CHAPTER 13 Chemical Equilibrium

1. Which of the following statements concerning equilibrium is not true?
   a) A system that is disturbed from an equilibrium condition responds in a manner to restore equilibrium.
   b) Equilibrium in molecular systems is dynamic, with two opposing processes balancing one another.
   c) The value of the equilibrium constant for a given reaction mixture is the same regardless of the direction from which equilibrium is attained.
   d) A system moves spontaneously toward a state of equilibrium.
   e) The equilibrium constant is independent of temperature.

   ANS: e) The equilibrium constant is independent of temperature. **PAGE:** 13.1,2

2. Which of the following statements is true?
   a) When two opposing processes are proceeding at identical rates, the system is at equilibrium.
   b) Catalysts are an effective means of changing the position of an equilibrium.
   c) The concentration of the products equals that of reactants and is constant at equilibrium.
   d) An endothermic reaction shifts toward reactants when heat is added to the reaction.
   e) None of these statements is true.

   ANS: a) When two opposing processes are proceeding at identical rates, the system is at equilibrium. **PAGE:** 13.1,7

3. Indicate the mass action expression for the following reaction:

   $$2X(g) + Y(g) \rightleftharpoons 3W(g) + V(g)$$

   a) $[X]^2[Y][W]^3[V]$

   b) $\dfrac{[W]^3[V]}{[X]^2[Y]}$

   c) $\dfrac{[3W][V]}{[2X][Y]}$

   d) $\dfrac{[X]^2[Y]}{[W]^3[V]}$

   ANS: b) $\dfrac{[W]^3[V]}{[X]^2[Y]}$ **PAGE:** 13.2

4. If, at a given temperature, the equilibrium constant for the reaction

$$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$$

is K_p, then the equilibrium constant for the reaction

$$HCl(g) \rightleftharpoons (1/2)\, H_2(g) + (1/2)Cl_2\,(g)$$

can be represented as:

a) $\dfrac{1}{K_p{}^2}$

b) $K_p{}^2$

c) $\dfrac{1}{\sqrt{K_p}}$

d) $\sqrt{K_p}$

ANS: c) $\dfrac{1}{\sqrt{K_p}}$ **PAGE:** 13.2,3

5. The value of the equilibrium constant, *K*, is dependent on

I. The temperature of the system.
II. The nature of the reactants and products.
III. The concentration of the reactants.
IV. The concentration of the products.

a) I, II
b) II, III
c) III, IV
d) It is dependent on three of these choices.
e) It is not dependent on any of these choices.

ANS: a) I, II **PAGE:** 13.2

6. Apply the law of mass action to determine the equilibrium expression for $2NO_2Cl \rightleftharpoons 2NO_2 + Cl_2$

a) $2[NO_2][Cl_2]/2[NO_2Cl]$
b) $2[NO_2Cl]/2[NO_2][Cl_2]$
c) $[NO_2Cl]^2/[NO_2]^2[Cl_2]$
d) $[NO_2]^2[Cl_2]/[NO_2Cl]^2$
e) $[NO_2Cl]^2[NO_2]^2[Cl_2]$

ANS: d) $[NO_2]^2[Cl_2]/[NO_2Cl]^2$ **PAGE:** 13.2

7–9. Consider the chemical system $CO + Cl_2 \rightleftharpoons COCl_2$; $K = 4.6 \times 10^9$ L/mol.

7. How do the equilibrium concentrations of the reactants compare to the equilibrium concentration of the product?

   a) They are much smaller.
   b) They are much bigger.
   c) They are about the same.
   d) They have to be exactly equal.
   e) You can't tell from the information given.

   Ans: a) They are much smaller. **PAGE:** 13.2

8. If the concentration of the product were to double, what would happen to the equilibrium constant?

   a) It would double its value.
   b) It would become half its current value.
   c) It would quadruple its value.
   d) It would not change its value.
   e) It would depend on the initial conditions of the product.

