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

## Chapter: Chapter 11: Reaction Rates and Equilibrium

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

### Unit Title:

**Energy, Rates, and Equilibrium**

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**Reaction Rates and Equilibrium**

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**Lesson 1: Factors Affecting Reaction Rates**

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### Essential Question:

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

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### 1. Big Idea:

**Chemical reaction rates are influenced by multiple factors, such as temperature, concentration, pressure, surface area, and the presence of catalysts, which affect how fast reactions occur.**

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### 2. Essential Questions:

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

**Answer:**

The rate of a chemical reaction is affected by:

1. **Temperature:** Higher temperatures generally increase reaction rates because particles move faster and collide more often with energy strong enough for a reaction to occur.

2. **Concentration:** Increasing the concentration of reactants leads to more frequent collisions, which increases the reaction rate.

3. **Pressure (for gases):** In reactions involving gases, an increase in pressure brings particles closer together, leading to more collisions and a faster reaction.

4. **Surface Area:** The larger the surface area of a reactant, the more space available for collisions, which increases the reaction rate.

5. **Catalysts:** A catalyst speeds up a reaction by lowering the energy needed for the reaction (activation energy), allowing particles to react more easily.

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### 3.1 Phenomenon-Based Learning:

**Unit Phenomenon:**

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

In this unit's story, you and your classmates find yourselves trapped in a high-tech laboratory escape house. To unlock the doors and progress through the house, you must solve puzzles about how energy changes take place in chemical reactions. You will also learn how different reaction conditions—such as temperature, concentration, and catalysts—affect how fast reactions occur and how they reach equilibrium.

**Chapter Phenomenon:**

In the first story of the house, the rooms contain challenges that show you how to control how fast reactions occur and how they reach a state of balance (equilibrium).

**Lesson Phenomenon:**

**"Speeding Up or Slowing Down"**

As you open the first room in the escape house, you see a large locked box. Inside it is the key to unlock the room and move to the next one. The box will open only if you decompose hydrogen peroxide (H₂O₂) and produce at least 50 bubbles of oxygen gas within 5 minutes. You have several different chemical options to choose from, including water, manganese dioxide, potassium iodide, and different strengths of hydrogen peroxide.

How can the rate of this reaction be controlled to win this challenge?

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### 3.2 Lesson Phenomenon:

"Speeding Up or Slowing Down"—You must decompose hydrogen peroxide to release oxygen bubbles. Can the rate of this reaction be adjusted using different conditions such as catalysts or changing concentrations?

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### 4. Vocabulary:

- **Catalyst:** A substance that speeds up a chemical reaction but is not consumed in the reaction. Catalysts work by lowering the activation energy needed for the reaction to occur.

- **Concentration:** The amount of a substance in a given volume. In chemical reactions, higher concentrations of reactants can increase the frequency of collisions between particles, speeding up the reaction.

- **Pressure:** The force exerted by gas particles in a reaction. Higher pressure forces gas particles into a smaller space, increasing the collision frequency and reaction rate.

- **Surface Area:** The amount of exposed outer surface of a substance. When a reactant has a large surface area, more particles can collide with it, leading to a faster reaction.

- **Temperature:** A measure of how hot or cold a substance is. Higher temperatures give particles more kinetic energy, resulting in more collisions and faster reactions.

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### 5. SMART Objectives:

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

- Summarize how collision theory explains these factors.

- Describe the effect of temperature, concentration, surface area, and catalysts on reaction rates.

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### 6. Engage (Ignite):

**Phenomenon-Related Question:**

What can you change about the conditions in the room to speed up the decomposition of hydrogen peroxide and unlock the box?

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### # Experiment:

**Decomposing Hydrogen Peroxide (H₂O₂) to Produce Oxygen**

**Materials:**

- 3% hydrogen peroxide (H₂O₂ solution)

- Manganese dioxide (catalyst)

- Potassium iodide (catalyst)

- Water (as a control)

- Measuring beaker

- Stopwatch

- Small clear plastic bottles with tops

- Balloons

**Procedure:**

1. Measure 50 mL of hydrogen peroxide solution and add it to four separate bottles.

2. Add nothing to the first bottle (this will act as the control).

3. In the second bottle, add a small spoonful of manganese dioxide.

4. In the third bottle, add a small spoonful of potassium iodide.

5. In the fourth bottle, add 50 mL of water to dilute the hydrogen peroxide.

6. Cap all bottles quickly, attach balloons to the tops, and start the stopwatch.

7. Notice which balloon fills with gas bubbles the fastest.

**Follow-Up Questions:**

1. **Which bottle filled its balloon with oxygen the fastest?**

\*Answer:\* The bottle with manganese dioxide filled the fastest because manganese dioxide is a catalyst that increases the rate at which oxygen gas is produced.

