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# Unit 6 Kinetics and Equilibrium

*For each of the following, select the word, number, or phrase that best completes the statement and write its letter in the answer space at the right.*

1. The study of the rates of chemical reactions is labeled
(A) activation (B) entropy (C) reactivity (D) kinetics. 1. D

2. Changes in reaction rate are explained using
(A) collision theory (B) quantum theory (C) uncertainty theory (D) probability theory. 2. A

3. Rates of many reactions are approximately doubled when the temperature
(A) is doubled (B) increases by 10°C (C) increases by 100°C (D) decreases by 10°C. 3. B

4. The catalysts in many of the biochemical changes in the human body are
(A) radioactive isotopes (B) suppressants (C) narcotics (D) enzymes. 4. D

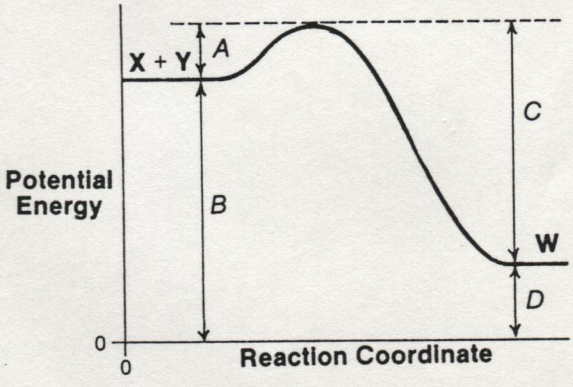
5. The series of steps in a chemical reaction is called the reaction
(A) breakdown (B) order (C) sequence (D) mechanism. 5. D

6. If the reaction $N_2 + 3H_2 \rightarrow 2NH_3$ were to take place in one step, the number of particles that would have to come together at the same time would be (A) 1 (B) 2 (C) 3 (D) 4. 6. D

7. Each of the several steps in a chemical reaction may occur at a different rate. The slowest step is called the (A) rate-determining step (B) catalyzed step (C) intermediate step (D) activated step. 7. A

8. Unstable, intermediate products that form when particles of the reactants collide with sufficient energy are called (A) activated complexes (B) catalytic substances (C) threshold products (D) reversible products. 8. A

9. In the graph for the reaction $X + Y \rightarrow W$, the activation energy is represented by the letter
(A) A (B) B (C) C (D) D. 9. A




10. A catalyst enables a reaction to speed up by providing a new mechanism with a
(A) lower activation energy (B) higher activation energy (C) lower heat of reaction (D) higher heat of reaction. 10. A

11. The heat of reaction for a reaction in general is equal to the
(A) $\Delta H_f^\circ$(Products) − $\Delta H_f^\circ$(Reactants) (B) $\Delta H_f^\circ$(Products) + $\Delta H_f^\circ$(Reactants)
(C) $\Delta H_f^\circ$(Reactants) − $\Delta H_f^\circ$(Products) (D) $\Delta H_f^\circ$(Products). 11. A

12. The example below which is in a state of high entropy is
(A) an arrangement of pennies with all heads upward
(B) an arrangement of pennies with all tails upward
(C) a box of pennies that has been shaken vigorously for a few minutes
(D) a roll of pennies with all heads facing in the same direction. 12. C

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13. An increase in the entropy of a system is caused by
(A) an increase in the order of a system
(B) an increase in the temperature of the system
(C) a change from liquid to solid phase
(D) a change from gas to liquid phase. 13. B

14. All spontaneous reactions show a net decrease in
(A) enthalpy (B) entropy (C) free energy (D) temperature. 14. C

15. When equilibrium exists between two opposing processes, the value of $\Delta G$ is
(A) zero (B) greater than zero (C) less than zero (D) either greater or less than zero. 15. A

16. Reactions that proceed in both the forward and reverse directions under the same conditions at the same rate are said to be (A) complete (B) balanced (C) static (D) in equilibrium. 16. D

