Name _____ Date _____ Class _____

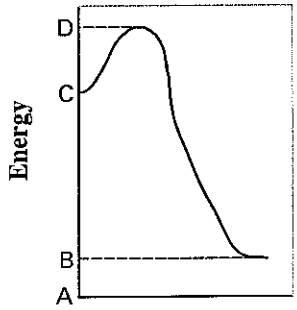
CHAPTER 17 REVIEW

Reaction Kinetics

SECTION 1

SHORT ANSWER **Answer the following questions in the space provided.**

1. Refer to the energy diagram below to answer the following questions.



d **a.** Which letter represents the energy of the activated complex?

(a) A (c) C
(b) B (d) D

c **b.** Which letter represents the energy of the reactants?

(a) A (c) C
(b) B (d) D

d **c.** Which of the following represents the quantity of activation energy for the forward reaction?

(a) the amount of energy at C minus the amount of energy at B
(b) the amount of energy at D minus the amount of energy at A
(c) the amount of energy at D minus the amount of energy at B
(d) the amount of energy at D minus the amount of energy at C

c **d.** Which of the following represents the quantity of activation energy for the reverse reaction?

(a) the amount of energy at C minus the amount of energy at B
(b) the amount of energy at D minus the amount of energy at A
(c) the amount of energy at D minus the amount of energy at B
(d) the amount of energy at D minus the amount of energy at C

b **e.** Which of the following represents the energy change for the forward reaction?

(a) the amount of energy at C minus the amount of energy at B
(b) the amount of energy at B minus the amount of energy at C
(c) the amount of energy at D minus the amount of energy at B
(d) the amount of energy at B minus the amount of energy at A

Name _____ Date _____ Class _____

SECTION 1 continued

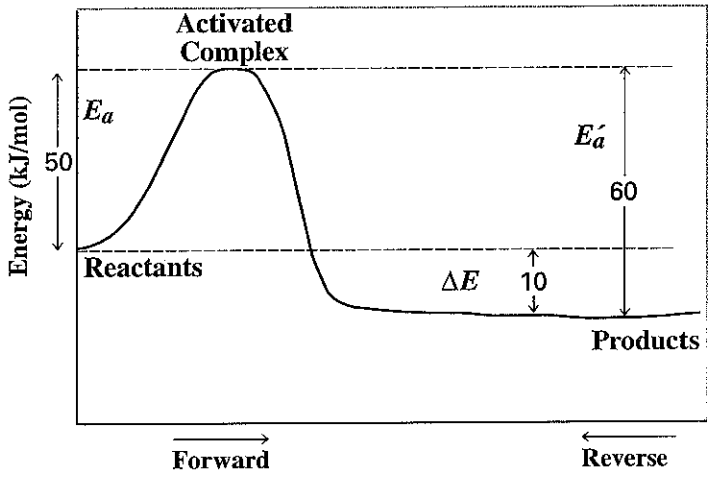
2. For the reaction described by the equation A + B → X, the activation energy for the forward direction equals 85 kJ/mol and the activation energy for the reverse direction equals 80 kJ/mol.

the product — **a.** Which has the greater energy content, the reactants or the product?

+5 kJ/mol — **b.** What is the enthalpy of reaction in the forward direction?

True — **c.** The enthalpy of reaction in the reverse direction is equal in magnitude but opposite in sign to the enthalpy of reaction in the forward direction. True or False?

3. Below is an incomplete energy diagram.



a. Use the following data to complete the diagram: $E_a = +50$ kJ/mol; $\Delta E_{forward} = -10$ kJ/mol. Label the reactants, products, ΔE, E_a, E_a', and the activated complex.

+60 kJ/mol — **b.** What is the value of E_a'?

4. It is proposed that ozone undergoes the following two-step mechanism in our upper atmosphere.

$$O_3(g) \rightarrow O_2(g) + O(g)$$
$$O_3(g) + O(g) \rightarrow 2O_2(g)$$

a. Identify any intermediates formed in the above equations.

Monatomic O is the intermediate formed.

b. Write the net equation.

$2O_3(g) \rightarrow 3O_2(g)$

exothermic — **c.** If ΔE is negative for the reaction in part **b**, what type of reaction is represented?

