# Unit 4: Energy, Rates, and Equilibrium

## Chapter 11: Reaction Rates and Equilibrium

# Lesson Title: Factors Affecting Reaction Rates

### Essential Questions:

- What factors influence the rate of a chemical reaction?

### 1. Big Idea:

The rate at which a chemical reaction occurs depends on several factors, including temperature, concentration, surface area, and the presence of a catalyst.

### 2. Essential Questions:

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

The factors that influence the rate of a chemical reaction include temperature, concentration of reactants, surface area of the reactants, pressure (for gases), and catalysts. These factors affect how often and how effectively particles collide, which is key to the reaction rate.

### 3.1 Phenomenon-Based Learning:

**Unit Phenomenon:**

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

In this unit, you are trapped in a high-tech laboratory and must solve puzzles involving energy and chemical reactions to escape. To unlock the final door, you must learn how chemical reactions behave under different conditions.

**Chapter Phenomenon:**

In this chapter, you will explore how to control the speed of reactions and how reactions reach equilibrium during your journey through the first story of the escape house.

### 3.2 Lesson Phenomenon:

**Lesson 1 Phenomenon:** "Speeding Up or Slowing Down"

As you enter the first room in the escape house, you see a large, locked box. Inside the box is the key to move forward. The box will unlock if you can decompose hydrogen peroxide and produce at least 50 bubbles of oxygen gas within 5 minutes. Around the box, there are bottles labeled "water," "manganese dioxide," "potassium iodide," and various concentrations of hydrogen peroxide (H₂O₂). You must figure out how to speed up the decomposition of hydrogen peroxide to release enough oxygen gas to unlock the box.

The lesson phenomenon here is focused on speeding up or slowing down the decomposition of hydrogen peroxide. By understanding how different factors affect the rate of this reaction, you can solve the puzzle and unlock the box.

### 4. Vocabulary:

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

- **Concentration:** The amount of a substance in a given volume. Increasing concentration usually increases the rate of reaction.

- **Pressure:** In reactions involving gases, higher pressure increases the rate of reaction by bringing gas molecules closer together.

- **Surface Area:** The total area of the surface of a solid. A larger surface area increases the rate of reaction by providing more space for collisions to occur.

- **Temperature:** A measure of how hot or cold something is. Higher temperatures increase the energy of particles, leading to more frequent and effective collisions.

### 5. SMART Objectives:

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

- Summarize how the collision theory accounts for the factors affecting reaction rates.

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

### 6. Engage (Ignite)

**Activity: Decomposing Hydrogen Peroxide**

You are tasked with decomposing hydrogen peroxide (H₂O₂) to release oxygen gas. Follow the steps to see how different factors affect the speed of this reaction.

**Materials Required:**

- Hydrogen peroxide (H₂O₂)

- A few small pieces of manganese dioxide (MnO₂)

- An empty water bottle

- A balloon

- Timer

**Instructions for Hands-On Experiment:**

1. Pour 50 mL of hydrogen peroxide into the water bottle.

2. Stretch the balloon over the mouth of the bottle without letting any air escape.

3. Start the timer and observe. How long does it take for the balloon to inflate with oxygen gas as the hydrogen peroxide decomposes?

4. Now, add a small amount of manganese dioxide (a catalyst) to a new bottle with 50 mL of hydrogen peroxide. Stretch a fresh balloon over the mouth of the bottle and start the timer. Observe how the reaction changes and how fast the balloon inflates.

5. Compare the time it took for the balloon to inflate in both cases.

**Follow-Up Questions:**

1. **What was the difference in the speed of the reaction when manganese dioxide was added?**

- The reaction with manganese dioxide was faster because manganese dioxide acts as a catalyst, speeding up the decomposition of hydrogen peroxide.

2. **Why do you think the reaction was faster with the catalyst?**

- Catalysts lower the activation energy needed for the reaction, allowing more particle collisions to result in a reaction.

3. **How would changing the temperature or concentration of hydrogen peroxide affect the reaction rate?**

- Increasing the temperature or concentration would also speed up the reaction by making particle collisions more frequent and energetic.