2. **Why did the bottle with no added substances show slow oxygen production?**

\*Answer:\* The reaction in the control bottle was slow because it lacked a catalyst to speed up the decomposition process.

3. **What would happen if you used a stronger concentration of hydrogen peroxide?**

\*Answer:\* A higher concentration would increase the reaction rate, producing more bubbles faster because there would be more reactant particles available for collisions.

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

Starting the lesson with a task related to the phenomenon—a slow or fast chemical reaction—helps you dive into the central question: \*What causes reactions to speed up or slow down?\*

There are five key factors that affect reaction rates:

1. **Temperature**

2. **Concentration**

3. **Pressure (for gases)**

4. **Surface Area**

5. **Catalysts**

We’ll explore each of these, using the idea that reactions happen because particles collide with each other. The faster they collide and the more energy they have when they collide, the faster the reaction will occur. This idea is called the **collision theory**.

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

**Scaffolded Questions:**

1. **What is the main idea behind collision theory?**

\*Answer:\* Collision theory states that chemicals react when their particles collide with enough energy.

2. **How does increasing the temperature affect collision frequency?**

\*Answer:\* Increasing temperature gives particles more energy, so they move faster and collide more often, leading to faster reactions.

3. **What role does a catalyst play in the decomposition of hydrogen peroxide?**

\*Answer:\* A catalyst like manganese dioxide lowers the activation energy needed for the reaction, allowing the hydrogen peroxide to decompose faster into water and oxygen gas.

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### 9. Explain (Lightbulb):

Now that you know the basics, let’s dive deeper into how each factor we just introduced affects reaction rates.

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**9.1 Temperature:**

In chemical reactions, when you increase the temperature, the particles in both solids, liquids, and gases start moving faster. This increases the number of collisions between particles because they’re bouncing around much more forcefully. Not just that—at higher temperatures, these collisions have more energy, giving them a better chance of breaking the bonds in molecules, which allows them to react.

Take for example, placing a burning log in a campfire. If the fire heats up, the log burns faster. The molecules in the log are colliding more frequently and with more energy.

### # Sample Problem (Temperature):

**Problem:**

If you heat a reaction from 25°C to 50°C, how will that affect the speed of the reaction?

**Answer:**

By increasing the temperature, the reaction rate will increase because the particles will collide more frequently and with more energy.

**Progress Check Question:**

**Why does a reaction slow down when the temperature is reduced?**

**Answer:**

When the temperature is reduced, particles move slower and collide less frequently, decreasing the reaction rate.

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**9.2 Concentration:**

Concentration refers to how much of a substance is present in a given space. When you increase concentration in a reaction mixture, you have more reactant particles in that space. This leads to more frequent collisions, so the reaction speeds up.

Think about adding more vinegar to baking soda. When you increase the amount of vinegar, you see more bubbles, indicating the reaction is going faster.

### # Sample Problem (Concentration):

**Problem:**

How does increasing the amount of reactant H₂O₂ in the earlier experiment affect the rate of oxygen production?

**Answer:**

With more H₂O₂ molecules present, more collisions will take place, leading to faster oxygen production.

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**9.3 Surface Area:**

Imagine reacting a large block of metal with acid. Only the outer part of the metal is exposed to the acid, meaning few collisions are happening at once. But if you grind the metal into a fine powder, now the acid can react with every tiny piece of metal, speeding up the reaction.

In other words, increasing the surface area of a solid reactant increases the reaction rate because it exposes more particles to collide with the reactant molecules.

\*Real-world example:\* Chewing your food increases its surface area, so your body can digest it faster.

**Progress Check Question:**

**Explain what happens to the reaction rate when a large piece of a solid is broken into smaller pieces.**

**Answer:**

Breaking a solid into smaller pieces increases the surface area, allowing more collisions to occur, and therefore increasing the reaction rate.

