Stoichiometry: Baking Soda and Vinegar Reactions
Student Version

In this lab, students will examine the chemical reaction between baking soda and vinegar, and mix different amounts of these household chemicals to learn about the concept of stoichiometry.

Key Concepts:

- **Stoichiometry** is the quantitative balancing of elements in chemical reactions.
- **Conservation of mass** requires that all atoms that enter a reaction as reactants must exit the reaction in the products.
- The **Ideal Gas Law** is used to model equilibrium conditions of most gases, relating the pressure, volume, temperature, and moles of gas.

Introduction:

This lab demonstrates the reactivity of two household cooking items, baking soda and vinegar. Baking soda is a powdered chemical compound called sodium bicarbonate, and vinegar includes acetic acid. These 2 components react in solution to form carbon dioxide, water, and sodium acetate as shown in the chemical reaction below:

(baking soda) + (vinegar) → (carbon dioxide) + (water) + (sodium acetate)
$NaHCO_3$ (aq) + CH_3COOH (aq) → CO_2 (g) + H_2O (l) + CH_3COONa (aq)

Looking closely at this equation, examine whether it is balanced or not.

*How many Hydrogen atoms are in the reactants?*_________ *In the products?*________

*How many Oxygen atoms are in the reactants?*___________ *In the products?*________

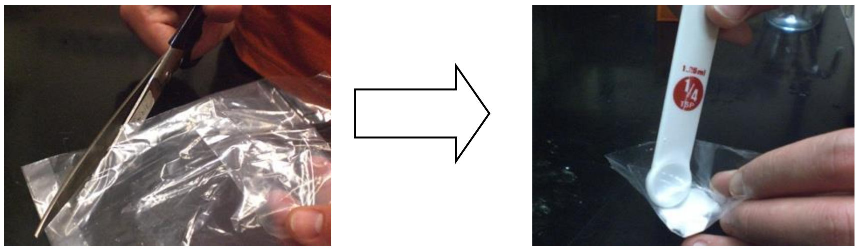
*How many Carbon atoms are in the reactants?*_____ _____ *In the products?*_______

*How many Sodium atoms are in the reactants?*___________ *In the products?*_________

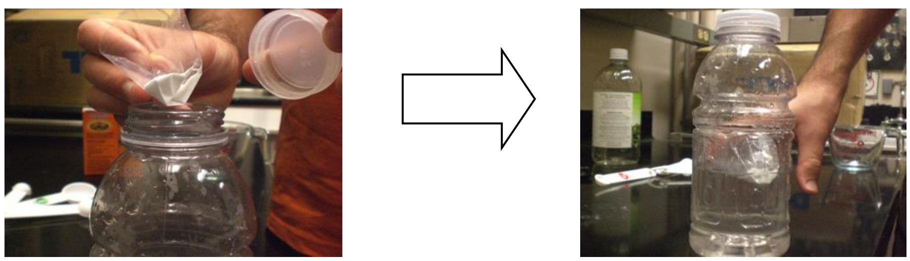
*Is this reaction in Equation 1 stoichiometrically balanced?*________________

Part 1:

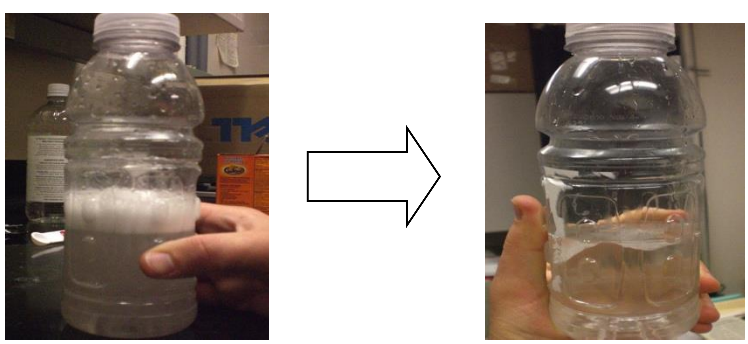
1. Fill the soda bottle with 1 cup of vinegar.
2. Cut a small corner from the clear bag and add ¼ tsp of baking soda into the bag fragment as shown below:



3. Carefully, drop the small bag into the soda bottle with the corner of the bag pointed downwards and quickly close the bottle. The goal is to twist the cap so it is airtight before the baking soda reacts comes into contact with the vinegar.