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

**Background Information:**

Chemical reactions occur when particles (atoms, ions, or molecules) collide with enough energy to break bonds and form new ones. This is known as the **collision theory**. For a reaction to happen, particles must:

- Collide with enough energy (called activation energy)

- Collide in the right orientation

Several factors can increase the number of successful collisions, thereby speeding up the reaction. These factors include:

1. **Temperature**: Higher temperatures give particles more energy, making them move faster and collide more often and with greater force.

2. **Concentration**: When the concentration of reactants is higher, there are more particles in a given volume, leading to more collisions.

3. **Surface Area**: For solid reactants, breaking them into smaller pieces increases the surface area, allowing more collisions to happen.

4. **Catalysts**: Catalysts provide an alternative pathway for the reaction, requiring less energy for the reaction to proceed.

5. **Pressure**: In reactions involving gases, increasing the pressure pushes particles closer together, increasing the frequency of collisions.

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

**Scaffolded Questions:**

1. **What is one way to speed up a chemical reaction?**

- Increasing the temperature is one way to speed up a chemical reaction.

2. **How does a catalyst affect a reaction?**

- A catalyst speeds up a reaction by lowering the activation energy required for the reaction to take place.

3. **What happens to the rate of reaction when the concentration of reactants increases?**

- The rate of reaction increases because there are more particles available to collide and react.

### 9. Explain (Lightbulb)

Now that you’ve explored how reactions work, let’s dive deeper into the factors that affect reaction rates. Understanding these factors will help you solve the puzzle in the escape house and get out of the first room.

### 9.1 Collision Theory – The Science Behind Reactions

According to the **collision theory**, for a reaction to happen, particles must collide with enough energy and in the correct orientation. If the energy is too low, or if the particles collide at the wrong angle, no reaction will take place.

The minimum amount of energy required for a reaction to happen is called the **activation energy**. Think of activation energy as the "energy barrier" that particles need to overcome to start reacting.

### Real-World Example:

Imagine you are lighting a match. Simply holding the matchstick isn't enough; you need to strike it against a rough surface to create enough friction (energy) for it to ignite. The friction provides the activation energy needed for the reaction (ignition) to happen.

### 9.2 Temperature – Heating Things Up

Temperature is one of the most important factors that affect reaction rates. When you heat something, its particles move faster. Faster-moving particles collide more often and with more energy, making it more likely that a reaction will happen.

**Illustration**:

Think about boiling pasta in water. If the water is cold, it will take a long time for the pasta to soften. But if you heat the water, the pasta cooks much faster because the molecules in the hot water are moving rapidly, and they transfer their energy to the pasta more quickly.

**Sample Problem**:

Suppose you are decomposing hydrogen peroxide at room temperature, and it takes 10 minutes to produce 50 bubbles of oxygen gas. If you heat the solution to 50°C, will the reaction go faster or slower? Explain why.

**Answer**:

The reaction will go faster because increasing the temperature gives the particles more energy, resulting in more frequent and energetic collisions.

**Progress Check:**

If a reaction slows down, what could be happening to the temperature?

- The temperature may be decreasing, causing the particles to move more slowly and collide less frequently.

### 9.3 Concentration – More Particles, More Collisions

Concentration refers to the number of particles in a given volume. If you increase the concentration of reactants, you increase the number of particles that can collide, thereby speeding up the reaction.

**Real-World Example**:

Think about a crowded room. In a room full of people, you are more likely to bump into someone than in an empty room. The same applies to molecules in a chemical reaction. If the concentration of particles is high, they are more likely to collide and react.

**Sample Problem**:

You have two solutions of hydrogen peroxide: one has a concentration of 3%, and the other has a concentration of 6%. Which solution will decompose faster, and why?

**Answer**:

The 6% solution will decompose faster because it has a higher concentration of hydrogen peroxide molecules, leading to more collisions.

**Progress Check:**

What happens to the reaction rate if the concentration of reactants decreases?

- The reaction rate decreases because there are fewer particles available to collide and react.

### 9.4 Surface Area – Bigger Isn’t Always Better

For solid reactants, surface area plays a big role in how fast a reaction occurs. If you break a solid into smaller pieces, you increase its surface area. This means more particles are exposed to the other reactants, leading to more collisions.

