Seltzer Reaction Rates

Section **CHEMICAL REACTIONS** *Topic* **REACTION RATES & CATALYSTS**

Estimated Time Setup: 5 minutes; Procedure: 5-10 minutes

OVERVIEW

Students explore how temperature affects reaction rates in this simple, bubbly experiment.

In this activity, students place seltzer tablets into samples of water at different temperatures. Higher temperatures often mean reactions proceed faster, and students will see that the seltzer tablets in the hot water bubble and fizz at a high higher rate than tablets in the cold water. This chemical reaction is also endothermic – meaning it absorbs heat – and students can feel the water cooling as the reaction comes to completion.

INQUIRY QUESTIONS

Getting Started:

- Is the change that occurs in this reaction a chemical or physical change? What evidence do we have for either case?

Learning More:

- What effect does temperature have on the rate of a reaction?

Diving Deeper:

- What happens at the molecular level when the temperature of a reaction is increased or decreased, and how does this change the rate of reaction?

CONTENT TOPICS

This activity covers the following content topics: properties of matter, chemical reactions, chemical change, temperature, reaction rate, energy (temperature, kinetic), endothermic and exothermic reactions, acid-base reactions

This activity can be extended to discuss: equilibrium, reversible and irreversible reactions, conservation of matter and mass, density

NGSS CONNECTIONS

This activity can be used to achieve the following Performance Expectations of the Next Generation Science Standards:

- **5-PS1-4:** Conduct an investigation to determine whether the mixing of two or more substances results in new substances.
- **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.

MATERIALS

For one setup:

- 3 seltzer tablets
- 3 clear glass or thick plastic cups
- Hot, cold, and room temperature water

Optional materials:

- Stopwatch
- Thermometer

ACTIVITY NOTES

This activity is good for:

- Individuals
- Pairs
- Small groups

Safety Tips & Reminders:

- Seltzer tablets are used as a medicine; be sure to pour the product down the drain after the reaction is complete.
- Review the Safety First section in the Resource Guide for additional information

Fun Fact #1

Alka-Seltzer, the original seltzer tablet brand, was invented in 1931 by A. R. "Hub" Beardsley, the president of a laboratory in Indiana. He found that during a flu epidemic in Elkhart, Indiana, none of the employees of a local paper got sick. He found that the editor of the paper made his staff drink a mixture of aspirin and bicarbonate of soda each day. Beardsley worked with his staff to develop this concoction into a pill, which later became Alka-Seltzer!

ENGAGE

Use the following ideas to engage your students in learning about chemical reactions:

- Start with an overview of physical versus chemical changes, including their definitions and how we distinguish them. Show students a variety of pictures, video clips, or demos and ask them whether a physical or chemical change has occurred, and the evidence they have for their answer. Some examples of physical changes could be melting an ice cube, mixing sand and salt, shredding paper, crushing a can, or chopping wood. Examples of chemical changes could be roasting a marshmallow, baking a cake, cooking an egg, food rotting, iron rusting, a match burning, or digesting food.

See more ideas for engagement in the Reaction Rates & Catalysts Background section! You can also look at the Elaborate section of this activity for other ideas to engage your students.

Fun Fact #2

Baking soda, or sodium bicarbonate,can be used to put out small electrical or grease fires because it helps smother the flames.

EXPLORE

Procedure:

1. Fill three cups with the same amount of water: one with hot water, one with room temperature water, and one with ice-cold water.
   Optional: Take the temperature of each sample and record.
2. Label each cup as "hot," "room temperature," or "cold"
3. At the same time, drop a seltzer tablet into each cup. Observe and record your findings.

Alternate method:

1. Fill three cups with the same amount of water: one with hot water, one with room temperature water, and one with ice-cold water. Label each cup accordingly.
   Optional: Take the temperature of each sample and record.
2. Drop the seltzer tablet in the cold water and start the stopwatch immediately.
3. Stop the stopwatch when bubbles stop forming and record the time.
4. Take the temperature of the water solution at the end of the reaction and record.
5. Repeat for the other two samples of water: room temperature and hot.

DATA COLLECTION & ANALYSIS

Analyze and discuss the results of this activity using the following questions:

- What are the physical properties of the seltzer tablet? How do you think it works?
- Write your observations: what was happening in each cup? What was different between each sample? Why do you think that is?
- If you timed the experiment, how long did it take the bubbles to stop forming in the hot water? The room temperature water? The cold water? What does this tell you? Graph your data to look for a pattern.
- In which cup was the reaction the slowest? The fastest? Why?
- Where do you think the bubbles were coming from? What are the bubbles composed of?
- Was this a chemical or physical change? How do you know? What evidence do you have?
- Feel each cup at the end of the experiment. Do they feel warmer or cooler than at the start? Or, if you measured the temperature, did it change from the start to the end of the experiment? What does this mean?