17. The value of the equilibrium constant changes with
(A) initial concentration of the reactants
(B) initial concentration of the products
(C) increases or decreases in temperature
(D) the time required to reach equilibrium. 17. C

18. If the equilibrium constant is very large, the reaction (A) produces a greater concentration of the reactants (B) produces a greater concentration of the products (C) reaches equilibrium very quickly (D) reaches equilibrium very slowly. 18. B

19. In the reaction $X + Y \rightarrow W$, an increase in the concentration of $X$ will cause the equilibrium point to (A) shift to the right favoring products (B) shift to the left favoring reactants (C) remain unchanged (D) shift but in an unpredictable way. 19. A

20. The statement "when a system at equilibrium is subjected to a stress, the equilibrium will shift in a direction to counteract the effect of the stress" is known as the principle of
(A) equilibrium (B) mass action (C) Le Chatelier (D) dynamics. 20. C

21. The value of $K_{sp}$ for the solubility equilibrium of $BaSO_4(s)$ with its ions, as shown by the equation $BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$, is equal to

(A) $[Ba^{2+}][SO_4^{2-}]$ (B) $[Ba^{2+}]^2[SO_4^{2-}]^2$ (C) $\dfrac{[Ba^{2+}][SO_4^{2-}]}{[BaSO_4]}$ (D) $[BaSO_4]$. 21. A

22. The solubility product expression for the equilibrium expressed by the equation $PbSO_4(s) \rightleftharpoons Pb^{2+}(aq) + SO_4^{2-}(aq)$ would be
(A) $[Pb^{2+}]$ (B) $[SO_4^{2-}]$ (C) $[Pb^{2+}][SO_4^{2-}]$ (D) $[Pb^{2+}][SO_4^{2-}]^2$. 22. C

23. Which of the following substances would you predict to be *most soluble*?
(A) PbS for which $K_{sp} = 7 \times 10^{-29}$
(B) CdS for which $K_{sp} = 1 \times 10^{-28}$
(C) $PbCrO_4$ for which $K_{sp} = 2 \times 10^{-16}$
(D) $BaCO_3$ for which $K_{sp} = 2 \times 10^{-9}$ 23. D

24. The difference in the enthalpy, $\Delta H$, of the reactants and products in a chemical reaction is also known as the (A) threshold energy (B) heat of reaction (C) activation energy (D) internal energy. 24. B

25. Suppose the heat of formation of a compound is positive. The enthalpy of the compound formed compared to the enthalpy of the elements from which it is formed is then (A) greater (B) smaller (C) impossible to predict (D) sometimes greater and sometimes smaller. 25. A

26. The compound in the group below that is the most unstable would be (standard heats of formation, $\Delta H_f^\circ$ are given)
(A) $Al_2O_3$; $\Delta H_f^\circ = -399.1$ kcal/mole
(B) $NH_3$; $\Delta H_f^\circ = -11.0$ kcal/mole
(C) $SO_2$; $\Delta H_f^\circ = -71.0$ kcal/mole
(D) $H_2O$; $\Delta H_f^\circ = -68.3$ kcal/mole. 26. B

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27. If the standard heats of formation, $H_f^\circ$, are as given for the following reactions
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g)$; $\Delta H_f^\circ = -57.8$ kcal/mole
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$; $\Delta H_f^\circ = -68.3$ kcal/mole
what is the heat of reaction under standard conditions for changing $H_2O(g)$ to $H_2O(l)$?
(A) −126.1 kcal/mole (B) +126.1 kcal/mole (C) −10.5 kcal/mole (D) +10.5 kcal/mole 27. C

28. A spontaneous chemical change is favored by the
(A) lowering of energy and decreasing of entropy
(B) lowering of energy and increasing of entropy
(C) increasing of energy and increasing of entropy
(D) increasing of energy and decreasing of entropy. 28. B

29. The net driving force of a reaction is described by the value of the quantity
(A) $\Delta H$ (B) $\Delta S$ (C) $\Delta T$ (D) $\Delta G$. 29. A