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**9.4 Pressure (for gases):**

In reactions involving gases, if you squeeze a lot of gas particles into a smaller space (increased pressure), they collide more often, which makes the reaction go faster. More frequent collisions mean a quicker reaction.

Imagine a sealed soda bottle. When you open the cap, the pressure is released and the gas (CO₂) escapes.

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**9.5 Catalysts:**

A **catalyst** is a special actor in reactions. It doesn’t get used up, but it helps the reaction take place faster. It works by lowering the amount of energy needed to get the reaction going, meaning the reactant particles don't have to smash together at super high energy to start reacting.

For example, in car engines, a catalyst helps convert harmful gases into safer byproducts without being consumed.

### # Sample Problem (Catalyst):

**Problem:**

Manganese dioxide was used as a catalyst to break down hydrogen peroxide. Why does using a catalyst make the reaction faster?

**Answer:**

Manganese dioxide lowers the activation energy needed for the reaction, making the decomposition of hydrogen peroxide happen faster.

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### Recap:

Now you understand the five factors that affect reaction rates: temperature, concentration, pressure, surface area, and catalysts. Next time you’re stuck in a puzzle room (even if it’s fictional), you’ll know just what to change to make reactions happen faster or slower to achieve your goal!

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### End of Lesson Progress Check:

**1. Why do chemical reactions happen faster at a high temperature?**

**Answer:**

At higher temperatures, particles move faster and collide more frequently and energetically, leading to faster reactions.

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This concludes your structured and detailed lesson plan for **"Factors Affecting Reaction Rates"** aligned with the "Thermodynamics House" storyline.

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

In this section, we will ask a few questions based on what we learned earlier. Try your best to answer these questions carefully. They will help you check how well you understand the key ideas.

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**Question 1: How many protons are in the nucleus of a hydrogen atom?**

Answer:

Hydrogen has **1 proton** in its nucleus. This is what makes hydrogen unique because it is the simplest element.

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**Question 2: What is the difference between a covalent bond and an ionic bond?**

Answer:

A **covalent bond** involves the sharing of electrons between atoms to fill their outer shells, like in a water molecule (H2O). An **ionic bond** is when one atom donates an electron to another atom, creating charged ions that attract each other, like in table salt (NaCl).

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**Question 3: How do you calculate the number of neutrons in an atom if you know the atomic number and the atomic mass?**

Answer:

To find the number of neutrons, subtract the **atomic number** from the **atomic mass**. **Atomic mass** is the number of protons and neutrons together, while the **atomic number** is only the protons.

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### 11. Elaborate (Power Up)

Now, let’s dig a little deeper into some ideas. These questions will help you think harder about what you've learned. They don’t always have only one right answer!

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**Mini Task 1: Imagine you have to explain how water’s covalent bonds make it a good solvent. How can covalent bonds play a part in dissolving substances?**

Answer:

Water has **polar covalent bonds**, which means that one side of the water molecule has a slight negative charge (near the oxygen), and the other side has a slight positive charge (near the hydrogens). This allows water to interact and mix with lots of substances, especially those that also have charges, like salt. Water molecules pull particles apart by interacting with charged atoms.

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**Mini Task 2: Write down two different everyday examples where you can observe the effects of chemical bonding in real life.**

Answer:

1. **Rusting** of iron demonstrates how elements like oxygen interact with iron through bonding.

2. **Baking a cake** shows how heat can break and form new chemical bonds between ingredients like sugar and flour.

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**Mini Task 3: If a scientist discovers a new element with an atomic number of 120, what can you predict about its atomic structure—and how might it behave chemically?**

Answer:

This element would have **120 protons**, and we can also predict that it would have **120 electrons**. Since it is such a large element, it might be unstable, possibly radioactive. Its position on the periodic table might also help predict how it bonds with other elements. It could be highly reactive if its outer shell has a similar electron configuration to known reactive elements.

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### 12. Final Evaluation

Now it’s time to show what you’ve learned by answering a few more questions. Give it your best shot!

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### # 1. Debate Question:

**Should scientists try to create new synthetic elements? Why or why not?**

**Arguments for:**

- Creating new elements can lead to discoveries in new materials, technology, or energy production.

