# Unit: Unit 4: Energy, Rates, and Equilibrium

## Chapter: Chapter 11: Reaction Rates and Equilibrium

### Lesson: Lesson 1: Factors Affecting Reaction Rates

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### Essential Questions:

- What factors influence the rate of a chemical reaction?

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### 1. Big Idea:

The speed of a chemical reaction can be influenced by several factors, including temperature, concentration, surface area, and the presence of a catalyst.

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### 2. Essential Questions:

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

**Answer:** The rate of a chemical reaction can be influenced by several factors, including:

1. **Temperature**: Increasing temperature generally increases the reaction rate.

2. **Concentration**: Higher concentration of reactants usually leads to faster reactions.

3. **Surface Area**: More surface area allows for more collisions, speeding up the reaction.

4. **Catalysts**: Catalysts speed up reactions without being consumed.

5. **Pressure**: In reactions involving gases, increasing pressure can increase the reaction rate.

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### 3.1 Phenomenon-Based Learning

### # Unit Phenomenon:

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

### # Chapter Phenomenon:

In the first story of the house, you encounter puzzles related to controlling how fast reactions occur and how they reach a state of balance.

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

In the first room, a locked box contains the key to move forward. The box will unlock if you decompose hydrogen peroxide (H₂O₂) and produce at least 50 bubbles of oxygen gas in 5 minutes. Around the box are bottles labeled with different substances: water, manganese dioxide, potassium iodide, and various concentrations of hydrogen peroxide. Your task is to figure out how to speed up the reaction to unlock the box.

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### 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.

- **Pressure**: The force exerted by the gas particles in a container.

- **Surface Area**: The total area of the surface of a solid reactant.

- **Temperature**: A measure of the average kinetic energy of the particles in a substance.

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### 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.

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### 6. Engage (Ignite)

### # Phenomenon-Related Question:

- **What can you do to make the hydrogen peroxide decompose faster to unlock the box?**

### # Hands-on Experiment: Decomposing Hydrogen Peroxide

**Materials Needed:**

- Hydrogen peroxide (3%)

- Manganese dioxide (or yeast as a safer alternative)

- Water

- Potassium iodide (optional)

- Test tubes

- Stopwatch

- Measuring spoons

**Procedure:**

1. Pour 20 mL of hydrogen peroxide into a test tube.

2. Add a small amount of manganese dioxide (or yeast) to the test tube.

3. Observe the reaction and count the number of oxygen bubbles produced in 1 minute.

4. Repeat the experiment with different concentrations of hydrogen peroxide (e.g., 1%, 3%, 6%) and record the number of bubbles in each case.

5. Try adding water to dilute the hydrogen peroxide and observe how the reaction changes.

**Follow-up Questions:**

1. **What effect did the manganese dioxide (or yeast) have on the reaction?**

- **Answer:** It sped up the reaction, producing more bubbles in a shorter time. This is because manganese dioxide acts as a **catalyst**, lowering the activation energy needed for the reaction to occur.

2. **How did changing the concentration of hydrogen peroxide affect the reaction rate?**

- **Answer:** Higher concentrations of hydrogen peroxide produced more bubbles faster. This is because a higher concentration means more reactant particles are available to collide and react.

3. **What do you think would happen if you increased the temperature of the hydrogen peroxide?**

- **Answer:** Increasing the temperature would likely speed up the reaction, as the particles would move faster and collide more frequently.

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

### # Background Information:

To understand why reactions speed up or slow down, we need to look at **collision theory**. This theory states that for a reaction to occur, particles must collide with enough energy and the right orientation. The rate of a reaction depends on how often and how energetically these collisions happen.

- **Temperature**: When temperature increases, particles move faster and collide more often with more energy. This results in a faster reaction.

- **Concentration**: When the concentration of reactants is higher, there are more particles in a given space, leading to more collisions and a faster reaction.

- **Surface Area**: If a solid reactant has more surface area (for example, if it's powdered instead of in large chunks), more particles are exposed and available to collide, speeding up the reaction.

