Unit 4: Energy, Rates, and Equilibrium

## Chapter 11: Reaction Rates and Equilibrium

# Lesson 1: Factors Affecting Reaction Rates

### Essential Question:

- **What factors influence the rate of a chemical reaction?**

### 1. Big Idea:

The rate of a chemical reaction depends on several factors such as temperature, concentration, surface area, and the presence of a catalyst.

### 2. Essential Questions:

1. **What factors influence the rate of a chemical reaction?**

The main factors that influence the rate of a chemical reaction are temperature, concentration, surface area, and catalysts. These factors can either speed up or slow down a reaction.

### 3.1 Phenomenon-Based Learning

- **Unit Phenomenon:**

The Thermodynamics House: Can You Solve the Puzzles and Escape?

You and your classmates are trapped in a high-tech 2-story lab escape house. To unlock the final door, you must solve puzzles that show how energy flows through chemical reactions and how reactions behave under different conditions.

- **Chapter Phenomenon:**

On the first floor of the house, there are rooms with puzzles related to controlling the speed of reactions and how they reach equilibrium.

- **Lesson 1 Phenomenon:**

Speeding Up or Slowing Down

As you enter the room, a locked box sits in the center, containing the key to move to the next room. The box will unlock if you decompose hydrogen peroxide and produce 50 oxygen bubbles within 5 minutes. You have various substances around you (water, manganese dioxide, potassium iodide, and different concentrations of hydrogen peroxide). How will you speed up the reaction and produce enough oxygen bubbles in time?

### 3.2 Lesson Phenomenon

In this lesson, you will investigate how to speed up or slow down a chemical reaction, using the example of hydrogen peroxide decomposition. By understanding how temperature, concentration, surface area, and catalysts affect the reaction, you will learn how to control reaction rates and escape the room more quickly.

### 4. Vocabulary

- **Catalyst:** A substance that increases the rate of a chemical reaction without being consumed in the process.

- **Concentration:** The amount of a substance in a given volume. Higher concentration means more particles in the same space.

- **Pressure:** The force exerted by gas particles when they collide with the walls of a container.

- **Surface Area:** The total area available for a reaction to take place.

- **Temperature:** A measure of how much kinetic energy the particles in a substance have. Higher temperatures mean faster-moving particles.

### 5. SMART Objectives

By the end of this lesson, you will be able to:

- Identify the factors that affect the rate of a reaction.

- Summarize how the collision theory explains the factors affecting reaction rates.

- Describe how temperature, concentration, surface area, and catalysts affect the rate of a reaction.

### 6. Engage (Ignite)

**Phenomenon-Related Question:**

Imagine you're in a room with a locked box, and to escape, you need to produce 50 bubbles of oxygen gas in 5 minutes by decomposing hydrogen peroxide. How can you speed up the reaction?

**Hands-On Experiment:** Decomposing Hydrogen Peroxide

Materials:

- Hydrogen peroxide (H₂O₂)

- Manganese dioxide (MnO₂)

- Water

- Potassium iodide (KI)

- Stopwatch

- Beakers

- Gas collection apparatus

**Procedure:**

1. Pour 50 mL of hydrogen peroxide into a beaker.

2. Add a small amount of manganese dioxide.

3. Start the stopwatch and observe the bubbling reaction.

4. Count how many bubbles are produced in 1 minute.

5. Try the experiment again with different conditions:

- Add potassium iodide instead of manganese dioxide.

- Use a more concentrated hydrogen peroxide solution.

- Heat the solution with a hot plate or use cold water.

6. Observe and record the time it takes to produce the required number of bubbles.

**Follow-Up Questions:**

1. Which condition produced the most bubbles in the shortest time?

- **Answer:** Adding manganese dioxide as a catalyst speeds up the reaction the most.

2. How did increasing the temperature affect the reaction rate?

- **Answer:** Increasing the temperature increased the reaction rate because the particles moved faster and collided more often.

3. What effect did changing the concentration of hydrogen peroxide have on the reaction rate?

- **Answer:** Using a more concentrated hydrogen peroxide solution increased the reaction rate because there were more particles to react.

### 7. Pre-Explore (Direct Instruction)

**Background Information:**

In chemical reactions, reactants must collide with enough energy to break existing bonds and form new ones. This is the basis of the **collision theory**. The rate of a reaction depends on how often the particles collide and how much energy they have during the collisions.