   Ans: d) It would not change its value. **PAGE:** 13.2

9. Determine the equilibrium constant for the system $N_2O_4 \rightleftharpoons 2NO_2$ at 25°C. The concentrations are shown here: $[N_2O_4] = 4.27 \times 10^{-2}$ M, $[NO_2] = 1.41 \times 10^{-2}$ M

   a) 0.33
   b) 3.0
   c) 0.66
   d) 0.05
   e) 0.0047

   Ans: e) 0.0047 **PAGE:** 13.2

10. At 500.0 K, one mole of gaseous ONCl is placed in a one-liter container. At equilibrium it is 9.0% dissociated according to the equation shown here: $2ONCl \rightleftharpoons 2NO + Cl_2$

    Determine the equilibrium constant.

    a) 4.4×10^{-4}
    b) 2.2×10^{2}
    c) 1.1×10^{2}
    d) 2.2×10^{-4}
    e) 9.1×10^{-1}

    ANS: a) 4.4×10^{-4} **PAGE:** 13.5

11. Consider the reaction $H_2 + I_2 \rightleftharpoons 2HI$ whose $K = 54.8$ at 425°C. If an equimolar mixture of reactants gives the concentration of the product to be 0.50 M at equilibrium, determine the concentration of the hydrogen.

    a) 4.6×10^{-3} M
    b) 6.8×10^{-2} M
    c) 1.2×10^{-3} M
    d) 9.6×10^{-2} M
    e) 1.6×10^{-4} M

    ANS: b) 6.8×10^{-2} M **PAGE:** 13.5

12. Consider the gaseous reaction $CO(g) + Cl_2(g) \rightleftharpoons COCl_2(g)$. What is the expression for K_p in terms of K?

    a) $K(RT)$
    b) $K/(RT)$
    c) $K(RT)^2$
    d) $K/(RT)^2$
    e) $1/K(RT)$

    ANS: b) $K/(RT)$ **PAGE:** 13.3

13. Find the value of the equilibrium constant (K) (at 500 K) for

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

    The value for K_p at 500 K is $1.5 \times 10^{-5}/\text{atm}^2$.

    a) 7.5×10^{-2}
    b) 1.3×10^{-2}
    c) 9.6×10^{-2}
    d) 2.5×10^{-2}
    e) 6.0×10^{-2}

    ANS: e) 6.0×10^{-2} **PAGE:** 13.3

14. Consider the following reaction: $CS_2(g)\ 4H_2(g) \rightleftharpoons CH_4(g) + 2H_2S(g)$
    The equilibrium constant K is 0.28 at 900°C. What is K_p at this temperature?

    a) 5.0×10^{-5}
    b) 4.0×10^{-5}
    c) 3.0×10^{-5}
    d) 2.0×10^{-5}
    e) 1.0×10^{-5}

    ANS: c) 3.0×10^{-5} **PAGE:** 13.3

15. Consider the following system at equilibrium:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) + 92.94 \text{ kJ}$$

Which of the following changes will shift the equilibrium to the right?

I. increasing the temperature
II. decreasing the temperature
III. increasing the volume
IV. decreasing the volume
V. removing some NH_3
VI. adding some NH_3
VII. removing some N_2
VIII. adding some N_2

a) I, IV, VI, VII
b) II, III, V, VIII
c) I, VI, VIII
d) I, III, V, VII
e) II, IV, V, VIII

ANS: e) II, IV, V, VIII **PAGE:** 13.7

16. If the equilibrium constant for A + B $\rightleftharpoons$ C is 0.123, then the equilibrium constant for 2C $\rightleftharpoons$ 2A + 2B is _____.

a) 1.00 – 2(0.123)
b) 8.13
c) 0.123
d) 66.1
e) 16.3

ANS: d) 66.1 **PAGE:** 13.2

17. Calculate K_p for $H_2O(g) + \frac{1}{2} O_2(g) \rightleftharpoons H_2O_2(g)$ at 600 K, using the following data:

$H_2(g) + O_2(g) \rightleftharpoons H_2O_2(g)$ $K_p = 2.3 \times 10^6$ at 600 K

$2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$ $K_p = 1.8 \times 10^{37}$ at 600 K

a) 4.4×10^{43}
b) 9.8×10^{24}
c) 1.2×10^{-4}
d) 5.4×10^{-13}
e) 2.6×10^{-31}

ANS: d) 5.4×10^{-13} **PAGE:** 13.2,3

18. Given the equation: $2NOCl_2(g) \rightleftharpoons 2NO(g) + Cl_2(g)$. The equilibrium constant is 0.0150 at 115°C. Calculate K_p.