- **Catalysts**: Catalysts work by lowering the activation energy needed for a reaction to occur, allowing more collisions to be successful.

- **Pressure**: In reactions involving gases, increasing the pressure pushes the gas particles closer together, leading to more collisions and a faster reaction.

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

1. **What is the collision theory?**

- **Answer:** Collision theory explains that chemical reactions occur when particles collide with enough energy and the correct orientation.

2. **How does increasing the surface area of a reactant affect the reaction rate?**

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

3. **Why does a catalyst speed up a reaction?**

- **Answer:** A catalyst lowers the activation energy, making it easier for reactants to collide and react.

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### 9. Explain (Lightbulb)

### # Core Concepts of the Lesson:

In this lesson, we are focusing on the factors that affect the rate of a chemical reaction. These factors include **temperature**, **concentration**, **surface area**, **catalysts**, and **pressure**. Let's break down each factor and understand how they influence the speed of a reaction.

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### # 1. Temperature and Reaction Rate:

When you heat up a substance, the particles inside it start to move faster. This happens because temperature is a measure of the average kinetic energy of the particles. The faster the particles move, the more likely they are to collide with each other. But it’s not just about colliding; they need to collide with enough energy to break bonds and form new ones.

- **Real-World Example**: Think about cooking. When you boil water, the heat makes the water molecules move faster, and eventually, they turn into steam. Similarly, when you heat up a reaction, the particles move faster, and the reaction speeds up.

**Sample Problem**:

If you increase the temperature of a reaction from 20°C to 40°C, what happens to the rate of the reaction?

**Answer**:

The rate of the reaction will increase because the particles are moving faster and colliding more often with enough energy.

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### # 2. Concentration and Reaction Rate:

Concentration refers to how much of a substance is present in a given volume. When the concentration of reactants is higher, there are more particles available to collide. More collisions mean a faster reaction.

- **Real-World Example**: Imagine a crowded room. In a crowded room, you're more likely to bump into someone than if the room is empty. Similarly, in a reaction with a high concentration of particles, collisions happen more frequently.

**Sample Problem**:

If you increase the concentration of a reactant, how will it affect the reaction rate?

**Answer**:

The reaction rate will increase because more particles are available to collide, leading to more successful reactions.

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### # 3. Surface Area and Reaction Rate:

Surface area is important in reactions that involve solids. If a solid reactant is broken into smaller pieces, more of its surface is exposed to the other reactants. This increases the chances of collisions and speeds up the reaction.

- **Real-World Example**: Think about sugar cubes versus powdered sugar. If you dissolve a sugar cube in water, it takes longer to dissolve than powdered sugar because the powdered sugar has more surface area exposed to the water.

**Sample Problem**:

Why does powdered sugar dissolve faster than a sugar cube?

**Answer**:

Powdered sugar has a larger surface area, allowing more sugar particles to come into contact with the water, speeding up the reaction.

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### # 4. Catalysts and Reaction Rate:

A **catalyst** is a substance that speeds up a reaction without being used up in the process. It works by lowering the **activation energy**, which is the minimum energy needed for a reaction to occur. With a catalyst, more particles have enough energy to react, so the reaction happens faster.

- **Real-World Example**: Catalysts are used in car engines to speed up the breakdown of harmful gases into less harmful substances. Without the catalyst, these reactions would happen too slowly to be effective.

**Sample Problem**:

How does a catalyst affect the activation energy of a reaction?

**Answer**:

A catalyst lowers the activation energy, making it easier for particles to collide and react.

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### # 5. Pressure and Reaction Rate:

Pressure affects reactions involving gases. When the pressure is increased, the gas particles are forced closer together, leading to more frequent collisions. This increases the reaction rate.

- **Real-World Example**: In a pressure cooker, the increased pressure speeds up the cooking process by forcing water molecules to collide more frequently, which heats the food faster.

**Sample Problem**:

How does increasing the pressure of a gas affect the reaction rate?