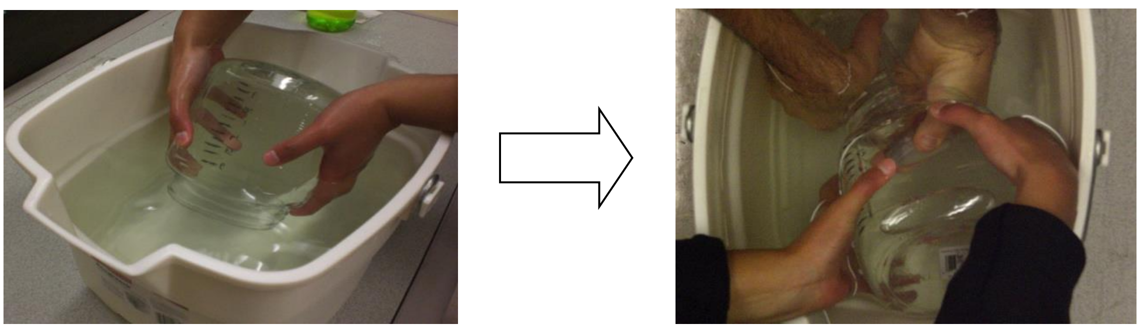
4. Shake the bottle gently until all the baking soda has reacted with the vinegar. Allow the solution to fizz up then slowly settle. Wait until the baking soda has dissolved completely into the vinegar, shown by no significant bubbling in the bottle. Keep the bottle sealed for Part 2. (Note: The bottle should be stiffening to a squeeze as the reaction continues.)



Part 2:

1. Submerge the closed jar in the water tub with the lid facing downward.
2. Remove the lid while keeping the jar below water. By keeping the opening of the jar under water at all times, all of the water will remain inside the jar

3. As your partner holds the jar, place the 20 oz. bottle from part 1 underwater and then slide the top of it inside the opening of the jar. Slowly unscrew the cap to release all of the carbon dioxide into the jar. Note: The water level inside the jar should be slowly decreasing as the gas inside the bottle is released. Be very careful to catch all the carbon dioxide in the jar.



4. Record the amount of trapped air inside the jar. Make sure the water inside and outside the bottle is at the same level before you record.

5. Establish a control by repeating the experiment, but omitting the addition of any baking soda. This will measure the amount of air already inside the bottle before any reaction has occurred.

6. Repeat the same experiment, but instead use ½ tsp of baking soda. Record your results in the table below:

7. Repeat the same experiment, but instead use ½ tsp of baking soda. Record your results in the table below:

Amount/ tsp	Total Volume/mL	Volume CO_2 produced (V_{total} - $V_{control}$)
¼		
Control (0 tsp)		--------
½		

Concept Questions:

Stoichiometry

Determine whether the amount of reaction products you observed agrees with stoichiometric predictions. One underlying assumption is that the baking soda is the only limiting reactant. In other words, there is essentially an unlimited supply of acetic acid in the vinegar bottle, and the reaction output is only dictated by the amount of baking soda you add – every mole added results in a mole of carbon dioxide produced.

Use the following steps to calculate the number of moles of carbon dioxide produced:

Q1. Determine the density of baking soda ($NaHCO_3$).

a. *Net weight of the baking soda container (labeled on box): _______________ g*
b. *Volume in the container (from Nutrition Facts: serving size x number of servings): _____________ tsp*
c. *Density = Net weight/volume = ______________________ g/tsp*

Q2. Mass in ¼ tsp $NaHCO_3$= ________________ g

Q3. Molecular weight (the mass of one mole) of $NaHCO_3$ (get from periodic table):

Na= ________ H= ________ C= ________ O=_______ ; $NaHCO_3$ =__________ g/mol

Q4. Moles in ¼ tsp baking soda:

$$\frac{\text{grams used of } NaHCO_3}{\text{molecular weight of } NaHCO_3} = \frac{\_\_\_\_\_\_\_\_\_\_\_\_\_\ \text{g}}{\_\_\_\_\_\_\_\_\_\_\_\_\_\ \text{g/mol}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\ \textit{moles}$$

Q5. How many moles of CO_2 do you expect from ¼ tsp $NaHCO_3$? ____________moles CO_2

Q6. How many moles of CO_2 do you expect from ½ tsp $NaHCO_3$? ___________ moles CO_2

Gaseous Volume Prediction

The Ideal Gas Law is an equation that roughly models equilibrium properties of most gases:

(pressure) x (volume) = (moles) x (Ideal Gas Constant) x (temperature)

or $pV = nRT$, where R, the Ideal Gas Constant, = 0.0821 L-atm/mol-K

Essentially, this law states that increasing the amount of moles of gas in a system can increase the system's volume and pressure.

Q7. Rearrange the ideal gas law to give an expression for the number of moles of a gas with known temperature, pressure and volume (solve for moles):

Q8. The pressure of the gas when measuring its volume as described in the lab is approximately 1 atm, and the temperature is approximately 300 K. Using the volume of gas you measured in the lab, how many moles of CO_2 did you observe as reaction products:

from ¼ tsp baking soda? __________

*from ½ tsp baking soda?*___________

Q9. Did your stoichiometric predictions agree with the experimental observations?

Q10. Why was it necessary to add the baking soda to the vinegar inside a plastic pouch?

Q11. Why is it important to have a tight "seal" of the cap on top of the bottle when mixing the two reaction components?