

LESSON 4: Seltzer Reaction Rates

ESTIMATED TIME Setup: 5 minutes | Procedure: 5–10 minutes



DESCRIPTION

Place seltzer tablets in water of different temperatures to demonstrate the effects of temperature on reaction rates.

OBJECTIVE

This lesson demonstrates a chemical reaction and the impact of temperature on the rate of the reaction. Students place seltzer tablets in water at different temperatures to observe the different reaction rates. This lesson can be extended to address parts of a reaction, energy of reactions, and other ways to affect the rate of a reaction.

CONTENT TOPICS

Scientific inquiry; properties of matter; chemical reactions; energy

MATERIALS

- Alka-Seltzer™ tablets (or any brand of seltzer tablets)
- Clear glass or thick plastic cups
- Hot, cold, and room-temperature water
- Stopwatch (optional)



Always remember to use the appropriate safety equipment when conducting your experiment. Refer to the **Safety First** section in the **Resource Guide** on pages 391–393 for more detailed information about safety in the classroom.



Jump ahead to page 56 to view the Experimental Procedure.

NATIONAL SCIENCE EDUCATION STANDARDS SUBJECT MATTER

This lesson applies both *Dimension 1: Scientific and Engineering Practices* and *Dimension 2: Crosscutting Concepts* from “A Framework for K–12 Science Education,” established as a guide for the updated National Science Education Standards. In addition, this lesson covers the following Disciplinary Core Ideas from that framework:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer

OBSERVATION & RESEARCH

BACKGROUND

Scientists sort matter by its physical and chemical properties. **Physical properties** can be observed by using our senses and taking measurements. Some examples of physical properties are color, shape, boiling point, melting point, and density. **Chemical properties** can be identified by observing how a chemical reacts with other substances. Some examples of chemical properties include acidity, toxicity, and flammability.

A **chemical change** or **chemical reaction** is a change that takes place when atoms of a substance are rearranged, and the bonds between the atoms are broken or formed.

During a chemical reaction, the structure or composition of the materials is changed. When a chemical change is complete, the resulting substance(s) is/are different from the original substance(s). On the other hand, a **physical change** is any change in a substance’s form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change.

Physical and chemical changes occur around us all the time. Making ice from water is an example of a physical change. Baking a cake is an example of a chemical change. Chemical changes even take place inside our bodies! When we breathe, we take in oxygen from the



LESSON 4: Seltzer Reaction Rates

air, which combines with glucose (a sugar) in our bodies. These substances react to produce carbon dioxide and water vapor, which we exhale.

Seltzer tablets are used to neutralize excess stomach acid and relieve minor aches and pains, an upset stomach, headaches, and indigestion. Seltzer tablets are designed to be dissolved in water and then ingested. When the tablets are placed in water, a chemical reaction occurs. The bubbles that form and rise out of the water are carbon dioxide gas and are a sign that a chemical reaction is taking place.

The rate (speed) of chemical reactions is commonly affected by temperature. In general, an increase in temperature increases the rate of the reaction. Therefore, students are able to demonstrate this relationship using water of different temperatures. When a seltzer tablet is dropped in hot water, the reaction will occur more quickly than when one is dropped in room-temperature water. Likewise, the reaction will occur the slowest in the cold water.

FORMULAS & EQUATIONS

Alka-Seltzer™ tablets are composed of sodium bicarbonate and citric acid. Sodium bicarbonate is commonly called baking soda.

The chemical formula for sodium bicarbonate is NaHCO_3 .

The chemical formula for citric acid is $\text{C}_6\text{H}_8\text{O}_7$.

When baking soda and citric acid react, they produce sodium citrate, carbon dioxide gas, and water.

The bubbles that are seen rising out of the water are the carbon dioxide gas.

The chemical equation for the reaction is:
$$3\text{NaHCO}_3 + \text{C}_6\text{H}_8\text{O}_7 \rightarrow \text{C}_6\text{H}_5\text{Na}_3\text{O}_7 + 3\text{CO}_2 + 3\text{H}_2\text{O}$$

Sodium citrate is an antacid, which means it helps to neutralize stomach acid.