EXPLAIN

What's happening in this Activity?

First review the Reaction Rates & Catalysts Background section to gain a deeper understanding of the scientific principles behind this activity.

Seltzer tablets are used to treat a variety of symptoms—including fever, heartburn, acid reflux, indigestion, and stomachaches. These tablets do all of this by reacting with excess acid in the stomach and neutralizing it.

People take these tables by first dissolving it in water and then drinking the solution. When a tablet is put in water, it doesn't just a dissolve—a chemical reaction takes place! We can see this because bubbles are forming, which is often a sign of a chemical reaction. Alka-Seltzer tablets contain three different compounds: sodium bicarbonate, citric acid, and aspirin.

When the tablet is put in water, the sodium bicarbonate and the citric acid react. The reaction produces carbon dioxide gas, CO_2, which forms bubbles and floats to the top. The other products of the reaction are sodium citrate and water. Sodium citrate, $C_6H_5Na_3O_7$, is the compound that neutralizes stomach acid when someone takes an Alka-Seltzer tablet. These kinds of compounds are called antacids.

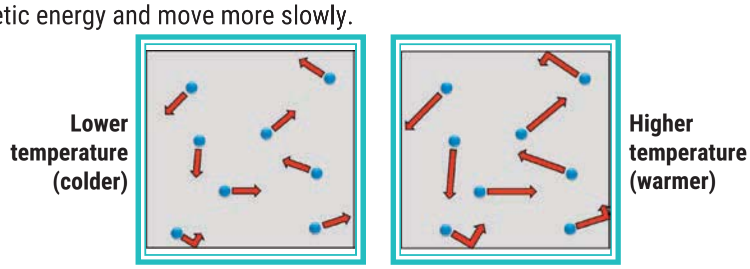
Reactants			→	Products				
Sodium bicarbonate	+	Citric acid	→	Carbon dioxide gas	+	Sodium citrate	+	Water
$3NaHCO_3$	+	$C_6H_8O_7$	→	$3CO_2$	+	$C_6H_5Na_3O_7$	+	$3H_2O$

How fast the bubbles are produced depends on how fast the reaction takes place. One factor that can change the rate of a chemical reaction is temperature. Generally, increasing the temperature increases the rate of a chemical reaction. The warmer the water, the faster the Alka-Seltzer tablet reacts.

A chemical reaction occurs when particles of the reactants run into each other. The Alka-Seltzer produces a gas because of millions of tiny collisions between sodium bicarbonate molecules and citric acid molecules, each of which produces carbon dioxide gas molecules. The particles collide because all particles have something called kinetic energy. **Kinetic energy** is the energy of motion. Anything that is moving has kinetic energy—whether it is a baseball, a car, or a cheetah.

Because particles have kinetic energy, they are always in random motion. The air particles in a room are constantly zooming around and colliding with each other, the walls, and objects in the room (unlike in Alta-Seltzer, these collisions don't cause a reaction).

Temperature is a measure of the average kinetic energy of particles in a substance. Think of temperature as how fast particles are moving around. The higher the temperature, the more kinetic energy particles have, and the faster they move. Most people think of temperature as a measure of hot and cold. If something feels "hot," that means its particles have high kinetic energy and move more quickly. If something feels "cold" its particles have low kinetic energy and move more slowly.



Each arrow shows the motion of a particle. The length of the arrow shows how fast the particle is moving—the longer the arrow, the faster it is moving. When the particles are moving faster they collide with things around them more often.

Notes

EXPLAIN continued

How does this fit in with chemical reactions? Increasing the temperature increases the rate of a reaction in two ways.

More collisions! When particles are moving faster, they are more likely to collide. Since collisions happen more often, particles react more often and the reaction goes faster.

Higher energy collisions! Not every collision results in a reaction. For two particles to react when they collide, they need to have a certain amount of energy—if they don't have enough energy, they will just collide and not react. Increasing the temperature means that particles have higher kinetic energy, and more particles have enough energy to react when they collide. This is the main way that increasing temperature increases the reaction rate.

Increasing the temperature makes the particles collide more often and makes it more likely that particles react when they collide. We can see this by putting Alka-Seltzer tablets in water at different temperatures and watching how fast the carbon dioxide bubbles are produced. The tablet in hot water produces bubbles the fastest. The tablet in cold water produces bubbles the slowest.

During this reaction, the glasses of water feel cold to the touch. This is because the reaction in Alka-Seltzer is **endothermic**, meaning that it takes in or absorbs energy from its surroundings. The feeling of "cold" is energy being transferred from your hand to the reaction mixture. Other types of reactions release energy and feel warm to the touch. These are **exothermic reactions**.

