Demonstration: Firefighter or Fireball

FOR THE TEACHER

Summary
In this demonstration the teacher will complete two chemical reactions inside of separate balloons that each produces a gas. Students will observe and record data as the teacher attempts to ignite each balloon. This demonstration will help students better understand how to predict products, as well as familiarize them with double replacement and combustion reactions.

Grade Level
High School

NGSS Alignment
This demonstration will help prepare your students to meet the performance expectations in the following standards:

- **MS-PS1-2**: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.
- **HS-PS1-4**: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- **Scientific and Engineering Practices**:
  - Analyzing and Interpreting Data
  - Engaging in Argument from Evidence

Objectives
By the end of this demonstration, students should be able to

- Use the given reactants in a double replacement reaction to predict the possible products.
- Use data from observations to make evidence-based conclusions.
- Predict the products of a combustion reaction.
- Identify a reversible and a nonreversible reaction.

Chemistry Topics
This demonstration supports students’ understanding of

- Chemical Reactions
- Classifying Reactions
- Predicting Products
- Balancing Equations
- Stoichiometry
- Combustion Reactions
- Reversible Reactions
- Nonreversible Reactions

Time
**Teacher Preparation**: 20-30 minutes
**Lesson**: Demonstration takes ~10 minutes; follow-up discussion 20-30 minutes

Materials
- 8 grams Calcium carbide
- 20 mL Water
- 150mL Vinegar
- 10 grams Baking soda
- 3-5L capacity Latex balloons
- Funnel
- Wooden splints
- Lighter
- Meter/wooden stick
- Safety shield

**Safety**

- Always wear safety goggles when handling chemicals in the lab.
- When lighting the match and wooden splint, be cautious with the flame.
- An operational fire extinguisher should be in the classroom.
- A safety shield should be used during this demonstration.
- Students should wear proper safety gear during chemistry demonstrations. Safety goggles and lab apron are required.

**Teacher Notes**

- In this demonstration you will create two chemical reactions, one in each balloon. Each chemical reaction will produce a gas, which will be contained in the balloon. You will then attempt to burn each of the gases in the balloons. One balloon will contain the reaction between baking soda and vinegar, which produces carbon dioxide gas (when it is produced it will cause the balloon to expand). In the other balloon, calcium carbide and water react together to produce acetylene gas.
- You can view a video of me performing this demonstration on YouTube.
- Prior to the demonstration students should be asked several questions to explore their prior knowledge about the products of chemical reactions. Also, encourage students to predict what may happen to the balloons when a lit splint is drawn close. When students observe the reactions they will discover the properties of carbon dioxide and acetylene based on their observations, and the concept of reversible or non-reversible reactions.
- Students should be able to describe carbon dioxide as a product of a combustion reaction, which is a non-reversible reaction. They also should be able to offer an explanation about why one balloon puts out fires and the other is combustible.
- It's encouraged that this demonstration is conducted outside. Try to pick a day/area with no wind.
- This demonstration should be practiced and successfully performed by the teacher prior to demonstrating in front of students.
- The acetylene balloon should not be ignited inside. The black smoke is very thick. Review the Material Safety Data Sheet for Acetylene, as the gas is dangerous.
- When preparing the materials, be sure to add the solids to the balloons before the liquids.

**Procedure:**

1. Start with the baking soda, adding the 10 grams of baking soda to the balloon with a metal scoop.
2. Twist the balloon just above the baking soda in order to prevent the baking soda and vinegar from reacting right away. Then add the 150mL of vinegar with a funnel (if it is available it works better if you use a slightly more concentrated acetic acid)
3. Tie off the balloon as the reaction begins so that the gas doesn’t escape.
4. Plan to fill the acetylene balloon right before you will use it. The reaction is hot and may melt through the balloon.
5. Add 8 grams of calcium carbide with the metal scoop to the balloon.
6. Add 20 mL of water with the funnel. The recipe includes excess water to help cool the reaction.
7. Place the balloons on a nonflammable ground, outdoors, and use a safety shield as a barricade between the balloons and students.
8. The wooden splint should be attached to the end of the meter stick. Ignite the end of the splint and first draw it close to the baking soda and vinegar balloon. As it burns a hole in the balloon the carbon dioxide gas released will extinguish the flame.
9. Finally, ignite the end of the splint and first draw it close to the balloon containing calcium carbide and water. As it burns a hole in the balloon the acetylene gas released will ignite.
10. It is important to discuss the outcomes with your students during the demonstration.