The chemical formula for sodium citrate is $\text{C}_6\text{H}_5\text{Na}_3\text{O}_7$.

Many new seltzer tablets also contain acetylsalicylic acid (ASA), commonly known as aspirin.

The chemical formula for ASA is $\text{C}_9\text{H}_8\text{O}_4$.

When this compound is added to the reaction, sodium acetylsalicylate is produced and acts as a pain reliever.

The chemical formula for sodium acetylsalicylate is $\text{C}_9\text{H}_7\text{NaO}_4$.



CONNECT TO THE YOU BE THE CHEMIST CHALLENGE

For additional background information, please review CEF's Challenge study materials online at <http://www.chemed.org/ybtc/challenge/study.aspx>.

- Additional information on physical and chemical properties and changes can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on temperature can be found in the Measurement section of CEF's *Passport to Science Exploration: The Core of Chemistry*.
- Additional information on chemical reactions and reaction rates can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections*.

HYPOTHESIS

► When seltzer tablets are placed in water, a chemical reaction will take place. The chemical reaction that results will take place faster in hot water than in cold water.



Fun Fact

In 1979, the advertising jingle "Plop, plop, fizz, fizz. Oh, what a relief it is" was introduced by Bayer. The jingle soon became one of the most recognized jingles in commercial history.

LESSON 4: Seltzer Reaction Rates

DIFFERENTIATION IN THE CLASSROOM

LOWER GRADE LEVELS/BEGINNERS

Conduct the experiment as described on page 56, but focus the lesson on describing and classifying matter. Discuss physical properties in more detail and the different uses of different substances.

Likewise, go over physical and chemical changes in more detail. For example, show a picture of a pencil. Then show a picture of the pencil broken—that's a physical change! Next, show a picture of cake batter and then a baked cake—that's a chemical change!

HIGHER GRADE LEVELS/ADVANCED STUDENTS DESCRIPTION

Place seltzer tablets in water of various temperatures to demonstrate the effects of temperature on reaction rates.

OBJECTIVE

This lesson demonstrates the effect of temperature on the rate of a chemical reaction and addresses energy of reactions and other means of affecting reaction rates.

OBSERVATION & RESEARCH

Matter can undergo a number of changes. A **physical change** is any change in a substance's form that does not change its chemical makeup. The chemical formula of the substance stays the same before and after the change. Pouring water from one container to another does not change the chemical makeup of the water. Therefore, pouring water from one container to another is a physical change.

On the other hand, a **chemical reaction** occurs when two or more substances interact, and the bonds between atoms are broken or formed. As a result of a chemical reaction, new substance(s) with new properties are formed. The starting material or materials for a chemical reaction are referred to as the **reactants**. The substance or substances produced from a chemical reaction are called **products**. Sometimes a secondary product, a **byproduct**, can also be created at the same time as the desired product(s).

Matter often changes when energy is added or taken away. A change that gives off energy is an **exothermic reaction**. Burning reactions are examples of exothermic reactions because they release thermal energy. In contrast, an

endothermic reaction is a change that needs energy to be added. Melting ice is an endothermic reaction. The ice absorbs energy from the surrounding environment. Likewise, the reaction between a seltzer tablet and water is an endothermic reaction. The absorption of energy by the reaction can often be sensed as cold. Therefore, if you put your hand around the cup as the reaction takes place, you may feel this reduction in temperature during the reaction. Once the reaction is complete, the temperature of the mixture will return to room temperature.

In addition, scientists often need to predict how fast reactions will occur. Several factors can affect the rate of a reaction, such as the temperature, pressure, and concentration of reactants or products. This experiment demonstrates the effect of temperature. In general, as temperature increases, the rate of the reaction increases. As temperature increases, the average motion of particles in the substances increases. As a result, those particles come in contact with each other more quickly, speeding up the reaction. Students are able to demonstrate this relationship using water at different temperatures. When a seltzer tablet is dropped in hot water, the reaction will occur more quickly than when one is dropped in room-temperature water. Likewise, the reaction will occur the slowest in cold water.



CONNECT TO THE YOU BE THE CHEMIST CHALLENGE

For additional background information, please review CEF's Challenge study materials online at <http://www.chemed.org/ybtc/challenge/study.aspx>.

