Target Stoichiometry Lab

Mole Relationships and the Balanced Equation

Introduction

A simple decomposition reaction of sodium bicarbonate (baking soda) presents the opportunity for students to test their knowledge of stoichiometry, factoring labels, and the mole concept. This outcome-based lab requires the students to precisely predict the mass of the solid product. An electronic balance will reveal how close the students come to their "target" and determines their grades!

Concepts

- Mole concept
- Stoichiometry
- Balanced chemical equation

Materials

For each student group

Sodium bicarbonate, $NaHCO_3$, 5–6 g
Universal indicator solution, a few drops
Bunsen burner
Butane safety lighter
Clamp, single buret
Glass wool "paint brush" (See *Preparation* below)
Support stand
Test tube, borosilicate glass
Test tube clamp

To be shared

Balances, electronic, 0.01-g precision, 3
Test tube "holder" for balances (See *Preparation* below)
Cardboard or thin metal sheets, 4″ × 4″, 3
Drinking straw

For teacher preparation

Glass wool
Electrical tape
Scissors

Safety Precautions

Universal indicator solution is alcohol-based and is a flammable liquid. When heating sodium bicarbonate, use a borosilicate glass test tube. Inspect the test tube for chips and cracks before use and handle the hot test tube using a test tube clamp. Use a cool flame to heat the test tube. Do not handle glass wool with bare hands. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. Make a glass wool "paint brush" for each student lab group. Wearing gloves, cut small pieces of glass wool and tape a piece to the end of each straw.
2. Fold a piece of cardboard or thin metal sheet accordion-style (see Figure 1). Place one folded sheet on each balance as a test tube holder to prevent the tube from rolling off the balance.
3. Set up a support stand and clamp with a Bunsen burner for each lab station.

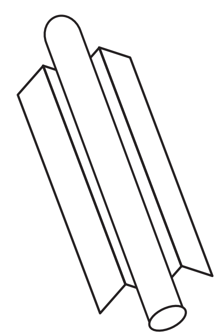

Figure 1.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. After completely cooling, the test tube of sodium carbonate may be rinsed and the waste disposed of down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tips

- Be sure the test tubes used are borosilicate glass. Inspect the test tubes for chips or cracks before using.
- A burning splint may be used to test for CO_2 in the test tube; however, students may think the water vapor is what causes the flame to be extinguished. The universal indicator solution is a better test to show the gas in the tube is a nonmetal oxide.
- Remind students to use the same balance each time.
- If time permits, you may allow students a second attempt if they are not satisfied with their grades. Do not show them the actual mass on the balance, just tell them their score. This second attempt may cost them one point, and they may end up with a lower score, so tell them to only try the second attempt if they are fairly sure they can correct whatever mistake they may have made the first time.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement
Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard G: History and Nature of Science, nature of science
Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, chemical reactions
Content Standard G: History and Nature of Science, nature of scientific knowledge

Sample Data and Answers to Worksheet Questions *(Student data and answers will vary.)*

Data Table

Mass of test tube (g)	*31.43*
Mass of test tube + sodium bicarbonate (g)	*37.04*
Mass of sodium bicarbonate (g)	*5.61*

Answers to Observations and Questions

1. What color change occurs, if any, when the brush with the universal indicator solution is inserted into the test tube (step 9)?

   The indicator solution changes from green to yellow-orange.

2. Is the reaction in the test tube producing a metal or a nonmetal oxide?

   Since the color indicates an acid, the reaction is producing a nonmetal oxide.

3. The chemical formula of sodium bicarbonate is $NaHCO_3$. What common oxide is being produced in the test tube?

   Carbon dioxide, CO_2

4. What do you observe in the upper half of the test tube (step 10)?

   Condensation is occurring.

5. What common substance appears to be a second product of this reaction?

Water, H_2O

6. The third product of the reaction is sodium carbonate. What is the correct formula for sodium carbonate? *Hint:* Remember to balance the charges.

   Na_2CO_3

7. Write the balanced chemical equation for the reaction that took place in the test tube. *Note:* Check with your instructor before balancing to make sure the products are correct.

   $2NaHCO_3(s) \rightarrow H_2O(g) + CO_2(g) + Na_2CO_3(s)$

8. Starting with the mass of $NaHCO_3$ you started with in the test tube (see the Data Table), use stoichiometry and your balanced equation to calculate the mass of sodium carbonate you should have in the test tube. Show your calculations in factor label form.

   $$5.61\text{ g }NaHCO_3 \times \frac{1\text{ mole }NaHCO_3}{84\text{ g }NaHCO_3} \times \frac{1\text{ mole }Na_2CO_3}{2\text{ moles }NaHCO_3} \times \frac{106\text{ g }Na_2CO_3}{1\text{ mole }Na_2CO_3} = 3.54\text{ g }Na_2CO_3$$

9. Assuming all the baking soda you started with has been converted into sodium carbonate (with the product gases driven off), what should the test tube and contents weigh now?