30. The free energy of formation of a compound differs from the heat of formation of a compound by the value of (A) $\Delta S$ (B) $T\Delta S$ (C) $\Delta T$ (D) $S\Delta T$. 30. B

31. Chemical equilibrium is reached when
(A) both forward and reverse reactions stop (C) rates of opposing reactions are equal
(B) all the reactants are used up (D) amounts of reactants and products are equal. 31. C

32. The mass action expression for the reaction $2X + Y \rightarrow 3W + V$ would be
(A) $\frac{[W]^3[V]}{[X]^2[Y]}$ (B) $\frac{[X]^2[Y]}{[W]^3[V]}$ (C) $[X][W][Y]$ (D) $[X]^3[W][Y]$ 32. A

33. For the reaction $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$, at a particular temperature, the equilibrium concentrations of $H_2$ and $I_2$ are 0.15 mole/liter, and of HI is 0.50 mole/liter. At this temperature, the numerical value of the equilibrium constant is (A) 11 (B) 38 (C) 567 (D) 1000. 33. A

34. For the reaction A + B → C + D + energy, an increase in temperature would result in the equilibrium position (A) remaining unchanged (B) shifting to the right (C) shifting to the left (D) being impossible to predict. 34. C

35. For the reaction X(g) + 2Y (g) → W (g), an increase in pressure would result in the equilibrium position (A) remaining unchanged (B) shifting to the right (C) shifting to the left (D) being impossible to predict. 35. B

36. In the preparation of ammonia by the reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g) + 22$ kcal, the temperature is kept quite high (about 550°C) to (A) force the equilibrium position to the right (B) force the equilibrium position to the left (C) slow up the reaction to the right (D) allow the reaction to reach equilibrium more quickly. 36. D

37. The solubility of $Mg(OH)_2$ is $1.3 \times 10^4$ moles/liter. The concentration of magnesium ions, $Mg^{2+}$, in a saturated solution of $Mg(OH)_2$ would be (A) 0 mole/liter (B) $1.3 \times 10^4$ moles/liter (C) $2.6 \times 10^4$ moles/liter (D) $3.9 \times 10^4$ moles/liter. 37. B

38. If the $K_{sp}$ for $MgCO_3$ is $4.0 \times 10^{-8}$, the solubility of $MgCO_3$ is (A) $4.0 \times 10^{-8}$ mole/liter (B) $4.0 \times 10^{-4}$ mole/liter (C) $2.0 \times 10^{-8}$ mole/liter (D) $2.0 \times 10^{-4}$ mole/liter. 38. D

39. A slightly soluble ionic compound $AB_2$ dissociates according to the equation
$AB_2(s) \rightarrow A^{2+}(aq) + 2B^-(aq)$
If the solubility of $AB_2$ at a particular temperature is $2.0 \times 10^{-4}$ mole/liter, then the value of $K_{sp}$ at this temperature is (A) $3.2 \times 10^{-11}$ (B) $8.0 \times 10^{-12}$ (C) $4.0 \times 10^{-8}$ (D) $2.0 \times 10^{-4}$. 39. A

40. For the equilibrium $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$, $K_{sp}$ at room temperature is $1.7 \times 10^{-10}$. A solution with $[Ag^+] = 1 \times 10^{-2}$ M and $[Cl^-] = 1 \times 10^{-3}$ M will
(A) precipitate AgCl and the ion product of dissolved ions will be $1.0 \times 10^{-5}$
(B) not precipitate AgCl and the ion product of dissolved ions will be $1.0 \times 10^{-5}$
(C) precipitate AgCl and the ion product of dissolved ions will be $1.7 \times 10^{-10}$
(D) not precipitate AgCl and the ion product of dissolved ions will be $1.7 \times 10^{-10}$. 40. C

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# Unit 6 Kinetics and Equilibrium

*For each of the following, select the word, number, or phrase that best completes the statement and write its letter in the answer space at the right.*