**Answer**:

Increasing the pressure forces the gas particles closer together, leading to more collisions and a faster reaction.

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

1. **What happens to the reaction rate when the temperature is increased?**

- **Answer**: The reaction rate increases because the particles move faster and collide more often with enough energy.

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

- **Answer**: More surface area means more particles are exposed and available to collide, leading to a faster reaction.

3. **How does a catalyst make a reaction happen faster?**

- **Answer**: A catalyst lowers the activation energy, allowing more particles to collide with enough energy to react.

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### 11. Elaborate (Deep Dive)

Now that we’ve explored the factors that affect reaction rates, let’s connect these ideas back to the **escape room** scenario. In the first room, you were tasked with decomposing hydrogen peroxide to produce oxygen gas. By adding manganese dioxide, you introduced a **catalyst** that sped up the reaction. If you had used a higher concentration of hydrogen peroxide, the reaction would have been even faster, producing more bubbles in less time.

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### 12. Extend (Apply)

Now that you understand the factors affecting reaction rates, think about how these concepts apply to real-world situations. For example, in the food industry, enzymes (which are biological catalysts) are used to speed up reactions in the production of cheese and bread. Similarly, in medicine, reaction rates are carefully controlled to ensure that drugs are released into the body at the right speed.

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### 13. Evaluate (Final Progress Check)

1. **If you wanted to slow down a reaction, what could you do?**

- **Answer**: You could lower the temperature, decrease the concentration of reactants, reduce the surface area, or remove any catalysts.

2. **Why do reactions happen faster at higher temperatures?**

- **Answer**: At higher temperatures, particles move faster and collide more often with enough energy to react.

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

- **Answer**: Increasing the concentration increases the number of particles available to collide, speeding up the reaction.

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This concludes **Lesson 1: Factors Affecting Reaction Rates**. You now have a solid understanding of how temperature, concentration, surface area, catalysts, and pressure influence the speed of chemical reactions.

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

To evaluate your understanding of the key concepts, here are three questions that will help you check your learning. Try to answer them before moving on.

1. **What is an atom, and what are its main parts?**

\*Answer:\* An atom is the smallest unit of matter that retains the properties of an element. Its main parts are the nucleus, which contains protons and neutrons, and the electron cloud, where electrons are found.

2. **How do protons, neutrons, and electrons differ in terms of charge and location within the atom?**

\*Answer:\* Protons have a positive charge and are located in the nucleus. Neutrons have no charge (neutral) and are also found in the nucleus. Electrons have a negative charge and orbit around the nucleus in the electron cloud.

3. **Why do atoms form bonds with each other, and what are the two main types of bonds?**

\*Answer:\* Atoms form bonds to achieve a more stable electron configuration, often by filling their outer electron shells. The two main types of bonds are ionic bonds, where electrons are transferred between atoms, and covalent bonds, where electrons are shared between atoms.

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### 11. Elaborate (Power Up)

Now that you’ve reviewed the basics, let’s dive deeper into the concepts. These questions will help you think more critically about what you’ve learned.

1. **How might the number of protons in an atom affect its chemical properties?**

\*Answer:\* The number of protons in an atom determines its atomic number, which defines the element. The chemical properties of an element are largely determined by its atomic number because this affects how many electrons the atom has and how it interacts with other atoms.

2. **If you could change the number of neutrons in an atom, would it still be the same element? Why or why not?**

\*Answer:\* Changing the number of neutrons in an atom would create an isotope of that element, but it would still be the same element because the number of protons (which defines the element) remains unchanged. However, isotopes can have different physical properties, such as stability.

3. **Why do some atoms form ionic bonds while others form covalent bonds?**

\*Answer:\* Atoms with a large difference in electronegativity (the ability to attract electrons) tend to form ionic bonds because one atom can easily take electrons from the other. Atoms with similar electronegativity tend to share electrons, forming covalent bonds.

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### 12. Final Evaluation

### # Debate Question:

**Is it more important to understand the structure of an atom or the way atoms bond with each other to form compounds?**

- **For understanding atomic structure:** Knowing the structure of an atom helps explain why atoms behave the way they do and how they interact with other atoms. It’s the foundation of chemistry.

