

## Chemistry of Leavening Agents in Bread Making

**Subject Area:** Chemistry

**Grade Level:** High School Chemistry

**Lesson Title:** Chemistry of Leavening Agents in Bread Making

### National Science Education Standards:

- Science as Inquiry: Abilities to do scientific inquiry, 9–12
- Science as Inquiry: Understanding about scientific inquiry, 9–12
- Structure and Properties of Matter: 9–12
- Chemical reactions: 9–12

**Suggested Prior Knowledge:** acid–base reactions, identification of acids and bases, moles, balanced equations, formulas

**Purpose:** To enrich student concept knowledge of chemical reactions in a comparative study of leavening agents used in bread making

### Key Vocabulary:

**acid**—a chemical compound that dissociates in solution, releasing hydrogen ions and lowering the solution pH (a proton donor).

**base**—a chemical species that donates electrons or hydroxide ions or that accepts protons.

**decomposition reaction**—the breakdown of a compound into its corresponding elements or smaller compounds, e.g., electrolysis of water  $2\text{H}_2\text{O}(l) \rightarrow 2\text{H}_2 + \text{O}_2$

**leavening agent**—incorporates gas bubbles into doughs and batters; usually carbon dioxide produced by biological agents, or by chemical agents reacting with moisture, heat, acidity, or other triggers.

**neutralization reaction**—for purposes of this lesson plan we will refer to the point at which 1 mole of hydrogen ions reacts with one mole of hydroxide ions, or the neutralization of an acid and a base to produce water.

### Objectives:

1. Students will draw conclusions about leavening agents and their implications for the food industry.
2. Students will balance equations relating to leavening agents used to make bread.

- Students will identify the acids and bases in a chemical reaction.
- Students will collaboratively design an experiment that collects data about leavening agents.

**Materials (each group should have access to the following):**

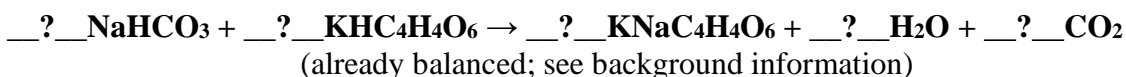
- goggles and formal safety procedures
- student worksheet
- 20 g of sodium bicarbonate (baking soda)
- 20 g of potassium hydrogen tartrate (cream of tartar)
- 20 g of baking powder containing sodium aluminum sulfate and sodium bicarbonate
- 20 g of yeast
- 20 g of glucose or sucrose (sugar)
- 20 ml of acetic acid (vinegar)
- digital scale
- scoopula
- clock with second hand (stopwatch)
- hot and cold tap water
- bucket or trough
- 2 one-hole rubber stoppers
- 2 short pieces of glass tubing to fit stoppers
- 250 ml Erlenmeyer flask
- approx. 100 cm of plastic tubing to fit over glass tubing
- filter paper or paper
- 100 ml beaker

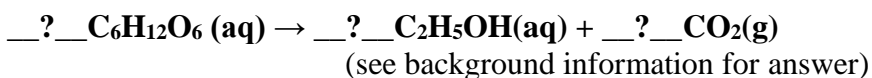
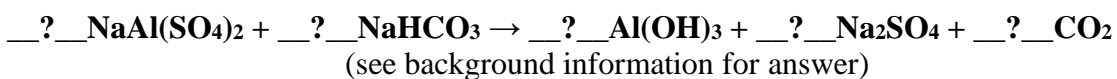
**Procedure:**

1. Introduce students to what they will be doing. They will be conducting an experiment that tests and compares three leavening agents used to make bread. Refresh student concept knowledge with a discussion about molarity, products of acid–base reactions, key vocabulary, or additional concepts relating to this lab. If possible have students conduct some prior research about leavening agents used to make bread or other products, if not, use the following question to get the class focused:

- *Has anybody ever noticed that bread has small air pockets inside (holes)? How do you think those holes get there? Leavening agents produce carbon dioxide that is trapped inside the dough when bread is cooked. Yeast, baking powder, and baking soda are leavening agents that produce carbon dioxide.*

2. Show the chemical reactions for each of the three leavening agents and discuss the stoichiometry and the chemical reactions in each. Familiarize students with the reactions and what is happening in each. Balance the equations, identify the stoichiometric ratios, and identify the acids and bases in the following reactions. (A complete breakdown of these reactions is included in this lesson plan.)