1. The major factors that affect the rates of chemical reactions include all of the following *except* (A) temperature (B) humidity (C) concentration (D) nature of reactants. 1. B

2. Collision theory explains the increase in rate with increase in concentration by the (A) increased frequency of collisions (B) more energetic collisions (C) lowered number of collisions (D) less energetic collisions. 2. A

3. The effect of temperature on the rate of reaction is explained by (A) the increased number of collisions (B) the increased effectiveness of the collisions (C) both of the above (D) neither of the above. 3. C

4. A substance that speeds up a chemical reaction without being permanently changed itself is a(an) (A) contaminant (B) catalyst (C) inhibitor (D) impurity. 4. B

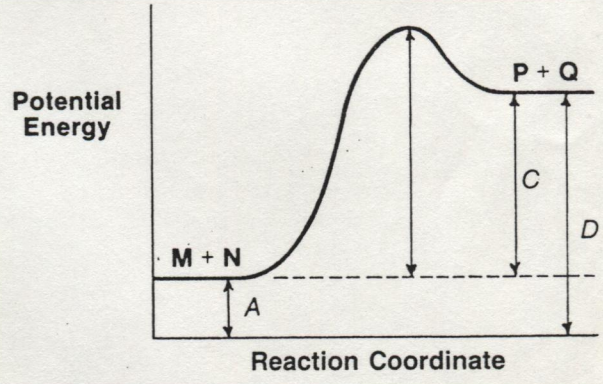
5. The sum of the series of steps in a specific chemical reaction is called the (A) net reaction (B) theoretical reaction (C) rate determining reaction (D) long reaction. 5. A

6. The reason that reactions are believed to occur in several simple steps is based on the low probability of (A) collisions of three or more particles (B) two-particle collisions (C) the formation of intermediate products (D) the presence of a catalyst. 6. A

7. Efforts to increase the speed of a net reaction are most effective if they are directed at increasing the speed of (A) the fastest step of the reaction (B) all of the steps of the reaction (C) the slowest step of the reaction (D) any competing reactions. 7. C

8. The substances that would be at the highest level of potential energy in a reaction would be the (A) reactants (B) activated complex (C) products (D) impossible to predict. 8. B

9. According to the graph for the reaction M + N → P + Q, the heat of the reaction is indicated by the letter (A) A (B) B (C) C (D) D. 9. C




10. A lowered activation energy makes it possible for substances to react
(A) without colliding
(B) with increased heats of reaction
(C) with lowered heats of reaction
(D) at lowered temperatures. 10. D

11. For an exothermic reaction, the energy term is
(A) positive and on the right hand side of the equation
(B) negative and on the right hand side of the equation
(C) positive and on the left hand side of the equation
(D) negative and on the left hand side of the equation. 11. A

12. In the choices below, the standard heats of formation, $\Delta H_f^\circ$, are given for each substance. The compound in the group below that you would expect to be the most stable would be
(A) $Al_2O_3$; $\Delta H_f^\circ = -399.1$ kcal/mole
(B) $NH_3$; $\Delta H_f^\circ = -11.0$ kcal/mole
(C) $SO_2$; $\Delta H_f^\circ = -71.0$ kcal/mole
(D) $H_2O$; $\Delta H_f^\circ = -68.3$ kcal/mole. 12. A

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13. If a reaction in the forward direction results in a decrease in enthalpy and an increase in entropy, the reaction would be expected to
(A) occur spontaneously in the forward direction (C) not take place in either direction
(B) occur spontaneously in the reverse direction (D) give results that could not be predicted. 13. A

14. The measure of the disorder or lack of organization of a system is its
(A) energy (B) enthalpy (C) enquiry (D) entropy. 14. D

15. The Gibbs energy, $\Delta G$, is equal to
(A) $\Delta H - S\Delta T$ (B) $\Delta S - T\Delta H$ (C) $\Delta H + T\Delta S$ (D) $\Delta H - T\Delta S$. 15. D