   $3.54\text{ g }Na_2CO_3 + 31.43\text{ g test tube} = 34.97\text{ g }Na_2CO_3 + \text{test tube}$

10. Observe the sodium carbonate left in the test tube; compare and contrast the product to some fresh sodium bicarbonate. Record your observations.

    Both are solids in powder form. The sodium carbonate has a slightly grayish tint compared to the sodium bicarbonate, which is whiter.

Answers to Post-Lab Questions

11. How would the final results be affected if the test tube had not been heated long enough? Explain.

    If the test tube had not been heated long enough, the decomposition reaction would not have gone to completion, and the mass of the test tube and contents would be higher than predicted.

12. CO_2 is more dense than air. Why did the CO_2 produced from the reaction rise upward and out of the mouth of the tube?

    The CO_2 was heated, causing it to expand and become less dense than the surrounding cooler air.

13. Using the original mass of $NaHCO_3$, determine the mass of H_2O produced in this reaction. Show your calculations.

    $$5.61\text{ g }NaHCO_3 \times \frac{1\text{ mole }NaHCO_3}{84\text{ g }NaHCO_3} \times \frac{1\text{ mole }H_2O}{2\text{ moles }NaHCO_3} \times \frac{18\text{ g }H_2O}{1\text{ mole }H_2O} = 0.60\text{ g }H_2O$$

14. Using the original mass of $NaHCO_3$, determine the mass of CO_2 produced in this reaction. Show your calculations.

    $$5.61\text{ g }NaHCO_3 \times \frac{1\text{ mole }NaHCO_3}{84\text{ g }NaHCO_3} \times \frac{1\text{ mole }CO_2}{2\text{ moles }NaHCO_3} \times \frac{44\text{ g }CO_2}{1\text{ mole }CO_2} = 1.47\text{ g }CO_2$$

15. Add the two masses from Questions 13 and 14 above along with the calculated mass of Na_2CO_3 from Question 8. What is the total mass of products in this reaction?

    $0.60\text{ g }H_2O + 1.47\text{ g }CO_2 + 3.54\text{ g }Na_2CO_3 = 5.61\text{ g total}$

16. How does the mass from Question 15 compare with the initial mass of sodium bicarbonate you put in the test tube? Explain why this makes sense.

    The masses are the same. This agrees with the law of conservation of mass; any chemical reaction leaves the total mass unchanged, regardless of the extent to which other properties are changed.

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Target Stoichiometry Lab* activity, presented by Bob Becker, is available in *Mole Relationships and the Balanced Equation* and in *Bob Becker Target Labs*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Target Stoichiometry Lab* are available from Flinn Scientific, Inc.

Catalog No.	Description
S0042	Sodium Bicarbonate, 500 g
G0034	Glass Wool, 100 g
U0001	Universal Indicator Solution, 100 mL
AP8765	Universal Indicator, Color Chart, Pkg/30
GP6015	Test Tube, 15 × 125 mm
AP8338	Scoop

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

Target Stoichiometry Lab Worksheet

In this lab your powers of observation, reasoning, equation balancing and knowledge of stoichiometric calculations will be combined to earn a perfect 10/10 (we hope), determined by how close your prediction comes to the target mass indicated by the electronic balance.

Safety Precautions

Universal indicator solution is alcohol-based and is a flammable liquid. When heating sodium bicarbonate, use a borosilicate glass test tube. Inspect the test tube for chips and cracks before use and handle the hot test tube using a test tube clamp. When using the Bunsen burner, tie back long hair and do not wear loose, long sleeves. Never leave lit burners unattended. Do not handle glass wool with bare hands. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Wash hands thoroughly with soap and water before leaving the laboratory. Follow all laboratory safety guidelines.

Procedure

1. Obtain a large borosilicate test tube and weigh it on one of the balances. Record this mass in the Data Table. *Note:* Borosilicate is a type of glass that can be subjected to very high (and low) temperatures without shattering.
2. Go back to your lab station and place one large scoop of baking soda (sodium bicarbonate, $NaHCO_3$) into the test tube.
3. Using the same scale as before, weigh the test tube with the baking soda. Record this mass in the Data Table.
4. Calculate the mass of the baking soda in the test tube and record the amount in the Data Table.

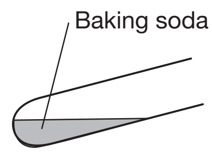

Figure 1.

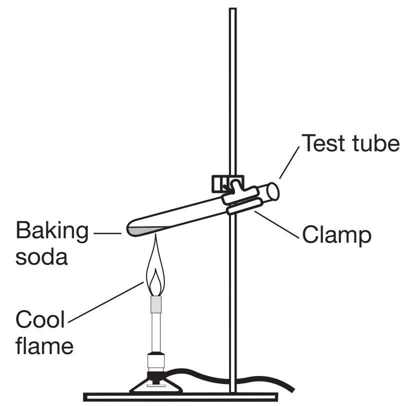

Figure 2.