Differentiation for Younger or More Advanced Students

You can differentiate this activity for students of different grade levels by focusing on the concepts outlined below.

GETTING STARTED	DIVING DEEPER
For younger students, emphasize the following concepts: • Compounds can react with the body in certain ways based on their chemical properties • During a chemical reaction the original substances are used up, and a new substance is formed • Changing temperature changes the rate of a chemical reaction	**For more advanced students, emphasize the following concepts:** • Kinetic energy is the energy of motion, and temperature measures average kinetic energy • All particles have kinetic energy and are in constant random motion • A chemical reaction takes place when particles collide with sufficient energy

ELABORATE

Elaborate on your students' new ideas and encourage them to apply them to different situations. The section below provides some alternative methods, modifications, and extensions for this activity.

- What are other ways we could speed up a reaction? What about ways we could slow it down? Have students brainstorm some ideas and test them out. What worked and what didn't work? Why? (Hint: try the experiment again, but this time use water all at the same temperature but keep one seltzer tablet whole, break one into a few pieces, and crush the final one into a fine powder. What happens? What does this tell us about surface area and reaction rates?)
- What are some ways we could slow down the rate of reaction? Ask students to brainstorm some ideas, then test them out. Which worked? Why do they think that is? (Hint: less water, coating the tablet in something like an oil to prevent it from reacting, decreasing surface area, or cooling the water even more will all slow down the process!)
- Make a homemade lava lamp! Fill a jar 3/4 with oil and 1/4 with water. Mix in a few drops of food coloring, then drop in small pieces of seltzer tablets. Watch as the CO_2 bubbles pull the colored water up and down through the oil. Seal the jar and use again and again!
- To better understand how changes in temperature affect reaction rates, set up multiple trials at different temperatures. Students can decide how they want to display their data and add each trial they complete to a class data set, then graph the results. How does the reaction rate change as temperature changes in either direction?
- For more advanced students: look up the chemical formulas for the reactants. Can you predict any of the products? Can you balance the equation? (Sodium bicarbonate is $NaHCO_3$ and citric acid is $C_6H_8O_7$, which are the two reactants. The bubbles rising in the reaction are CO_2, which is one of the products. The other two products are sodium citrate, $C_6H_5Na_3O_7$, and water, H_2O. The unbalanced chemical equation is $NaHCO_3 + C_6H_8O_7 \rightarrow C_6H_5Na_3O_7 + CO_2 + H_2O$. The balanced chemical equation is $3NaHCO_3 + C_6H_8O_7 \rightarrow C_6H_5Na_3O_7 + 3CO_2 + 3H_2O$)

CHEMISTRY IN ACTION

Share the following real-world connections with your students to demonstrate how chemistry is all around us.

Real-World Applications

Glowsticks glow because of a chemical reaction called chemiluminescence that produces light. Temperature affects how quickly this reaction happens, so putting a glowstick in a cool environment can slow down the reaction, making the glow last longer, whereas a glowstick in a hot environment will wear out faster.

A different type of endothermic reaction is also used for pain to help people find relief. Instant cold packs consist of two bags, one of which has water in it, while a second bag around the first contains ammonium nitrate, calcium ammonium nitrate or urea. To activate the reaction, the inner bag of water is broken (from the user squeezing the package). The water then dissolves the solid around it through an endothermic reaction, creating the desired cold temperature.

Careers in Chemistry

- Seltzer tablets, like many medicines today, were created by chemists! By learning what home remedies people were using to fight illness, then replicating and testing them in the laboratory, chemists have been able to develop thousands of substances that we can easily access at the pharmacy to cure our aches and pains!
- Chemistry is important for pharmacists to know. When they advise patients on medications to take – both prescribed and over-the-counter – they need to know the molecules in each drug in detail, and how they might react with other chemicals in the body. This helps them to share information about potential uses, side effects, and any drug combinations that could be dangerous.

EVALUATE

- Ask students to try one of the simulations for temperature and reaction rate (see the examples in the Elaborate section). Ask them to explain what happens to the particles when the temperature increases or decreases? What effect does this have once the reaction starts? What do they notice when particles collide? How does temperature change the rate of collisions? What can they do to make the reaction go faster? Slower? Can they relate this to what they saw with the experiment they tried?
- If students graphed out their results, provide them with a different scenario and ask what results they would get. For example, what might be the reaction time if the water were at 2 °C? What about 97 °C? Or, provide them with a reaction time and ask what the temperature of the water likely was.
- Can students think of any reactions at home, school, or in their community where the rate changes based on temperature? Ask them to brainstorm some ideas or record their ideas throughout the week in a journal or in voice memos. Have them share their findings the next week with the class and explain the reaction, how temperature was involved, and what they noticed about the rate of reaction.