Name _____ Date _____ Class _____

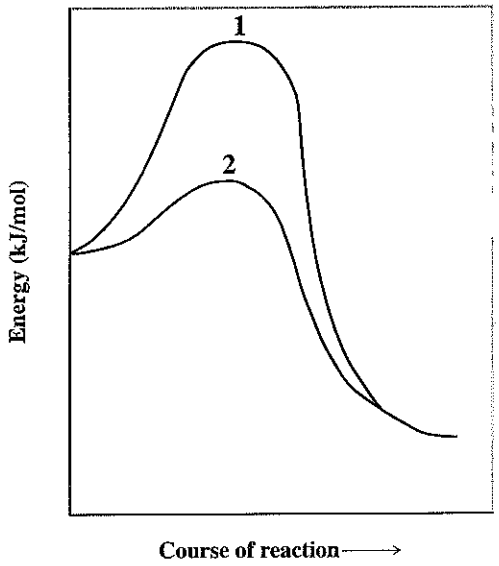
CHAPTER 17 REVIEW

Reaction Kinetics

SECTION 2

SHORT ANSWER **Answer the following questions in the space provided.**

1. Below is an energy diagram for a particular process. One curve represents the energy profile for the uncatalyzed reaction, and the other curve represents the energy profile for the catalyzed reaction.



a **a.** Which curve has the greater activation energy?

(a) curve 1
(b) curve 2
(c) Both are equal.

c **b.** Which curve has the greater energy change, ΔE?

(a) curve 1
(b) curve 2
(c) Both are equal.

b **c.** Which curve represents the catalyzed process?

(a) curve 1
(b) curve 2

d. Explain your answer to part **c**.

The catalyst forms an alternative activated complex that requires a lower activation energy, as represented by the lower curve.

Name _____ Date _____ Class _____

SECTION 2 continued

2. Is it correct to say that a catalyst affects the speed of a reaction but does not take part in the reaction? Explain your answer.

It is not correct. The catalyst does take part in the reaction. However, if it is used up in one step of the mechanism, it is regenerated in a later step. There is no net change in mass for the catalyst.

3. The reaction described by the equation $X + Y \rightarrow Z$ is shown to have the following rate law:

$$R = k[X]^3[Y]$$

a. What is the effect on the rate if the concentration of Y is reduced by one-third and [X] remains constant?

The rate is reduced by one-third as well.

b. What is the effect on the rate if the concentration of X is doubled and [Y] remains constant?

The rate increases by a factor of eight.

c. What is the effect on the rate if a catalyst is added to the system?

The rate will increase if the catalyst added is specific for this reaction.

4. Explain the following statements, using collision theory:

a. Gaseous reactants react faster under high pressure than under low pressure.

At high pressure, gas molecules are more closely packed and collide more frequently. Thus, more-effective collisions occur per unit of time.

b. Ionic compounds react faster when in solution than as solids.

Ions in solution have more freedom of motion than do ions in a solid; therefore, they can collide with one another more frequently.

c. A class of heterogeneous catalysts called surface catalysts work best as a fine powder.

The fine powder has more surface area on which reactant particles can be absorbed and, in effect, increases the concentration of the reactants. An increase in concentration increases the number of effective collisions between reactant particles.

Name _____ Date _____ Class _____

CHAPTER 17 REVIEW

Reaction Kinetics

MIXED REVIEW

SHORT ANSWER **Answer the following questions in the space provided.**

1. The reaction for the decomposition of hydrogen peroxide is $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$.

List three ways to speed up the rate of decomposition. For each one, briefly explain why it is effective, based on collision theory.

increase the concentration of hydrogen peroxide—allows more collisions per unit of time to occur

increase the temperature of the solution—allows more energetic collisions per unit of time to occur

stir the solution—exposes more reactant surface area, which allows more collisions per unit of time to occur

add a catalyst—lowers the activation energy so that more-effective collisions can occur

2. An ingredient in smog is the gas NO. One reaction that controls the concentration of NO is

$$H_2(g) + 2NO(g) \rightarrow H_2O(g) + N_2O(g).$$

At high temperatures, doubling the concentration of H_2 doubles the rate of reaction, while doubling the concentration of NO increases the rate fourfold.

Write a rate law for this reaction consistent with these data.

