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CHAPTER 17 STUDY GUIDE FOR CONTENT MASTERY

Reaction Rates

Section 17.1 A Model for Reaction Rates

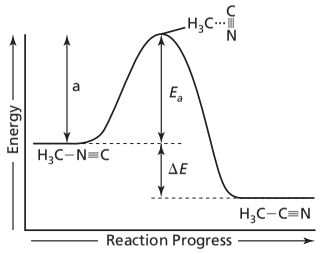
In your textbook, read about expressing reaction rates and explaining reactions and their rates.

Use each of the terms below just once to complete the passage.

collision theory	activated complex	transition state
activation energy	reaction rate	mol/(L·s)

According to the **(1)** collision theory, atoms, ions, and molecules must collide in order to react. Once formed, the **(2)** activated complex is a temporary, unstable arrangement of atoms that may then form products or may break apart to reform the reactants. This physical arrangement is known as the **(3)** transition state. Every chemical reaction requires energy, and the minimum amount of energy that reacting particles must have to form the activated complex is the **(4)** activation energy. In a chemical reaction, the **(5)** reaction rate is the change in concentration of a reactant or product per unit time. It may be expressed using the units of **(6)** mol/L·s.

Use the energy diagram for the rearrangement reaction of methyl isonitrile to acetonitrile to answer the following questions.



7. What kind of reaction is represented by this diagram, endothermic or exothermic?
exothermic

8. What is the chemical structure identified at the top of the curve on the diagram?
the activated complex

9. What does the symbol E_a represent?
the activation energy

10. What does the symbol ΔE represent?
the net energy released from the exothermic reaction

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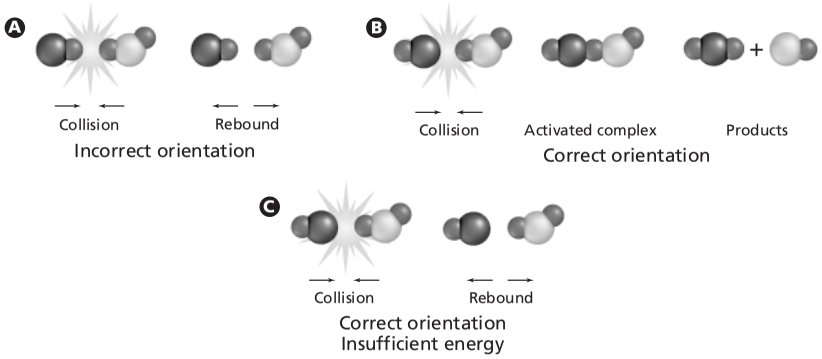
Section 17.1 *continued*

For each item in Column A, write the letter of the matching item in Column B.

Column A	Column B
c **11.** Expresses the average rate of loss of a reactant	**a.** average reaction rate
a **12.** Expressed as Δquantity/Δtime	**b.** positive number
b **13.** Expresses the average rate of formation of a product	**c.** negative number

Use the figure below to answer the following questions.



14. What molecules collided in collisions A, B, and C? **CO and NO_2**

15. What do the arrows represent?
The arrows represent the direction and the amount of energy of the moving molecules.

16. Which collision(s) formed products? What were the products? **Collision B; CO_2 and NO**

17. Explain why the other collision(s) did not form products.
Collision A did not form products because the carbon atom in the CO molecule did not contact an oxygen atom in the NO_2 molecule. Collision C did not form products because the CO molecule and the NO_2 molecule did not collide with sufficient energy.

18. Which collision(s) formed an activated complex? Identify the activated complex.
Collision B; the activated complex is an OCONO molecule.

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Section 17.2 Factors Affecting Reaction Rates

In your textbook, read about the factors that affect reaction rates (reactivity, concentration, surface, area, temperature, and catalysts).

In the space at the left, write *true* if the statement is true; if the statement is false, change the italicized word to make it true.

Increasing 1. *Decreasing* the concentration of reactants increases the collision frequency between reacting particles.

true 2. A *heterogeneous* catalyst exists in a different physical state than the reaction it catalyzes.

temperature 3. Increasing the *concentration* of a substance increases the kinetic energy of the particles that make up the substance.

lowering 4. Catalysts increase the rates of chemical reactions by *raising* the activation energy of the reactions.

true 5. *Increasing* the surface area of a reactant increases the rate of the reaction.

true 6. Raising the temperature of a reaction increases the rate of the reaction by increasing the *energy* of the collisions between reacting particles.

Answer the following questions.

7. A chemist heated a sample of steel wool in a burner flame exposed to oxygen in the air. He also heated a sample of steel wool in a container of nearly 100% oxygen. The steel-wool sample in the container reacted faster than the other sample. Explain why.
There was a greater concentration of oxygen in the container. Increasing the concentration of a reactant increases the rate of a reaction.

8. Would the chemist have observed the same results if he used a block of steel instead of steel wool? Explain your answer.
No; a block of steel would react more slowly because it has less surface area.