The factors that affect reaction rates include:

- **Temperature:** Higher temperatures give particles more energy, causing them to move faster. Faster particles collide more often and with more energy, making the reaction happen faster.

- **Concentration:** A higher concentration of reactants means more particles are present. More particles result in more frequent collisions, increasing the reaction rate.

- **Surface Area:** If one of the reactants is a solid, breaking it into smaller pieces increases the surface area. The more surface area, the more places where collisions can happen, speeding up the reaction.

- **Catalysts:** Catalysts provide an alternative pathway for the reaction with a lower activation energy. This means that even at the same temperature, more particles will have enough energy to react, so the reaction rate increases.

**Discussion Questions:**

1. Why do you think a catalyst helps speed up a chemical reaction?

- **Answer:** A catalyst lowers the activation energy, which means that more particle collisions result in a reaction.

2. What is the relationship between particle collisions and temperature?

- **Answer:** At higher temperatures, particles move faster, causing more frequent and energetic collisions, which increases the reaction rate.

### 8. Evaluate (Progress Check) - Pre-Explore

**Scaffolded Questions:**

1. What would happen to the reaction rate if you cooled down the hydrogen peroxide solution?

- **Answer:** The reaction rate would decrease because the particles would move slower and collide less often.

2. Why does increasing the concentration of hydrogen peroxide speed up the reaction?

- **Answer:** More hydrogen peroxide molecules result in more collisions between reactant particles, increasing the chance of a reaction.

3. How does breaking a solid reactant into smaller pieces affect the reaction rate?

- **Answer:** Breaking the solid increases the surface area, giving more places for collisions to happen, which speeds up the reaction.

### 9. Explain (Lightbulb)

**Core Concept: Factors Affecting Reaction Rates**

Chemical reactions can happen quickly or slowly. Think about the rusting of iron—it takes a long time for iron to rust. But when you light a match, the chemicals react almost instantly. What makes one reaction fast and another slow? Several factors can influence the speed, or rate, of a chemical reaction.

Let's break these factors down:

### 1. Temperature

Temperature is one of the most important factors affecting reaction rates. When you heat a substance, its particles gain energy. This added energy makes them move faster. The faster the particles move, the more likely they are to collide with other particles. Not only do they collide more often, but they also collide with more energy.

According to the **collision theory**, only particles that collide with enough energy will react. This energy is called the **activation energy**. Heating a substance increases the number of particles that have enough energy to overcome the activation energy barrier. As a result, the reaction rate increases.

**Example Problem:**

You are given two beakers, one containing hydrogen peroxide at room temperature and the other containing hydrogen peroxide heated to 50°C. Which one will decompose faster, and why?

- **Answer:** The hydrogen peroxide at 50°C will decompose faster because the higher temperature gives the molecules more energy, making them collide more frequently and with more energy, which increases the reaction rate.

**Student Problem:**

Imagine you left milk outside on a hot summer day and another container of milk in the refrigerator. Which one would spoil faster, and why?

- **Answer:** The milk left outside will spoil faster because the higher temperature speeds up the reactions that cause the milk to spoil.

### 2. Concentration

The concentration of reactants also affects the rate of a chemical reaction. In a concentrated solution, there are more reactant particles in a given volume. This increases the chances of particle collisions, speeding up the reaction.

**Example Problem:**

If you have two solutions of hydrochloric acid (HCl), one with a concentration of 1 M and the other with a concentration of 0.1 M, which solution will react more quickly with a piece of magnesium?

- **Answer:** The 1 M solution will react more quickly because it has more HCl particles per unit of volume, leading to more frequent collisions with the magnesium atoms, thus speeding up the reaction.

**Student Problem:**

Why do effervescent tablets dissolve faster in concentrated vinegar than in water?

- **Answer:** The concentrated vinegar has more acetic acid molecules, so there are more collisions with the tablet, causing it to dissolve faster.

### 3. Surface Area

The surface area of a solid reactant can also affect the reaction rate. If you break a solid into smaller pieces, you increase its surface area. A larger surface area means more particles are exposed to react, leading to more collisions and a faster reaction.

**Example Problem:**

Why does powdered sugar dissolve faster in water than a sugar cube?

- **Answer:** Powdered sugar has a larger surface area than the sugar cube. This means more sugar particles are exposed to the water, so they dissolve faster.