$R = k[H_2][NO]^2$

3. Use the following chemical equation to answer the question below:

$$Mg(s) + 2H_3O^+(aq) + Cl^-(aq) \rightarrow Mg^{2+}(aq) + 2Cl^-(aq) + H_2(g) + H_2O(l)$$

If 0.048 g of magnesium completely reacts in 20 s, what is the average reaction rate in moles/second over that time interval?

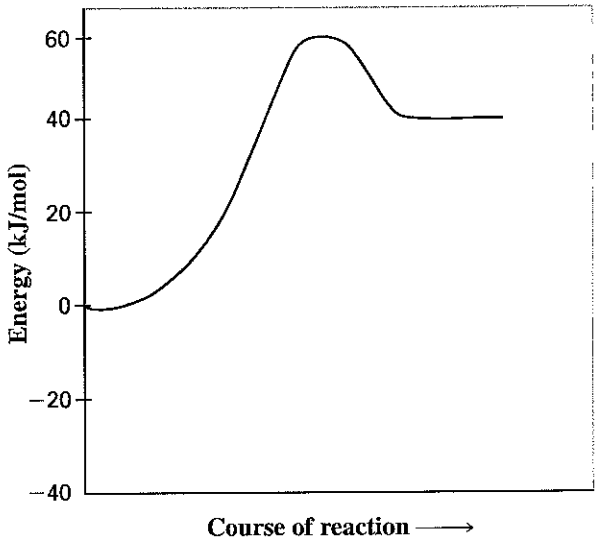
Average rate = 9.9×10^{-5} mol/s

Name _____ Date _____ Class _____

MIXED REVIEW continued

PROBLEMS **Write the answer on the line to the left. Show all your work in the space provided.**

4. Answer the following questions using the energy diagram below.



endothermic **a.** Is the forward reaction represented by the curve exothermic or endothermic?

+40 kJ/mol **b.** Estimate the magnitude and sign of $\Delta E_{forward}$.

+20 kJ/mol **c.** Estimate E_a'.

A catalyst is added to the reaction, which lowers E_a by about 15 kJ/mol.

speed up **d.** Does the forward reaction rate speed up or slow down?

speed up **e.** Does the reverse reaction rate speed up or slow down?

No **f.** Does $\Delta E_{forward}$ change from its value in part **b**?

5. a. Determine the overall balanced equation for a reaction having the following proposed mechanism:

Step 1: $2NO + H_2 \rightarrow N_2 + H_2O_2$ Slow
Step 2: $H_2 + H_2O_2 \rightarrow 2H_2O$ Fast

$2NO + 2H_2 \rightarrow N_2 + 2H_2O$

b. Which is the rate-determining step?

Step 1

c. What is the intermediate in the above reaction?

H_2O_2

Name _____ Date _____ Class _____

CHAPTER 18 REVIEW

Chemical Equilibrium

SECTION 1

SHORT ANSWER **Answer the following questions in the space provided.**

1. Write the equilibrium expression for the following hypothetical equation:

$$3A(aq) + B(aq) \rightleftarrows 2C(aq) + 3D(aq)$$

$$K = \frac{[C]^2[D]^3}{[A]^3[B]}$$

2. **a.** Write the appropriate chemical equilibrium expression for each of the following equations. Include the value of K.

(1) $N_2O_4(g) \rightleftarrows 2NO_2(g)$ $\quad K = 0.1$

$$\frac{[NO_2]^2}{[N_2O_4]} = 0.1$$

(2) $NH_4OH(aq) \rightleftarrows NH_4^+(aq) + OH^-(aq)$ $\quad K = 2 \times 10^{-5}$

$$\frac{[NH_4^+][OH_2]}{[NH_4OH]} = 2 \times 10^{-5}$$

(3) $H_2(g) + I_2(g) \rightleftarrows 2HI(g)$ $\quad K = 54.0$

$$\frac{[HI]^2}{[H_2][I_2]} = 54.0$$

(4) $2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g)$ $\quad K = 1.8 \times 10^{-2}$

$$\frac{[SO_3]^2}{[SO_2]^2[O_2]} = 1.8 \times 10^{-2}$$

Name _____ Date _____ Class _____

SECTION 1 continued

system 3 — **b.** Which of the four systems in part **a** proceeds furthest forward before equilibrium is established?

system 2 — **c.** Which system contains mostly reactants at equilibrium?