**Arguments against:**

- The process is very expensive and the elements might be too unstable to be useful.

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### # Assessment Questions

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**Multiple Choice Questions:**

1. **What does the atomic number of an element represent?**

A. Number of protons

B. Number of neutrons

C. Number of electrons and neutrons added together

D. Number of electrons

**Correct Answer: A. Number of protons**

Explanation: Atomic number is always equal to the number of protons, which defines the element.

2. **Which of the following molecules contains an ionic bond?**

A. O2

B. NaCl

C. H2O

D. CO2

**Correct Answer: B. NaCl**

Explanation: NaCl (table salt) is formed by transfer of an electron from sodium (Na) to chlorine (Cl), resulting in an ionic bond.

3. **What information does the atomic mass of an element give you?**

A. Total number of protons and neutrons

B. Total number of neutrons

C. Number of electrons

D. Number of ions

**Correct Answer: A. Total number of protons and neutrons**

Explanation: Atomic mass is the sum of protons and neutrons in the nucleus of an atom.

4. **Which element is most likely to form covalent bonds?**

A. Sodium (Na)

B. Oxygen (O)

C. Neon (Ne)

D. Calcium (Ca)

**Correct Answer: B. Oxygen (O)**

Explanation: Oxygen has six electrons in its outer shell, so it tends to share electrons (form covalent bonds) to fill its shell.

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**Long Answer Questions:**

1. **Explain why noble gases are generally unreactive.**

**Answer:**

Noble gases like helium, neon, and argon have **full outer electron shells**, meaning they do not need to gain, lose, or share electrons to become stable. This is why they don't form bonds easily and are considered **inert** or **non-reactive.**

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2. **Describe how the periodic table is arranged and why this arrangement is helpful to scientists.**

**Answer:**

The periodic table arranges elements according to their **atomic number** (number of protons). Elements in the same column (group) typically have similar properties because they have the same number of electrons in their outer shells. This arrangement helps scientists predict the reactivity and bonding behavior of elements they study.

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3. **Compare and contrast the properties of ionic and covalent compounds.**

**Answer:**

**Ionic compounds** are formed from the attraction between positively and negatively charged ions. They tend to have high melting points, and when dissolved in water, they conduct electricity. Examples include table salt (NaCl).

**Covalent compounds**, on the other hand, are formed by sharing electrons between atoms. They generally have lower melting points and do not conduct electricity in solution. Water (H2O) is a covalent compound.

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4. **How does the concept of isotopes relate to the atomic mass of an element?**

**Answer:**

Isotopes are atoms of the same element but with different numbers of **neutrons**. While the atomic number (number of protons) remains the same, the difference in neutrons changes the atomic mass. The **atomic mass listed on the periodic table** is usually an average of all the naturally occurring isotopes of that element.

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### 13. Extend (Beyond the Lesson)

Great work so far! Now, let's think about how what you’ve learned can be applied to new ideas and situations. Here are a few tasks and readings that can challenge your understanding:

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**Additional Readings:**

1. **Isotopes and Medicine**

Learn about how radioactive isotopes are used in medical treatments and imaging, such as in cancer treatment and the use of X-rays.

2. **Materials Science**

Explore how understanding atomic bonding helps scientists create new materials like ceramics and superconductors used in advanced technology.

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**Extended Tasks:**

1. **New Element Discovery Challenge:**

Imagine you're a scientist who has just discovered a new element. Draw its place on the periodic table, predict its properties, and describe how it might be used in technology or industry.

2. **Explore Water's Special Properties:**

Research why water has such unique characteristics, like its ability to float when frozen and its high specific heat capacity. Explain how these properties make life on Earth possible.

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**Spaced Practice:**

1. **Flashcards:**

Create flashcards for core concepts such as atomic structure, types of chemical bonds, and trends on the periodic table. Revisit these flashcards over time to reinforce your understanding.

2. **Periodic Table Trends:**

Over a week, focus on one major trend (such as atomic radius, ionization energy, or electronegativity) each day. Do practice problems or small tasks based on that trend regularly to build long-term memory.

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These activities and readings will help you expand on what you already know and think critically about how chemistry affects the world around you. Keep practicing, and soon you'll be a chemistry expert!