- Possible ways that the demonstration may not produce expected results:
  o Be sure to have a large flame on the acetylene balloon, or it might not ignite well.
  o The faster the balloon is ignited, the better the reaction.

- An answer key has been provided as a separate document for download.
- Another great lab, Classifying Reaction Types, could be used to help teach this topic.

**FOR THE STUDENT**

**Lesson**

**Demonstration: Firefighter or Fireball**

**Background**
Chemical reactions happen all around us. It is important for a chemistry student to be able to predict the products of a chemical reaction from the reactants used. In this way, students can decide whether or not one reaction will feed another, or if the products of a reaction will inhibit other reactions. We have learned to classify reactions into types, based on the reactants used and the products that will be formed. The types of reactions that have been discussed include synthesis, decomposition, single replacement, double replacement, and combustion reactions. In this demonstration, you will need to recall these classifications of reactions in order to predict and then confirm, the reactions that occur in the demonstration.

**Pre-lab Questions**
1. Define the following vocabulary words:
   a. Reactant:
   b. Product:
   c. Synthesis reaction:
   d. Decomposition reaction:
   e. Single replacement reaction:
   f. Double replacement reaction:
   g. Combustion reaction:
   h. Reversible reaction:
   i. Nonreversible reaction:

2. For the following reactions, identify the type of reaction and write it in the blank. Then predict the products of the reaction, then balance the equation:
   a. _______ Na + Cl₂ →
   b. _______ H₂CO₃ →
   c. _______ Li + HCl →
   d. _______ NaCl + Pb(NO₃)₂ →
   e. _______ C₃H₈ + O₂ →
**Problem**
Can the classification of a chemical reaction be used to predict the reactivity of the products of a chemical reaction?

**Safety**
- Wear proper safety gear during chemistry demonstrations. Safety goggles and lab apron are required.

**Procedure**
1. You will observe the demonstration performed by your teacher.
2. In the one balloon, baking soda and vinegar are combined. In the other balloon calcium carbide and water are combined.
3. Make careful observations about the reactions in each balloon in the data table below.

**Observations**

<table>
<thead>
<tr>
<th>Balloon 1</th>
<th>Balloon 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations: What you see, hear, smell, and feel (or when the reaction is described to you)</td>
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</tr>
<tr>
<td>Evaluation: What you think it means for each observation. Describe what is happening from the chemical point of view.</td>
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</tr>
</tbody>
</table>

**Analysis**

Balloon #1:
Finish the chemical reaction for Balloon #1:

\[
\text{NaHCO}_3 + \text{HC}_2\text{H}_3\text{O}_2 \rightarrow \]

1. Usually, in a double replacement reaction, there are 2 products. What are the products of the reaction above, if it was a typical double replacement reaction?

2. Since there was a gas produced from the reaction, what is the identity of the gas? Describe how the reaction of the match with the balloon helps to confirm your
guess about the identity of the gas.

3. What are the products for a combustion reaction? How is the reaction for Balloon #1 similar to a combustion reaction?

Analysis
Balloon #2:
Finish the chemical reaction for Balloon #2

\[ \text{CaC}_2 + \text{H}_2\text{O} \rightarrow \]

4. What was different for the reaction of the match with Balloon #2? Which product of the reaction was the match reacting with?

5. Describe the properties of the gasses produced from both reactions. How were they similar? How were they different? List and describe at least 2 similarities and differences between the two gases.

6. When the match was brought close to the balloon, why did the reaction of the gas produced in Balloon #2 stop? What reactant was consumed completely?

Conclusion
Chemical reactions can be reversible or nonreversible. Describe what you have learned about predicting whether a reaction is reversible or nonreversible, based off the type of reaction and the identity of the reactants and products of a reaction. Your description should be at least a paragraph in length and you should answer in terms of the Problem question posed at the beginning of this demonstration. Be sure to address the following aspects in your conclusion:

- Can you predict the reversibility of a chemical reaction from the reactants and products?
- How can you apply what you have learned in this demonstration to a real-life scenario? For example, can you write an equation for a reaction you have observed in real life?