3. a. Compare the rates of forward and reverse reactions when equilibrium has been reached.

The rate of the forward reaction equals the rate of the reverse reaction.

b. Describe what happens to the concentrations of reactants and products when chemical equilibrium has been reached.

The concentrations of the products and the reactants remain constant.

PROBLEMS **Write the answer on the line to the left. Show all your work in the space provided.**

4. 1.1 Consider the following equation:

$$2NO(g) + O_2(g) \rightleftarrows 2NO_2(g)$$

At equilibrium, [NO] = 0.80 M, [O_2] = 0.50 M, and [NO_2] = 0.60 M. Calculate the value of K for this reaction.

5. 0.0024 What is the K value for the following equation if the gaseous mixture in a 4 L container reaches equilibrium at 1000 K and contains 4.0 mol of N_2, 6.4 mol of H_2, and 0.40 mol of NH_3?

$$N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$$

Name _____ Date _____ Class _____

CHAPTER 18 REVIEW

Chemical Equilibrium

SECTION 2

SHORT ANSWER **Answer the following questions in the space provided.**

1. __d__ Raising the temperature of any equilibrium system always

(a) favors the forward reaction.
(b) favors the reverse reaction.
(c) favors the exothermic reaction.
(d) favors the endothermic reaction.

2. Consider the following equilibrium equation: $CH_3OH(g) + 101\ kJ \rightleftarrows CO(g) + 2H_2(g)$.

__b__ **a.** Increasing [CO] will

(a) increase $[H_2]$.
(b) decrease $[H_2]$.
(c) not change $[H_2]$.
(d) cause $[H_2]$ to fluctuate.

__b__ **b.** Raising the temperature will cause the equilibrium of the system to

(a) favor the reverse reaction.
(b) favor the forward reaction.
(c) shift back and forth.
(d) remain as it was before.

__a__ **c.** Raising the temperature will

(a) increase the value of *K*.
(b) decrease the value of *K*.
(c) not change the value of *K*.
(d) make the value of *K* fluctuate.

3. Consider the following equilibrium equation: $H_2O(g) + C(s) \rightleftarrows H_2(g) + CO(g) + \text{energy}$
At equilibrium, which reaction will be favored (forward, reverse, or neither) when

__reverse__ **a.** extra CO gas is introduced?

__neither direction__ **b.** a catalyst is introduced?

__forward__ **c.** the temperature of the system is lowered?

__reverse__ **d.** the pressure on the system is increased due to a decrease in the container volume?

4. __c__ Silver chromate dissolves in water according to the following equation:

$$Ag_2CrO_4(s) \rightleftarrows 2Ag^+(aq) + CrO_4^{2-}(aq)$$

Which of these correctly represents the equilibrium expression for the above equation?

(a) $\dfrac{2[Ag^+] + [CrO_4^{2-}]}{Ag_2CrO_4}$ (b) $\dfrac{[Ag_2CrO_4]}{[Ag^+]^2[CrO_4^{2-}]}$ (c) $\dfrac{[Ag^+]^2[CrO_4^{2-}]}{1}$ (d) $\dfrac{[Ag^+]^2[CrO_4^{2-}]}{2[Ag_2CrO_4]}$

Name _____ Date _____ Class _____

SECTION 2 continued

5. Are pure solids included in equilibrium expressions? Explain your answer.

Pure solids are not included in equilibrium expressions because their concentrations do not change. Their constant value is incorporated into *K*.

6. A key step in manufacturing sulfuric acid is represented by the following equation:

$$2SO_2(g) + O_2(g) \rightleftarrows 2SO_3(g) + 100 \text{ kJ/mol}$$

To be economically viable, this process must yield as much SO_3 as possible in the shortest possible time. You are in charge of this manufacturing process.

a. Would you impose a high pressure or a low pressure on the system? Explain your answer.

Impose a high pressure so the reaction that produces fewer gas molecules will be favored, which is the forward reaction in this case.

b. To maximize the yield of SO_3, should you keep the temperature high or low during the reaction?

Keep the temperature low to favor the forward, exothermic reaction, but not so low as to slow the rate of the forward reaction too much.

c. Will adding a catalyst change the yield of SO_3?

No, a catalyst does not change the percentage yield.