**Real-World Example**:

Think about how quickly sugar dissolves in water. A sugar cube takes longer to dissolve than granulated sugar because the cube has less surface area in contact with the water. When you break the cube into smaller grains, more sugar particles are exposed to the water, and it dissolves faster.

**Sample Problem**:

You are burning a log. Will it burn faster if you chop it into smaller pieces or leave it whole? Explain why.

**Answer**:

The log will burn faster if chopped into smaller pieces because this increases the surface area, allowing more oxygen to come into contact with the wood, speeding up the combustion reaction.

**Progress Check:**

How does surface area affect the rate of a chemical reaction?

- A larger surface area increases the rate of reaction by providing more spaces for collisions to occur.

### 9.5 Catalysts – Speeding Up Without Being Used Up

A **catalyst** is a substance that speeds up a reaction without being consumed in the process. Catalysts provide an alternative pathway for the reaction, one that requires less activation energy. This means that more particles can collide with enough energy to react.

**Real-World Example**:

Catalytic converters in cars use catalysts to speed up the reaction that breaks down harmful gases like carbon monoxide into less harmful substances. Without the catalyst, these reactions would happen too slowly to make a difference.

**Sample Problem**:

In the decomposition of hydrogen peroxide, adding manganese dioxide dramatically speeds up the reaction. Why does this happen?

**Answer**:

Manganese dioxide acts as a catalyst, lowering the activation energy needed for the decomposition of hydrogen peroxide, allowing the reaction to happen faster.

**Progress Check:**

What effect does a catalyst have on the activation energy of a reaction?

- A catalyst lowers the activation energy needed for the reaction to occur, speeding up the reaction.

### 10. Conclusion

In this lesson, you explored how temperature, concentration, surface area, and catalysts influence the rate of chemical reactions. By understanding these factors, you can control how fast or slow a reaction happens, which is crucial in many real-world applications, from cooking to industrial processes.

You’ve also learned how the collision theory explains why these factors work the way they do. Now, you should be ready to apply this knowledge to solve the puzzle in the escape house and unlock the box. Good luck!

### Final Progress Check:

1. **What are the four main factors that affect the rate of a chemical reaction?**

- Temperature, concentration, surface area, and catalysts.

2. **How does temperature affect the rate of a reaction?**

- Increasing the temperature increases the energy of the particles, leading to more frequent and effective collisions.

3. **Why does increasing the surface area of a solid reactant speed up a reaction?**

- Increasing the surface area exposes more particles to collisions, speeding up the reaction.

By the end of this lesson, you should be able to describe how each of the factors affects the rate of a chemical reaction and summarize how the collision theory explains these effects.

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

Let’s check how well you understood the concepts we covered in the "Explain" section.

**Question 1:**

What is an element?

**Answer:**

An element is a pure substance that cannot be broken down into simpler substances by chemical means. Each element is made up of one type of atom.

**Question 2:**

How does a chemical reaction differ from a physical change?

**Answer:**

In a chemical reaction, new substances are formed with different properties than the original substances. In contrast, in a physical change, the substance remains the same even though it may change states (like ice melting into water).

**Question 3:**

Why is the conservation of mass important in chemical reactions?

**Answer:**

The conservation of mass is important because it tells us that matter cannot be created or destroyed in a chemical reaction. This explains why the mass of the products must equal the mass of the reactants.

### 11. Elaborate (Power Up)

Let’s take it a step further by thinking more deeply about the concepts.

**Mini-Task:**

Imagine you are a scientist trying to create a new compound. How would you use your understanding of chemical reactions to ensure the right substances combine to form the compound you want?

**Answer:**

I would use my knowledge of chemical reactions and the properties of different elements and compounds. I would carefully choose reactants that, when combined, would undergo a reaction to form the desired compound. I would also pay attention to the law of conservation of mass to make sure I have the right amounts of each reactant.

**Open-Ended Question:**

How would the world be different if chemical reactions didn’t follow the law of conservation of mass? What practical problems might arise?

**Answer:**

If chemical reactions didn’t follow the law of conservation of mass, it would be difficult to predict the outcomes of reactions. Factories producing chemicals might end up with unexpected amounts of products, leading to waste or dangerous situations. Everyday processes, like cooking or even breathing, could become unpredictable.