- **For understanding bonding:** Bonding explains how atoms combine to form everything around us. Without understanding bonding, we wouldn’t know how substances like water or salt are formed.

### # Multiple-Choice Questions:

1. **Which subatomic particle determines the identity of an element?**

a) Neutron

b) Proton

c) Electron

d) Nucleus

\*Correct Answer:\* b) Proton

\*Explanation:\* The number of protons in an atom determines its atomic number, which identifies the element.

2. **What type of bond forms when electrons are shared between atoms?**

a) Ionic

b) Metallic

c) Covalent

d) Hydrogen

\*Correct Answer:\* c) Covalent

\*Explanation:\* In a covalent bond, atoms share electrons to achieve stability.

3. **Which of the following is true about neutrons?**

a) They have a positive charge.

b) They are found in the electron cloud.

c) They have no charge.

d) They determine the chemical behavior of an atom.

\*Correct Answer:\* c) They have no charge.

\*Explanation:\* Neutrons are neutral particles found in the nucleus of an atom.

4. **What happens when an atom loses an electron?**

a) It becomes a positive ion.

b) It becomes a negative ion.

c) It becomes neutral.

d) It becomes unstable.

\*Correct Answer:\* a) It becomes a positive ion.

\*Explanation:\* When an atom loses an electron, it has more protons than electrons, giving it a positive charge.

### # Long-Answer Questions:

1. **Explain how the periodic table is organized and why it is useful for predicting the properties of elements.**

\*Answer:\* The periodic table is organized by increasing atomic number (number of protons). Elements are arranged in rows (periods) and columns (groups) based on their electron configurations and chemical properties. Elements in the same group have similar properties because they have the same number of valence electrons. The periodic table helps predict how elements will react with each other and their physical properties.

2. **Describe the difference between an ionic bond and a covalent bond. Provide an example of each.**

\*Answer:\* An ionic bond occurs when one atom transfers electrons to another atom, resulting in oppositely charged ions that attract each other. For example, sodium chloride (NaCl) forms when sodium donates an electron to chlorine. A covalent bond occurs when two atoms share electrons. For example, in a water molecule (H₂O), oxygen and hydrogen share electrons.

3. **How do isotopes of an element differ, and what are some practical uses of isotopes?**

\*Answer:\* Isotopes of an element have the same number of protons but different numbers of neutrons. This means they have the same chemical properties but different atomic masses. Some isotopes are stable, while others are radioactive. Radioactive isotopes are used in medical imaging, cancer treatment, and carbon dating.

4. **Why is understanding electron configuration important in chemistry?**

\*Answer:\* Electron configuration determines how atoms interact with each other. It explains the chemical behavior of elements, including their bonding patterns and reactivity. For example, elements with a full outer shell of electrons are generally non-reactive, while those with incomplete outer shells tend to form bonds to achieve stability.

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### 13. Extend (Beyond the Lesson)

To extend your learning, here are some activities and challenges to help you apply what you’ve learned to new situations:

1. **Research Task:**

Investigate how isotopes are used in medicine. Write a short report on how radioactive isotopes are used in cancer treatment or medical imaging. Discuss the benefits and risks of using these isotopes.

2. **Real-World Application:**

Think about the materials you use daily, such as plastic, metal, or glass. Choose one material and research the types of chemical bonds that hold its atoms together. How do these bonds affect the material’s properties?

3. **Challenge Question:**

Imagine you are a scientist trying to create a new compound. Based on what you know about bonding, what elements would you combine, and what type of bond would you expect to form? Explain your reasoning.

4. **Spaced Practice:**

Revisit the concept of electron configuration by drawing the electron configurations for the first 10 elements of the periodic table. Practice this again in a week to reinforce your understanding.

By completing these tasks, you’ll deepen your understanding of atomic structure and bonding, and you’ll be better prepared to apply these concepts in future lessons.