16. A chemical reaction can occur only if the value of the free energy term is
(A) equal to zero (B) greater than zero (C) less than zero (D) equal to one. 16. C

17. Decreases in the entropy of a system occur when (A) liquids change to solids (B) liquids change to gases (C) the temperature is increased (D) any chemical reaction takes place. 17. A

18. Double arrows pointing in opposite directions between reactants and products indicate that the reaction is (A) complete (B) balanced (C) static (D) reversible. 18. D

19. Chemical equilibrium is recognized by the
(A) absence of any further observable change (C) rapid changes in physical properties
(B) absence of any of the reactants originally present (D) rapid changes in chemical properties. 19. A

20. The mass action expression for the reaction $3X + W \rightarrow 2Y$ would be
(A) $\frac{[Y]^2}{[X]^3[W]}$ (B) $\frac{[X]^3[W]}{[Y]^2}$ (C) $[X][W][Y]$ (D) $[X]^3[W][Y]^2$ 20. A

21. For all reversible reactions, the value of the mass action expression is a constant at constant temperature. This statement is referred to as the (A) law of reversibility
(B) law of concentrations (C) law of chemical equilibrium (D) law of mass action. 21. C

22. A very small value for the equilibrium constant suggests that
(A) equilibrium will be reached very quickly
(B) equilibrium will be reached very slowly
(C) equilibrium concentrations of products will be greatest
(D) equilibrium concentrations of reactants will be greatest. 22. D

23. In the reaction $A + B \rightarrow C + D$, a decrease in the concentration of C will cause the equilibrium point to
(A) shift to the left, favoring reactants (C) shift to the right, favoring products
(B) shift, but in an unpredictable way (D) remain unchanged. 23. C

24. The principle of Le Chatelier can be used to predict the (A) value of the equilibrium constant (B) law of mass action expression (C) effect of changing conditions on the equilibrium position (D) products of a chemical reaction. 24. C

25. For the reaction Energy + $X \rightarrow W + Y$, an increase in temperature would result in the equilibrium position (A) remaining unchanged (B) shifting to the right (C) shifting to the left (D) being impossible to predict. 25. B

26. For the reaction $A(g) + B(g) \rightarrow 2C(g)$, an increase in pressure would result in the equilibrium position (A) remaining unchanged (B) shifting to the right (C) shifting to the left (D) being impossible to predict. 26. A

27. The solubility product expression for $Al(OH)_3(s) \rightarrow Al^{3+}(aq) + 3OH^-(aq)$ would be
(A) $[Al^{3+}]$ (B) $[OH^-]$ (C) $[Al^{3+}][OH^-]$ (D) $[Al^{3+}][OH^-]^3$. 27. D

28. For each choice below, solubility product constants, $K_{sp}$, are given for each substance. The substance below that would be *least soluble* would be
(A) AgBr; $K_{sp} = 5.00 \times 10^{-13}$ (C) AgI; $K_{sp} = 8.5 \times 10^{-17}$
(B) $PbCrO_4$; $K_{sp} = 2 \times 10^{-16}$ (D) $Al(OH)_3$; $K_{sp} = 5 \times 10^{-33}$. 28. D

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29. An increase in enthalpy, $+\Delta H$, during a chemical reaction means that the
(A) reactants have a greater heat content than the products
(B) products have a greater heat content than the reactants
(C) activation energy has been increased for the reaction
(D) activation energy has been decreased for the reaction. 29. B

30. To answer the question below, use the heats of reaction, $H_f^\circ$, for the following two changes:

$$\tfrac{1}{2}N_2(g) + O_2(g) \rightarrow NO_2(g);\ \Delta H_f^\circ = +8.1 \text{ kcal/mole}$$
$$\tfrac{1}{2}N_2(g) + \tfrac{1}{2}O_2(g) \rightarrow NO(g);\ \Delta H_f^\circ = +21.6 \text{ kcal/mole}$$