**Student Problem:**

If you want to quickly dissolve a piece of chalk in vinegar, would you use a whole piece or crush it into powder first?

- **Answer:** Crushing the chalk into powder would make it dissolve faster because the powder has a larger surface area, allowing for more collisions with the vinegar.

### 4. Catalysts

Catalysts are substances that speed up chemical reactions without being consumed. They work by providing an alternative reaction pathway with a lower activation energy. This means that more particles will have enough energy to react, even at lower temperatures.

An example of a catalyst is **manganese dioxide (MnO₂)**, which speeds up the decomposition of hydrogen peroxide into water and oxygen gas.

**Example Problem:**

Why does adding a small amount of manganese dioxide to hydrogen peroxide cause it to bubble faster?

- **Answer:** Manganese dioxide acts as a catalyst by lowering the activation energy, allowing the hydrogen peroxide molecules to decompose more quickly into water and oxygen.

**Student Problem:**

Why are enzymes, which are biological catalysts, important for speeding up reactions in your body?

- **Answer:** Enzymes lower the activation energy for important reactions in your body, allowing these reactions to happen quickly enough to sustain life.

### 10. Explore (Student-Led Inquiry)

Have students experiment with different concentrations of hydrogen peroxide, temperatures, and catalysts to see how these factors affect the rate of oxygen bubble production.

### 11. Evaluate (Progress Check) - Post-Explore

**Scaffolded Questions:**

1. What happens to the reaction rate when you increase the surface area of a solid reactant?

- **Answer:** The reaction rate increases because more of the solid is exposed to react, leading to more frequent collisions.

2. What is the role of a catalyst in a reaction?

- **Answer:** A catalyst speeds up the reaction by providing an alternative pathway with a lower activation energy.

3. How does concentration affect the rate of a reaction?

- **Answer:** A higher concentration increases the reaction rate because there are more particles available to collide.

### Conclusion

By now, you should have a clear understanding of the factors that affect the rate of a chemical reaction. Whether it's temperature, concentration, surface area, or the use of a catalyst, each factor plays a crucial role in how fast or slow a reaction occurs. Understanding these factors is key to controlling reactions in everyday life, from cooking food to making industrial chemical processes more efficient.

### 10. Evaluate (Progress Check) - Explain

1. **What is the difference between a physical change and a chemical change?**

**Answer**: A physical change alters the form or state of a substance without changing its chemical composition. For example, melting ice is a physical change because water stays as H₂O. A chemical change results in the formation of a new substance with different properties, such as when iron rusts to form iron oxide.

2. **List three indicators that a chemical reaction has occurred.**

**Answer**: Common indicators of chemical reactions include:

a. Production of gas (bubbles)

b. Change in color

c. Formation of a precipitate (solid) or release of heat/light.

3. **Why is the Law of Conservation of Mass important when studying chemical reactions?**

**Answer**: The Law of Conservation of Mass states that mass is neither created nor destroyed in a chemical reaction. This means that the total mass of the reactants must equal the total mass of the products. This law helps chemists balance chemical equations and ensures that no matter is lost or gained during reactions.

### 11. Elaborate (Power Up)

1. **Mini-task: Create your own experiment to demonstrate a chemical reaction. Describe the materials you would use and what you expect to observe.**

**Answer**: Materials could include vinegar (acetic acid) and baking soda (sodium bicarbonate). When combined, they react to form carbon dioxide gas, water, and sodium acetate. I would expect to see bubbles forming, which indicate gas production, and hear a fizzing sound, signaling the reaction taking place.

2. **Open-ended question: How would you explain the importance of chemical reactions in everyday life? Provide examples.**

**Answer**: Chemical reactions are essential for many everyday processes. For instance, cooking involves chemical changes (like when baking soda reacts to make dough rise). Digestion is another example, where food is broken down chemically to release energy. Combustion in engines also involves chemical reactions that fuel cars.

3. **Mini-task: Think of two situations where you want to prevent chemical reactions from happening. How would you stop them?**

**Answer**: One situation could be preventing rust on metal. Coating the metal with paint or oil prevents oxygen from reacting with it. Another situation is keeping food from spoiling; refrigeration slows down the chemical reactions that cause food to rot.

### 12. Final Evaluation

**Debate Question**:

Should society invest more in chemical research to solve environmental problems like pollution and climate change?

