used, the drink tastes sour. If too much baking soda is used, it can taste bland, because baking soda reacts with the citric acid used for flavor in the drink mix; it can taste bitter if even more baking soda is present.
4. Aspartame is several hundred times sweeter than sugar. If sugar were used to achieve a similar sweetness, the Fizzies tablets would be much too large.
5. Use the ideal gas law to calculate the volume of carbon dioxide at STP. Since 1 gram of sodium bicarbonate is .0119 moles (1 g / 84 g/mol), using $PV = nRT$ gives: (1 atm) V = (.0119 mol)(.0826 L atm/mol K)(273 K); V = 268 mL.
6. Stoichiometry is used in cooking, formulation of drugs, the manufacture of chemical compounds.

References and Additional Activities

1. Rohrig, B. *ChemMatters* **1998**, *16* (1), 4–6.
2. *J. Chem. Educ.* **1997**, *74*, 1328A–1328B.

***JCE Classroom Activities* are edited by Nancy S. Gettys and Erica K. Jacobsen**

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There is a unique product on the market known as Fizzies, which enables you to make your own carbonated beverage by dropping a tablet into water. The ensuing chemical reaction produces carbon dioxide gas, which causes the drink to be carbonated, producing the "fizz". The same reaction occurs in Alka-Seltzer antacid tablets, effervescent denture cleaners, and Kool-Aid Slushies. In addition to color and flavoring, Fizzies contain citric acid ($H_3C_6H_5O_7$) and baking soda ($NaHCO_3$). When water is added they react, forming sodium citrate, water, and carbon dioxide gas.

In this activity, you will make your own carbonated beverage.

Try This

Be Safe! Do NOT do this activity in the laboratory or use any laboratory equipment other than a balance. The balance should be removed from the laboratory to a classroom or kitchen and should be cleaned thoroughly before using. Solids are weighed using clean paper muffin cups. If any solid is spilled on the balance or balance pan, the solid must be discarded. Taste only very small amounts of the beverages in cups B, C, and D.

You will need: 5 clean 10-ounce beverage cups, 4 paper muffin cups, plastic spoon, marker, balance, cup measure, aspartame sweetener (for example, Equal) or sugar, package of unsweetened powdered drink mix, food grade citric acid, food grade baking soda, and cold water.

__1. Read the instructions on a package of unsweetened powdered drink mix. Determine the mass of drink mix and the volumes of sugar and water for a single serving. Determine the amount of aspartame sweetener that replaces this amount of sugar. (The sweetener package should include a sweetness conversion table for sugar.)

__2. Label 4 paper muffin cups "drink mix", "sweetener", "citric acid", and "baking soda". Label 5 plastic cups A through E. Place the muffin cup labeled "drink mix" on the balance and tare the balance. Weigh the quantity of drink mix for a single serving and transfer it to the cup labeled A. Repeat for the other 4 cups. Add the amount of sweetener (or sugar if you are allergic to aspartame) for a single serving to each of the 5 plastic cups, using the balance and muffin cup labeled "sweetener" if necessary.

__3. Add the quantity of cold water for a single serving to the cup labeled A. Stir with a plastic spoon until all solid has dissolved. Taste and record your observations. Keep this cup as your control.

__4. Using the muffin cup labeled "citric acid" and the balance, add a measured amount of citric acid (1–5 grams) to the cup labeled B. Add the quantity of cold water for a single serving, stir, *taste only a very small amount*, record observations, and discard.

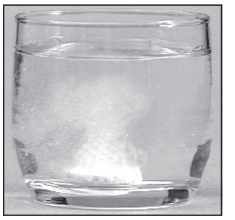
__5. Using the muffin cup labeled "baking soda" and the balance, add a measured amount of baking soda (1–5 grams) to the cup labeled C. Add the quantity of cold water for a single serving, stir, *taste only a very small amount*, record observations, and discard.

__6. Using the appropriate muffin cups and the balance, measure amounts of both baking soda and citric acid (no more than 5 grams each) and add to the cup labeled D. Add the quantity of cold water for a single serving, stir, *taste only a very small amount*, record observations, and discard.

__7. If time permits, experiment with different amounts of citric acid and baking soda (no more than 5 grams of each). Can you make a good-tasting beverage? *Taste only a very small amount of these beverages.*

__8. Write the balanced chemical equation for the reaction between citric acid and baking soda. Using stoichiometry, determine how much citric acid is required to react completely with 1.00 gram of baking soda. Have your instructor check your work before you proceed.

__9. With your instructor's approval, weigh 1.00 gram of baking soda and the amount of citric acid calculated in step 8. Add these amounts to the cup labeled E. Add the quantity of cold water for a single serving, stir, and taste. Compare to cup A. If you wish, you may drink the contents of cups A and E, but pour all others down the drain after you taste a very small amount.



A Fizzies tablet in water.

Questions

__1. Why do citric acid and baking soda not react until water is added?

__2. Why is fizzing observed in cup C?

__3. How will the drink taste if too much citric acid is used? How will it taste if too much baking soda is used?

__4. Why do commercial Fizzies tablets use aspartame sweetener instead of sugar?

__5. Assuming STP, what volume of carbon dioxide gas was produced during the reaction from the drink in step 9?

__6. What are some other practical uses of stoichiometry?

Information from the World Wide Web *(accessed October 2000)*

1. Fizzies Fun House; *http://www.fizzies.com*

2. Homemade Gifts: Bath Bomb Balls; *http://www.kattitudes.com/page33.html*