The heat of reaction for the change $NO(g) + \tfrac{1}{2}O_2(g) \rightarrow NO_2(g)$ would be
(A) +29.7 kcal/mole (B) −29.7 kcal/mole (C) −13.5 kcal/mole (D) +13.5 kcal/mole. 30. C

31. The heat of reaction, in general, is equal to the
(A) sum of the heats of formation of reactants and products
(B) heats of formation of reactants minus the heats of formation of products
(C) heats of formation of products minus the heats of formation of reactants
(D) heats of formation of the products. 31. C

32. The value of $\Delta G$ for the change from solid to liquid *at the melting temperature of water* could be expected to be (A) zero (B) greater than zero (C) less than zero (D) either greater or less than zero. 32. A

33. The change of phase from liquid to vapor is endothermic, yet liquids will change to vapors at even quite low temperatures. The value of $T\Delta S$ at those temperatures must be
(A) greater than zero (B) greater than $\Delta H$ (C) equal to $\Delta H$ (D) less than $\Delta H$. 33. B

34. Given the reaction $A(g) + 3B(g) \rightleftharpoons 2C(g)$ for which equilibrium concentrations at a particular temperature are 1.0 *M* for A, 2.0 *M* for B, and 0.5 *M* for C. The numerical value of the equilibrium constant for this particular temperature is (A) 1.0 (B) 0.50 (C) 0.031 (D) 0.25. 34. C

35. The equilibrium position of an exothermic reaction can be forced to the right by lowering the temperature. The yield of products, as a result,
(A) is increased but the rate of reaction is slower
(B) is increased and the rate of reaction is faster
(C) is decreased but the rate of reaction is faster
(D) is decreased and the rate of reaction is slower. 35. A

36. The value of $K_{sp}$ is obtained from the product of $K_{eq}$ and the
(A) concentration of the solid (B) concentration of the ions (C) temperature of the solid
(D) temperature of the ions. 36. A

37. The solubility of $Ag_2CrO_4$ is $6.5 \times 10^{-5}$ mole/liter. The concentration of $Ag^+$ ions in a saturated solution of $Ag_2CrO_4$ would be (A) $6.5 \times 10^{-5}$ mole/liter (B) $1.3 \times 10^{-4}$ mole/liter
(C) $2.6 \times 10^{-4}$ mole/liter (D) $1.0 \times 10^{-4}$ mole/liter. 37. B

38. If the $K_{sp}$ for CdS is $1.0 \times 10^{-28}$, the solubility of CdS is
(A) $1.0 \times 10^{-28}$ mole/liter (B) $1.0 \times 10^{-14}$ mole/liter
(C) $1.0 \times 10^{-7}$ mole/liter (D) 1.0 mole/liter. 38. B

39. An ionic solid, $CD_3$, dissociates according to the equation $CD_3(s) \rightarrow C^{3+}(aq) + 3D^-(aq)$. If the solubility of $CD_3$ is $1.0 \times 10^{-3}$ mole/liter, the value of $K_{sp}$ for $CD_3$ is
(A) $1.0 \times 10^{-6}$ (B) $3.0 \times 10^{-6}$ (C) $1.0 \times 10^{-12}$ (D) $2.7 \times 10^{-11}$. 39. D

40. The $K_{sp}$ for $PbSO_4(s) \rightarrow Pb^{2+}(aq) + SO_4^{2-}(aq)$ is $1.3 \times 10^{-8}$. A solution containing $[Pb^{2+}] = 1 \times 10^{-5}$ *M* and $[SO_4^{2-}] = 1 \times 10^{-7}$ *M* will
(A) precipitate $PbSO_4$ and the ion product will be $1 \times 10^{-12}$
(B) not precipitate $PbSO_4$ and the ion product will be $1 \times 10^{-12}$
(C) precipitate $PbSO_4$ and the ion product will be $1.3 \times 10^{-8}$
(D) not precipitate $PbSO_4$ and the ion product will be $1.3 \times 10^{-8}$. 40. B