9. How would the reaction have differed if the steel wool was not heated?
Not heating the steel wool would decrease the rate of the reaction.

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CHAPTER 17 STUDY GUIDE FOR CONTENT MASTERY

Section 17.3 Reaction Rate Laws

In your textbook, read about reaction rate laws and determining reaction order.

Use each of the terms below to complete the statements.

chemical reaction	rate law	specific rate constant
reaction orders	concentration	time

Equation 1 $aA + bB \rightarrow cC + dD$

Equation 2 $-\frac{\Delta[A]}{\Delta t} = k[A]^m[B]^n$

1. Equation 1 describes a chemical reaction.
2. Equation 2 expresses the mathematical relationship between the rate of a chemical reaction and the concentrations of the reactants. This is known as the rate law.
3. The variable k in equation 2 is the specific rate content, a numerical value that relates the reaction rate and the concentration at a given temperature.
4. The variables m and n are the reaction orders. These define how the rate is affected by the concentrations of the reactants.
5. The square brackets [ ] represent concentration.
6. The variable t represents time.

Answer the questions about the following rate law.

$$\text{Rate} = k\,[A]^1[B]^2$$

7. What is the reaction order with respect to A? the exponent to A, first order
8. What is the reaction order with respect to B? the exponent to B, second order
9. What is the overall reaction order for the rate law? the sum of 1 and 2, or third order
10. Doubling the concentration of A will cause the rate to double. What would happen if you doubled the concentration of B?
The rate would quadruple. The square of 2 is 4.
11. A reaction rate can be expressed as Rate $= k[A]^2$. What is the reaction order for this reaction?
This is a second-order reaction.

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CHAPTER 17 STUDY GUIDE FOR CONTENT MASTERY

Section 17.4 Instantaneous Reaction Rates and Reaction Mechanisms

In your textbook, read about instantaneous reaction rates.

Circle the letter of the choice that best completes the statement.

1. _____ is determined by finding the slope of the straight line tangent to the curve of a plot of the change in concentration of a reactant versus time.
   (a.) Instantaneous rate
   b. Change in temperature
   c. Reaction mechanism
   d. Reaction order

2. A(n) _____ consists of two or more elementary steps.
   (a.) complex reaction
   b. elementary step
   c. reaction mechanism
   d. reaction order

3. A(n)_____ is a substance produced in an elementary step and consumed in another elementary step.
   a. instantaneous rate
   (b.) intermediate
   c. reaction mechanism
   d. rate-determining step

4. A(n) _____ is the complete sequence of elementary reactions that make up a complex reaction.
   a. instantaneous rate
   b. elementary step
   (c.) reaction mechanism
   d. reaction order

5. The _____ is the slowest of the elementary steps in a complex reaction.
   a. instantaneous rate
   b. intermediate
   (c.) rate-determining step
   d. reaction order

6. The _____ can be used to determine the instantaneous rate for a chemical reaction.
   a. rate-determining step
   b. intermediates
   c. products
   (d.) rate law

7. An element or compound that reacts in one step of a complex reaction and reforms in a another step of the complex reaction is
   a. an intermediate.
   (b.) a catalyst.
   c. not part of the reaction mechanism.
   d. shown in the net chemical equation for the reaction.

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Section 17.4 *continued*

In the space at the left, write *true* if the statement is true; if the statement is false, change the italicized word or phrase to make it true.

true 8. To determine the *instantaneous rate*, you must know the specific rate constant, the concentrations of the reactants, and the reaction orders for the reaction.

0.1 mol/(L·s) 9. A reaction rate that is defined as k[A][B] and that has a specific rate constant of 1.0×10^1 L/(mol·s), [A] = 0.1M, and [B] = 0.1M would have an instantaneous rate of *0.01 mol/(L·s)*.

In your textbook, read about reaction mechanisms.

Answer the following questions about the proposed reaction mechanism for the complex reaction below.

$$2NO(g) + 2H_2(g) \rightarrow N_2(g) + 2H_2O(g)$$

Proposed Mechanism

$$2NO \rightarrow N_2O_2 \quad \text{(fast)}$$

$$N_2O_2 + H_2 \rightarrow N_2O + H_2O \quad \text{(slow)}$$

$$N_2O + H_2 \rightarrow N_2 + H_2O \quad \text{(fast)}$$

10. How many elementary steps make up the complex reaction?
    three

11. What is the rate-determining step for this reaction?
    The slow step is the rate-determining step.

12. What are N_2O_2 and N_2O in the reaction?
    intermediates

13. Is there a catalyst involved in the reaction? Explain your answer.
    There is no catalyst because no molecule reacted in one step and then was reformed in a subsequent step.

14. What can you conclude about the activation energy for the rate-determining step?
    Of all the steps, the rate-determining step has the highest activation energy.

15. If you wanted to increase the rate of the overall reaction, what would you do?
    Speed up the rate-determining step.