- Additional information on chemical reactions and reaction rates can be found in the Chemical Reactions section of CEF's *Passport to Science Exploration: Chemistry Connections*.
- Additional information on exothermic and endothermic reactions can be found in the Classification of Matter section of CEF's *Passport to Science Exploration: The Core of Chemistry*.

LESSON 4: Seltzer Reaction Rates

ANALYSIS & CONCLUSION

Use the questions from the activity sheet or your own questions to discuss the experimental data. Ask students to determine whether they should accept or reject their hypotheses. Review the information in the *Scientific Inquiry* section on pages 14–16 to discuss valid and invalid hypotheses.

ASSESSMENT/GOALS

Upon completion of this lesson, students should be able to ...

- Apply a scientific inquiry process and perform an experiment.
- Compare and contrast physical and chemical properties and give examples.
- Differentiate between physical and chemical changes and give examples.
- Describe the effect of temperature on the rate of reactions.
- Identify the parts of a chemical reaction, such as reactants and products (see *Differentiation in the Classroom*).
- Differentiate between exothermic and endothermic reactions and give examples of each (see *Differentiation in the Classroom*).
- List other ways to alter the rate of a chemical reaction (see *Differentiation in the Classroom*).

MODIFICATIONS/EXTENSIONS

Modifications and extensions provide alternate methods for performing the lesson or similar lessons. They also introduce ways to expand on the content topics presented and think beyond those topics. Use the following examples or have a discussion to generate other ideas as a class.

- Use a stopwatch to measure the rate of the reactions in each cup of water. The time for the reaction should be recorded when bubbles stop forming in each cup.
- Ask the students if they can think of any other methods to speed up the rate of a chemical reaction (breaking the tablet into smaller pieces, adding vinegar/an acid to the water). Ask them if they know how to slow the rate of a reaction (i.e., adding water a few drops at a time, coating the tablet in oil). Have students test their hypotheses, record their results, and discuss the results as a class.

REAL-WORLD APPLICATIONS

- Dissolving seltzer tablets in water produces sodium citrate, which helps to neutralize stomach acid (and in some cases sodium acetylsalicylate, which serves as a pain reliever). Another benefit of dissolving the tablets in water is that the sodium citrate (and sodium acetylsalicylate) is in a solution. The solution is then evenly distributed within the stomach to allow the neutralization process to occur more quickly. Likewise, the pain reliever can be absorbed by the body more quickly. The solution form reduces the amount of time it takes your body to dissolve the tablet itself, such as when you take other medicines or vitamins.

COMMUNICATION

Discuss the results as a class and review the activity sheet. Review the information in the *Scientific Inquiry* section on pages 14–16 to discuss the importance of communication to scientific progress.

LESSON 4 ACTIVITY SHEET: Seltzer Reaction Rates

OBSERVE & RESEARCH

1. Write down the materials you see. _____

2. How might these materials be used? _____

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical property		
Chemical property		
Physical change		
Chemical reaction		

4. Consider what will happen if seltzer tablets are added to cups of water with different temperatures and why.

► Write your hypothesis. _____



LESSON 4 ACTIVITY SHEET: Seltzer Reaction Rates

PERFORM YOUR EXPERIMENT

1. Place three empty cups on a table or desk.
2. Fill the first cup with hot water. (Your teacher will provide the hot water.)
3. Fill the second cup with room-temperature water.
4. Fill the third cup with ice water.
5. Place a seltzer tablet in each cup. Watch the reactions.

ANALYZE & CONCLUDE

1. What happens when you place a seltzer tablet in water? _____

2. At which temperature did the reaction take place the fastest? _____

3. At which temperature did the reaction take place the slowest? _____

4. How can you tell which reaction happened the fastest and slowest? _____

5. Circle the correct response: As the temperature *increases* / *decreases*, the rate of reaction increases.
6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? _____

LESSON 4 ACTIVITY SHEET: Seltzer Reaction Rates

EXPAND YOUR KNOWLEDGE—ADVANCED

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Reactant		
Product		
Byproduct		
Exothermic reaction		
Endothermic reaction		

2. Can you think of other examples that demonstrate a reaction occurring faster when temperature is increased?

3. Can you think of other ways to make a reaction happen faster? _____

LESSON 4 ACTIVITY SHEET: Seltzer Reaction Rates

ANSWER KEY Below are suggested answers. Other answers may also be acceptable.