### 12. Final Evaluation

Let’s wrap up by testing your understanding with some assessment questions and a debate.

### Debate Question:

**Debate:**

"Should the study of chemical reactions focus more on their practical uses or the theoretical understanding behind them?"

**Arguments for Practical Uses:**

- Practical uses help solve real-world problems, like creating new medicines or materials.

- Understanding applications helps students see the relevance of chemistry in their lives.

**Arguments for Theoretical Understanding:**

- A strong theoretical understanding allows scientists to predict new reactions and discover unknown compounds.

- Theory forms the foundation for all practical uses in the long run, leading to more innovation.

### Multiple-Choice Questions:

**Question 1:**

Which of the following is an example of a chemical reaction?

a) Water freezing into ice

b) Paper burning into ash

c) Breaking a glass bottle

d) Melting butter in a pan

**Answer:**

b) Paper burning into ash.

Explanation: Burning paper creates new substances (ash, smoke), which is a chemical reaction.

**Question 2:**

What must always be conserved in a chemical reaction?

a) Energy

b) Volume

c) Mass

d) Temperature

**Answer:**

c) Mass.

Explanation: According to the law of conservation of mass, mass is always conserved in a chemical reaction.

**Question 3:**

Which of the following statements is true about elements?

a) Elements can be broken down into simpler substances.

b) Elements are made up of different types of atoms.

c) Elements are pure substances.

d) Elements always exist in compound form.

**Answer:**

c) Elements are pure substances.

Explanation: An element is a pure substance consisting of only one type of atom.

**Question 4:**

What is the result of a chemical change?

a) A new substance is formed.

b) The substance remains unchanged.

c) The substance changes its state.

d) The substance melts.

**Answer:**

a) A new substance is formed.

Explanation: A chemical change results in the formation of new substances with different properties.

### Long-Answer Questions:

**Question 1:**

Explain the difference between an endothermic and exothermic reaction. Give an example of each.

**Answer:**

An endothermic reaction absorbs heat from its surroundings. For example, when ice melts, it absorbs heat. An exothermic reaction releases heat. An example is the burning of wood, which releases heat and light.

**Question 2:**

Describe how the conservation of mass applies to a reaction where hydrogen gas reacts with oxygen gas to form water.

**Answer:**

In this reaction, the mass of the hydrogen gas and oxygen gas before the reaction will equal the mass of the water produced. No matter is lost or gained, as the total number of atoms remains the same, just rearranged into a new substance (water).

**Question 3:**

Why is it important to balance chemical equations, and how does this relate to the law of conservation of mass?

**Answer:**

Balancing chemical equations ensures that the number of atoms of each element is the same on both sides of the equation. This reflects the law of conservation of mass, which states that mass cannot be created or destroyed in a chemical reaction.

**Question 4:**

Describe a real-world scenario where understanding chemical reactions is essential, and explain how knowledge of these reactions can be applied in that scenario.

**Answer:**

In the pharmaceutical industry, understanding chemical reactions is crucial for creating medicines. Chemists must know how different substances react to produce the active ingredients in drugs. They also ensure that the reactions are safe, effective, and produce the correct amount of the desired product.

### 13. Extend (Beyond the Lesson)

To deepen your understanding, here are some additional challenges and readings:

**Task:**

Research the role of chemical reactions in environmental science. How do chemical reactions contribute to issues like climate change, and how might they help solve these problems?

**Reading:**

Read about how the Haber process, a chemical reaction used to produce ammonia, has impacted agriculture and food production globally. Consider the environmental and societal effects of this reaction.

**Activity:**

Experiment with a simple chemical reaction at home, such as mixing baking soda and vinegar to produce carbon dioxide. Keep track of the amounts used and the gas produced. Can you explain what’s happening in terms of the conservation of mass?

**Spaced Practice:**

Over the next few weeks, revisit the following questions periodically to reinforce your understanding:

- Why does the conservation of mass apply to all chemical reactions?

- How are chemical reactions essential to life on Earth, like in breathing and digestion?

These activities will help you apply what you’ve learned to new situations and deepen your understanding of the role of chemical reactions in the world around you.