Demo: Understanding Limiting Reactants

Summary
In this demonstration, the teacher will perform a series of reactions between acetic acid (vinegar) and varying amounts of sodium bicarbonate (baking soda) in order to inflate several balloons. Students will observe the reactions and analyze the quantities of reactants used as well as the results in order to understand the concept of limiting reactants.

Grade Level
High school

Objectives
By the end of this demonstration, students should be able to
- Define limiting reactant.
- Understand the implications of a limiting reactant in a chemical reaction.
- Identify an excess reactant in a chemical reaction.

Chemistry Topics
This demonstration supports students’ understanding of
- Chemical reactions
- Stoichiometry
- Limiting Reactant
- Chemical Change
- Law of Conservation of Mass

Time
**Teacher Preparation:** 10 minutes
**Lesson:** 30 minutes

Materials
- 2.50g, 7.50g, 12.50g baking soda (sodium bicarbonate, NaHCO₃) -
- 300ml store bought vinegar (5% acetic acid solution, HC₂H₃O₂) divided into 3 portions of 100ml
- 3 empty plastic water bottles (700 ml are used in this video, larger volume will work as well. Another option is to use an Erlenmeyer flask)
- Funnel
- 3 Balloons, 12 inch diameter (having backup balloons is suggested)
- Electronic scale
- Graduated cylinder
- Scoopula
Safety

- Always wear safety goggles when handling chemicals in the lab.
- Students should wear proper safety gear during chemistry demonstrations. Safety goggles and lab apron are required.
- Students should wash their hands thoroughly before leaving the lab.

Teacher Notes

- The reaction of sodium bicarbonate (baking soda) and acetic acid (vinegar) produces carbon dioxide gas, water and sodium acetate (soluble in water). The carbon dioxide gas can originally be seen as bubbles in the solution, but will quickly be released from the solution. The amount of carbon dioxide gas will exceed the space in the bottle, and will move into the deflated balloon, and will inflate it.
- Chemical Equation: \( \text{NaHCO}_3 + \text{HC}_2\text{H}_3\text{O}_2 \rightarrow \text{NaC}_2\text{H}_3\text{O}_2 + \text{H}_2\text{O} + \text{CO}_2 \)
- The quantities of reactants used for the balloons and bottles are shown below:

<table>
<thead>
<tr>
<th></th>
<th>Amount of Vinegar</th>
<th>Amount of Baking Soda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balloon 1</td>
<td>100 ml</td>
<td>2.50 g</td>
</tr>
<tr>
<td>Balloon 2</td>
<td>100 ml</td>
<td>7.50 g</td>
</tr>
<tr>
<td>Balloon 3</td>
<td>100 ml</td>
<td>12.50 g</td>
</tr>
</tbody>
</table>

- Molarity of vinegar is approximately = 0.833M
- **Balloon 1** will produce a reaction that has excess vinegar, and all of the baking soda will react completely. This will produce the smallest amount of carbon dioxide, thus the smallest balloon of the three. The solution in the bottle will be clear, indicating all of the baking soda reacted.
- **Balloon 2** has an equal molar ratio of vinegar and baking soda (7.00 grams of baking soda would actually produce a 1:1 molar ratio, we used 0.5 extra to account for baking soda trapped in the balloon that does not react). The balloon formed will be larger than Balloon 1, and the solution in the bottle will be clear, indicating all of the baking soda reacted.
- **Balloon 3** has excess baking soda. The balloon formed will be the same size as Balloon 2 and the solution in the bottle will be cloudy, indicating an excess of baking soda that did not react.

- Teachers should engage students in a discussion about each of the reactions observed in this demonstration and focus on:
  - Limiting Reactants
  - Excess Reactants
  - Indicators of a Chemical Reaction
Procedure:
1. Label 3 balloons with a sharpie as: 2.50g, 7.50g and 12.50 g.
2. Measure 2.50 grams of baking soda.
3. Insert a funnel into the opening of a balloon and add the baking soda to the balloon through the funnel. See image below.

4. Repeat steps 2. & 3. For 7.50 grams and 12.50 grams of baking soda.
5. Measure 100 ml of vinegar and add the vinegar to an empty bottle. Repeat this measurement with the two additional bottles.
6. Secure each of the balloons around the opening of the bottle, but make sure that the baking soda remains in the balloon at this time. Allow the balloon to hang to the side once it is attached to the bottle until you are ready to complete the demo. See photo for reference.

7. One at a time, lift the balloon, beginning with Balloon 1 and straighten it out over the opening of the bottle. This will allow the baking soda to drop out of the balloon and enter the bottle.
8. Hold the bottle at the base, and swirl gently while the reaction occurs.
9. Repeat step 7. for the additional balloons.

Opportunities for extension:
- Teachers may want to extend this demonstration to a lab opportunity to teach Limiting Reactants & Percent Yield, or to focus on Acid-Base reactions and Mole Ratios.