OBSERVE & RESEARCH

1. Write down the materials you see. Seltzer tablets, plastic cups, water (hot, cold, and room temperature) ...

2. How might these materials be used? Seltzer tablets may be used to relieve an upset stomach. Plastic cups may be used to hold a substance. The different temperatures of water may be used to dissolve seltzer tablets at different rates.

3. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Physical property	A property of a substance that can be experienced using the human senses and often detected through a measuring device; physical properties can be observed without reacting the substance with some other substance.	
Chemical property	A property of a substance that can be revealed by the way the substance interacts with other substances; describes an object's "potential" to undergo some chemical change or reaction due to its composition.	
Physical change	A change that alters the form or appearance of a substance but does not change its chemical makeup or create a new substance.	
Chemical reaction	A change that takes place when atoms of one or more substances are rearranged, and the bonds between the atoms are broken or formed to produce new substances; also known as a chemical change.	

4. Consider what will happen if seltzer tablets are added to cups of water with different temperatures and why.

► **Write your hypothesis.** When seltzer tablets are placed in water, a chemical reaction takes place.
The chemical reaction that results will take place faster in hot water than in cold water because temperature increases the rate of the reaction.



LESSON 4 ACTIVITY SHEET: Seltzer Reaction Rates

ANSWER KEY Below are suggested answers. Other answers may also be acceptable.

PERFORM YOUR EXPERIMENT

1. Place three empty cups on a table or desk.
2. Fill the first cup with hot water. (Your teacher will provide the hot water.)
3. Fill the second cup with room-temperature water.
4. Fill the third cup with ice water.
5. Place a seltzer tablet in each cup. Watch the reactions.

ANALYZE & CONCLUDE

1. What happens when you place a seltzer tablet in water? When a seltzer tablet is placed in water, a chemical reaction occurs.
The bubbles that form and rise out of the water are carbon dioxide gas and are a sign that a chemical reaction is taking place.

2. At which temperature did the reaction take place the fastest? The hot water created the fastest reaction.

3. At which temperature did the reaction take place the slowest? The cold water created the slowest reaction.

4. How can you tell which reaction happened the fastest and slowest? The rate at which bubbles form and how fast the tablet
dissolves show which reaction occurs fastest and which occurs slowest.

5. Circle the correct response: As the temperature increases / decreases, the rate of reaction increases.
6. Is your hypothesis valid? Why or why not? If not, what would be your next steps? _____
Answer 1: Valid because the data support my hypothesis.

Answer 2: Invalid because the data do not support my hypothesis. I would reject my hypothesis and could form a new one, such as ...

LESSON 4 ACTIVITY SHEET: Seltzer Reaction Rates

ANSWER KEY Below are suggested answers. Other answers may also be acceptable.

EXPAND YOUR KNOWLEDGE—ADVANCED

Have students complete this section if you used the advanced differentiation information, or challenge them to find the answers to these questions at home and discuss how these terms relate to the experiment in class the next day.

1. Define the following key terms. Then, provide an example of each by writing the example or drawing/pasting an image of the example.

Term	Definition	Example (write or add image)
Reactant	The starting material or materials for a chemical reaction.	
Product	A substance formed as a result of a chemical reaction.	
Byproduct	A secondary product that is created from a chemical reaction at the same time as the primary, desired product(s).	
Exothermic reaction	A change that gives off energy, generally sensed as heat.	
Endothermic reaction	A change that needs energy to be added to take place.	

2. Can you think of other examples that demonstrate a reaction occurring faster when temperature is increased?

If you increase the temperature, it is easier to dissolve salt or sugar in water. You can dissolve sugar faster in hot tea than in cold tea.

In addition, the higher the temperature of an oven, the faster your food will cook.

3. Can you think of other ways to make a reaction happen faster? Other ways to make a reaction happen faster are to apply

pressure or add a catalyst.