5. Holding the test tube nearly horizontal, shake the baking soda gently so that it spreads out a bit (see Figure 1).
6. Tighten the test tube clamp securely around the test tube, just below the lip so that it is positioned nearly horizontally about 20 cm above the lab desk (see Figure 2).
7. Light a burner and adjust it to a large cool flame hitting the bottom half of the test tube as shown in Figure 2. Record the time you started heating. __________ *Note:* This heat will initiate a chemical change (a decomposition reaction) that breaks the $NaHCO_3$ down, not into its elements but into three separate compounds.
8. Put one drop of the green universal indicator solution on the small "paint brush." *Note:* The "bristles" of the brush are made of glass wool. Do not handle with bare hands.
9. Carefully insert the end with the universal indicator into the mouth of the test tube (see Figure 3). See if you can observe a distinct color change. If a metal oxide such as K_2O, Na_2O or MgO is being produced, it will create a basic solution and turn the indicator solution blue. If a nonmetal oxide like NO_2, SO_3 or CO_2 is being produced, it will create an acidic solution and turn the drop yellow or even orange. Answer Questions 1–3.

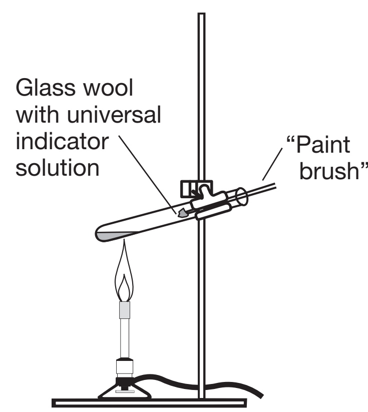

Figure 3.

10. Look carefully at the upper half of the test tube. Answer Questions 4–5.
11. Move the burner occasionally to a different spot to ensure a thorough heating of the entire bottom half of the test tube.
12. Consider the substance that is left in the test tube. It may look just like the baking soda you put in the test tube, but it has actually been converted into something else—sodium carbonate. Answer Question 6, keeping an eye on the time.
13. After you have been heating the test tube for 8–10 minutes, turn off the burner and let the test tube cool for 5–6 minutes.
14. While waiting for the test tube to cool, answer Questions 7–10.

15. If your test tube has been cooling for 5–6 minutes, it should be ready for the official weigh-in! Bring the test tube, along with this sheet containing your prediction from Question 9, to the instructor who will weigh it on the same scale you used before. Your grade will be based on how closely your prediction came to the actual mass (see the Scoring Table).
16. After you have finished all of the above, rinse out the test tube into the sink, then place it in the rack. Take a fresh (dry) test tube and place it in the clamp for the next group.
17. Answer the *Post-Lab Questions*.

Scoring Table

If you are within . . .	your grade will be . . .
0.03 g	10/10
0.10 g	9/10
0.20 g	8/10
0.30 g	7/10
0.50 g	6/10
1.00 g	5/10
5.00 g	4/10
10.00 g	3/10
20.00 g	2/10
50.00 g	1/10
>50.00 g	0/10

Data Table

Mass of test tube (g)	
Mass of test tube + sodium bicarbonate (g)	
Mass of sodium bicarbonate (g)	

Observations and Questions

1. What color change occurs, if any, when the brush with the universal indicator solution is inserted into the test tube (step 9)?
2. Is the reaction in the test tube producing a metal or a nonmetal oxide?
3. The chemical formula of sodium bicarbonate is $NaHCO_3$. What common oxide is being produced in the test tube?
4. What do you observe in the upper half of the test tube (step 10)?
5. What common substance appears to be a second product of this reaction?
6. The third product of the reaction is sodium carbonate. What is the correct formula for sodium carbonate? *Hint:* Remember to balance the charges.
7. Write the balanced chemical equation for the reaction that took place in the test tube. *Note:* Check with your instructor before balancing to make sure the products are correct.
8. Starting with the mass of $NaHCO_3$ you started with in the test tube (see the Data Table), use stoichiometry and your balanced equation to calculate the mass of sodium carbonate you should have in the test tube. Show your calculations in factor label form.
9. Assuming all the baking soda you started with has been converted into sodium carbonate (with the product gases driven off), what should the test tube and contents weigh now?

10. Observe the sodium carbonate left in the test tube; compare and contrast the product to some fresh sodium bicarbonate. Record your observations.

Post-Lab Questions

11. How would the final results be affected if the test tube had not been heated long enough? Explain.

12. CO_2 is more dense than air. Why did the CO_2 produced from the reaction rise upward and out of the mouth of the tube?

13. Using the original mass of $NaHCO_3$, determine the mass of H_2O produced in this reaction. Show your calculations.

14. Using the original mass of $NaHCO_3$, determine the mass of CO_2 produced in this reaction. Show your calculations.

15. Add the two masses from Questions 13 and 14 above along with the calculated mass of Na_2CO_3 from Question 8. What is the total mass of products in this reaction?

16. How does the mass from Question 15 compare with the initial mass of sodium bicarbonate you put in the test tube? Explain why this makes sense.