Questions students should be able to answer after these analyses include the following:

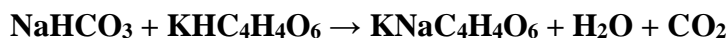
- *What is a common product in all of these reactions? (carbon dioxide)*
- *Looking at these reactions, which do you predict would produce the most carbon dioxide or the fluffiest bread?*
- *How many moles of each reactant are reactant are required in each reaction? (See the background to various reactions in this lesson plan.)*
- *Looking at the reaction, is there a base or an acid involved? Can we identify them? (See Background to Identifying Acids or Bases in this lesson plan.)*

#### Background to Identifying Acids or Bases:

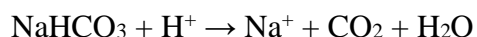
The names of most acids end in *acid*. Acid formulas have one of these forms:  $\text{HX(aq)}$  or  $\text{H}_a\text{X}_b\text{O}_c$ . Ionic compounds that contain hydroxide ( $\text{OH}^-$ ), carbonate ( $\text{CO}_3^{2-}$ ), or hydrogen carbonate ( $\text{HCO}_3^-$ ) anions are basic. Ammonia,  $\text{NH}_3$ , is also a base.

#### Background to Baking Soda and Cream of Tartar Reactions:

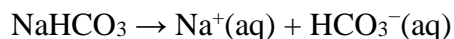
Baking soda (a base), also known as sodium bicarbonate, has the chemical formula  $\text{NaHCO}_3$ . Cream of tartar (an acid), also known as tartrate salt, has the formula  $\text{KHC}_4\text{H}_4\text{O}_6$ . The reaction is given by the following:



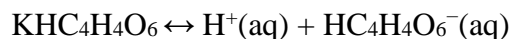
Baking soda is the source of the carbon dioxide, and the acid–base reaction in this case is more accurately described as an acid-activated decomposition of baking soda, which can be generically represented as:



When dissolved in water baking soda separates into sodium ( $\text{Na}^+$ ) and bicarbonate ions ( $\text{HCO}_3^-$ ):



Potassium hydrogen tartrate (cream of tartar) solution in water partially dissociates into hydrogen ( $\text{H}^+$ ) and hydrogen tartrate ions ( $\text{HC}_4\text{H}_4\text{O}_6^-$ ):



The reaction between baking soda and cream of tartar is actually two reactions, an acid–base

reaction followed by a decomposition reaction.

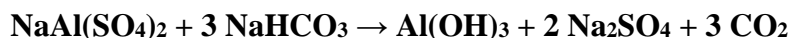
When the two ingredients are mixed, hydrogen ions ( $\text{H}^+$ ) from the cream of tartar react with the bicarbonate ions ( $\text{HCO}_3^-$ ) from the baking soda to form a new chemical called carbonic acid ( $\text{H}_2\text{CO}_3$ ):  $\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{CO}_3$

The carbonic acid thus formed then immediately decomposes into carbon dioxide gas ( $\text{CO}_2$ ) and water ( $\text{H}_2\text{O}$ ):  $\text{H}_2\text{CO}_3 \rightarrow \text{H}_2\text{O} + \text{CO}_2$

### **Background to Baking Soda and Sodium Aluminum Sulfate Reaction:**

Baking powders contain sodium aluminum sulfate:  $\text{NaAl}(\text{SO}_4)_2$ . You will notice that the generic formula for baking powder is the same as for baking soda and cream of tartar.