- **Arguments For**: Chemical research can help create cleaner energy sources, develop methods to reduce plastic waste, and design materials that are more environmentally friendly. For example, research might lead to better recycling processes or biodegradable plastics.

- **Arguments Against**: Some might argue that chemical research is expensive and that the focus should be on other areas like policy changes or renewable energy technologies. Additionally, there could be concerns about unintended consequences of new chemicals on health and the environment.

**Multiple-Choice Questions:**

1. **Which of the following is an example of a chemical change?**

a) Melting ice

b) Dissolving sugar in water

c) Baking a cake

d) Breaking a glass

**Correct Answer**: c) Baking a cake

**Explanation**: Baking a cake involves chemical reactions (like the formation of new compounds) that change the ingredients into a new substance.

2. **What happens to the atoms in a substance during a chemical reaction?**

a) They are destroyed

b) They are rearranged

c) They stay the same

d) They disappear

**Correct Answer**: b) They are rearranged

**Explanation**: During a chemical reaction, the atoms in the reactants are rearranged to form new products, but they are not destroyed or created.

3. **Which is NOT an indicator of a chemical reaction?**

a) Change in color

b) Formation of a precipitate

c) Change in state from solid to liquid

d) Release of gas

**Correct Answer**: c) Change in state from solid to liquid

**Explanation**: A change in state (like melting) is a physical change, not a chemical one.

4. **According to the Law of Conservation of Mass, what must be true in a chemical reaction?**

a) The total mass of reactants equals the total mass of products

b) The mass of the products is always greater

c) The mass of the products is always less

d) Mass is created during the reaction

**Correct Answer**: a) The total mass of reactants equals the total mass of products

**Explanation**: The Law of Conservation of Mass states that mass is neither created nor destroyed, so the mass remains constant.

**Long-Answer Questions:**

1. **Describe how the Law of Conservation of Mass applies to balancing a chemical equation.**

**Answer**: In a chemical reaction, the total mass of the reactants must equal the total mass of the products, according to the Law of Conservation of Mass. This means that when we write a chemical equation, we need to ensure that the number of atoms of each element on the reactant side is the same as the number of atoms on the product side. Balancing the equation ensures that mass is conserved.

2. **Explain how temperature can affect the rate of a chemical reaction. Provide an example.**

**Answer**: Temperature can increase the rate of a chemical reaction because it gives the reactant particles more energy, causing them to move faster and collide more frequently. For example, when you heat sugar in water, it dissolves faster than in cold water because the higher temperature speeds up the reaction.

3. **Why is it important to understand the difference between endothermic and exothermic reactions? Give an example of each.**

**Answer**: Understanding the difference is important because it helps us predict how a reaction will affect its surroundings. Exothermic reactions release energy, like when wood burns to produce heat. Endothermic reactions absorb energy, like when ice melts, taking heat from the surroundings.

4. **How can chemical reactions be used to solve environmental issues? Provide a specific example.**

**Answer**: Chemical reactions can be used to develop cleaner energy sources and reduce pollution. For instance, the development of catalytic converters in cars uses chemical reactions to convert harmful gases like carbon monoxide into less harmful substances like carbon dioxide and water, reducing air pollution.

### 13. Extend (Beyond the Lesson)

1. **Additional Task**: Research the role of catalysts in speeding up chemical reactions. Write a short report on how catalysts are used in industrial processes, such as the production of ammonia or biofuels.

**Challenge**: Consider how catalysts might be used to reduce energy consumption in everyday processes.

2. **Reading Assignment**: Read an article on green chemistry and write a summary. How does green chemistry aim to reduce the environmental impact of chemical processes?

**Challenge**: Propose a way that green chemistry principles could be applied in your own home.

3. **Real-World Application**: Think about the chemical changes that happen in food preservation. Why do we refrigerate food? How do chemical reactions slow down in cold temperatures? Describe an alternative method of preserving food that also relies on controlling chemical reactions (e.g., pickling or dehydration).

4. **Spaced Practice**: Over the next week, observe and list examples of physical and chemical changes in your daily life. Review your notes and classify each example. How does understanding these changes help in everyday problem-solving, such as cooking or cleaning?

These tasks will help reinforce the concepts learned and apply them to new and real-world situations, deepening the understanding of chemical reactions and their importance.