7. The equation for an equilibrium system easily studied in a lab follows:

$$2NO_2(g) \rightleftarrows N_2O_4(g)$$

N_2O_4 gas is colorless, and NO_2 gas is dark brown. Lowering the temperature of the equilibrium mixture of gases reduces the intensity of the color.

a. Is the forward or reverse reaction favored when the temperature is lowered?

The forward reaction is favored. The color becomes less intense because the equilibrium shifts in the direction that produces the colorless gas, N_2O_4.

b. Will the sign of ΔH be positive or negative if the temperature is lowered? Explain your answer.

Negative; lowering the temperature favors the forward reaction, which is exothermic, so ΔH has a negative sign.

Name _____ Date _____ Class _____

CHAPTER 18 REVIEW

Chemical Equilibrium

SECTION 4

SHORT ANSWER **Answer the following questions in the space provided.**

1. Match the solution type on the right to the corresponding relationship between the ion product and the K_{sp} for that solution, listed on the left.

c The ion product exceeds the K_{sp}.

a The ion product equals the K_{sp}.

b The ion product is less than the K_{sp}.

(a) The solution is saturated; no more solid will dissolve.

(b) The solution is unsaturated; no solid is present.

(c) The solution is supersaturated; solid may form if the solution is disturbed.

2. Silver carbonate, Ag_2CO_3, makes a saturated solution with $K_{sp} = 10^{-11}$.

a. Write the equilibrium expression for the dissolution of Ag_2CO_3.

$K_{sp} = [Ag^+]^2[CO_3^{2-}]$

reverse reaction

b. In this system, will the foward or reverse reaction be favored if extra Ag^+ ions are added?

PROBLEMS **Write the answer on the line to the left. Show all your work in the space provided.**

3. When the ionic solid XCl_2 dissolves in pure water to make a saturated solution, experiments show that 2×10^{-3} mol/L of X^{2+} ions go into solution.

$XCl_2(s) \rightleftarrows X^{2+}(aq) + 2Cl^-(aq)$

$K_{sp} = [X^{2+}][Cl^-]^2$

a. Write the equation showing the dissolution of XCl_2 and the corresponding equilibrium expression.

3×10^{-8}

b. Calculate the value of K_{sp} for XCl_2.

Name _____ Date _____ Class _____

SECTION 4 continued

less soluble — **c.** Refer to **Table 3** on page 615 of the text. Would XCl_2 be more soluble or less soluble than $PbCl_2$ at the same temperature?

4. The solubility of Ag_3PO_4 is 2.1×10^{-4} g/100. g.

$Ag_3PO_4(s) \rightleftarrows 3Ag^+(aq) + PO_4^{3-}(aq)$ — **a.** Write the equation showing the dissolution of this ionic solid.

5.0×10^{-6} M — **b.** Calculate the molarity of this saturated solution.

1.7×10^{-20} — **c.** What is the value of K_{sp} for this system?

5. As $PbCl_2$ dissolves, $[Pb^{2+}] = 2.0 \times 10^{-1}$ mol/L and $[Cl^-] = 1.5 \times 10^{-2}$ mol/L.

$K_{sp} = [Pb^{2+}][Cl^-]^2$ — **a.** Write the equilibrium expression for the dissolution of $PbCl_2$.

4.5×10^{-5} — **b.** Compute the ion product, using the data given above.

Quiz Keys

17 Reaction Kinetics

Section: The Reaction Process

1. a	2. c
3. c	4. b
5. d	6. d
7. a	8. d
9. b	10. c

Section: Reaction Rate

1. a	2. d
3. a	4. d
5. d	6. b
7. c	8. a
9. c	10. d

18 Chemical Equilibrium

Section: The Nature of Chemical Equilibrium

1. c	2. c
3. c	4. b
5. d	6. b
7. d	8. d
9. d	10. a

Section: Shifting Equilibrium

1. c	2. d
3. c	4. d
5. d	6. c
7. b	8. c
9. b	10. a

Section: Equilibria of Acids, Bases, and Salts

1. b	2. c
3. d	4. b
5. d	6. a
7. d	8. b
9. d	10. b

Section: Solubility Equilibrium

1. b	2. c
3. a	4. c
5. d	6. d
7. a	8. c
9. a	10. b