The reaction for baking powder is:

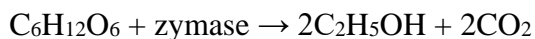
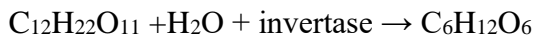
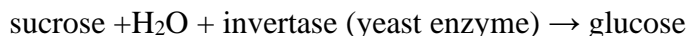


Baking soda and aluminum sulfate dissociate in water and, just as in baking soda with cream of tartar, the reaction is a two-step one. Sodium aluminum sulfate dissociates into  $\text{Na}^+$ ,  $\text{Al}^{+3}$ , and  $\text{SO}_4^{-2}$  ions during the reaction.

### **Background to Yeast, Glucose, and Water Reaction:**



The chemical equation summarizes the fermentation of glucose. One mole of glucose is converted into two moles of ethanol and two moles of carbon dioxide:



Note: Before fermentation takes place glycolysis occurs, a biological process involving 10 intermediate steps producing high-energy compounds necessary in both aerobic and anaerobic respiration. The intermediate steps have been excluded in the chemical equation above.

Glycolysis is summarized by the chemical equation  $\text{C}_6\text{H}_{12}\text{O}_6 + 2 \text{ADP} + 2 \text{P}_i + 2 \text{NAD}^+ \rightarrow 2 \text{CH}_3\text{COCOO}^- + 2 \text{ATP} + 2 \text{NADH} + 2 \text{H}_2\text{O} + 2 \text{H}^+$ , and can be discussed further with students in an extension or enrichment activity to demonstrate the biological and chemical complexity of living things.

3. Facilitate a conversation with students to design an experiment that allows us to understand the pros and cons of the different leavening agents in bread making. The following questions may help:

- *Leavening agents produce carbon dioxide. How can we design an experiment to test leavening agents to see how well they work? The experiment in this lab uses the collection of products (mainly carbon dioxide).*
- *What data should we collect?*
- *What variables should we account for in our experimental design?*

4. Once a class procedure has been designed, the experiments should resemble the following two examples:

Example 1: In a small beaker students test the varying leavening agents:

- with or without water
- with or without acid
- at cool or warm temperatures

Example 2: Set up a gas collection apparatus to collect the carbon dioxide produced from the varying reactants as follows:



5. During the course of student experimentation, reinforce the concepts associated with each reaction. As students experiment, ask questions that refer to the chemical reactions discussed earlier. Asking these questions will prompt students' thinking about what to include in their conclusions.

- *Why is that bubbling?*
- *What has happened to the reaction rate with an increase in temperature?*
- *Why doesn't baking soda react in water but baking powder does?*
- *What happens to sodium bicarbonate when placed in water?*
- *Are there ions in the solution you created?*

6. Finally, have students make decisions as to where error may have been introduced into the lab.

**Additional Resource:**

- <http://www.5min.com/Video/How-Leavening-Works-83227000>

## Student Worksheet for Chemistry of Leavening Agents in Bread Making

### (Part 1: Reactivity and Rates of Reaction of Leavening Agents)

Experiment Title: \_\_\_\_\_ Date: \_\_\_\_\_ Name: \_\_\_\_\_

Student Hypothesis:

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Materials:

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Procedure:

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Data:

Sample ID	Sample mass	Sample mass	Observations: Does a reaction occur?	Other
baking soda + water				
baking soda + vinegar				
baking soda + cream of tartar + water				
yeast + water				
yeast + vinegar				
yeast + water + sugar				
baking powder + water				
baking powder + vinegar				
other				

Conclusions (Part 1) (use the back if necessary):

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## Student Worksheet for Chemistry of Leavening Agents in Bread Making

### (Part 2: Comparing Carbon Dioxide Produced From Leavening Agents)

Experiment Title: \_\_\_\_\_ Date: \_\_\_\_\_ Name: \_\_\_\_\_


Student Hypothesis:

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Materials:

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Procedure:



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Data:

Sample ID	Sample Mass	Sample Mass	Sample Mass	T <sub>i</sub>	T <sub>f</sub>	Observations:	Volume CO <sub>2</sub>
baking soda + water							
baking soda + vinegar							
baking soda + cream of tartar + water							
yeast + water							
yeast + vinegar							
yeast + water + sugar							
baking powder + water							
baking powder + vinegar							
other							
other							