    a) 0.0150
    b) 0.478
    c) 0.142
    d) 1.41×10^{-4}
    e) none of these

    ANS: b) 0.478 **PAGE:** 13.3

19. For the reaction below, $K_p = 1.16$ at 800°C.

    $$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

    If a 20.0-gram sample of $CaCO_3$ is put into a 10.0-liter container and heated to 800°C, what percent of the $CaCO_3$ will react to reach equilibrium?

    a) 14.6%
    b) 65.9%
    c) 34.1%
    d) 100.0%
    e) none of these

    ANS: b) 65.9% **PAGE:** 13.3-5

20. At –80°C, K for the reaction

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

    is 4.66×10^{-8}. We introduce 0.050 mole of N_2O_4 into a 1.0-L vessel at –80°C and let equilibrium be established. The total pressure in the system at equilibrium will be:

    a) 0.23 atm
    b) 0.79 atm
    c) 1.3 atm
    d) 2.3 atm
    e) none of these

    ANS: b) 0.79 atm **PAGE:** 13.3,6

21. The reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

has $K_p = 45.9$ at 763 K. A particular equilibrium mixture at that temperature contains gaseous HI at a partial pressure of 4.00 atm and hydrogen gas at a partial pressure of 0.200 atm. What is the partial pressure of I_2?

a) 0.200 atm
b) 0.436 atm
c) 1.74 atm
d) 0.574 atm
e) 14.3 atm

ANS: c) 1.74 atm **PAGE:** 13.3

22. Consider the reaction:

$$CaCl_2(s) + 2H_2O(g) \rightleftharpoons CaCl_2 \cdot 2H_2O(s)$$

The equilibrium constant for the reaction as written is

a) $K = \dfrac{[CaCl_2 \bullet 2H_2O]}{[CaCl_2][H_2O]^2}$

b) $K = \dfrac{1}{[H_2O]^2}$

c) $K = \dfrac{1}{2[H_2O]}$

d) $K = [H_2O]^2$

e) $K = \dfrac{[CaCl_2 \bullet 2H_2O]}{[H_2O]^2}$

ANS: b) $K = \dfrac{1}{[H_2O]^2}$ **PAGE:** 13.4

23–24. Consider the following equilibrium:

$$H_2(g) + I_2(s) \rightleftharpoons 2HI(g) \qquad \Delta H = +68.0 \text{ kJ/mol}$$

23. The proper K_{eq} expression is:

a) $\dfrac{[H_2][I_2]}{[HI]}$

b) $\dfrac{\sqrt{([H_2][I_2])}}{[HI]^2}$

c) $\frac{[HI]}{\sqrt{([H_2])}}$

d) $\frac{[HI]^2}{[H_2][I_2]}$

e) $\frac{[HI]^2}{[H_2]}$

ANS: e) $\frac{[HI]^2}{[H_2]}$ **PAGE:** 13.4

24. Which of the following statements about the equilibrium is false?

a) If the system is heated, the right side is favored.
b) This is a heterogeneous equilibrium.
c) If the pressure on the system is increased by changing the volume, the left side is favored.
d) Adding more $H_2(g)$ increases the equilibrium constant.
e) Removing HI as it forms forces the equilibrium to the right.

ANS: d) Adding more $H_2(g)$ increases the equilibrium constant. **PAGE:** 13.7

25. Consider the reaction:

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

at constant temperature. Initially a container is filled with pure $SO_3(g)$ at a pressure of 2 atm, after which equilibrium is reached. If y is the partial pressure of O_2 at equilibrium, the value of K_p is:

a) $\dfrac{(2-2y)^2}{(y^2)(2y)}$

b) $\dfrac{(2-y)^2}{(y^2)(y/2)}$

c) $\dfrac{(2-y)^2}{(2y)^2(y)}$

d) $\dfrac{(2-2y)^2}{(2y)^2(y)}$

e) none of these

ANS: d) $\dfrac{(2-2y)^2}{(2y)^2(y)}$ **PAGE:** 13.5

26–27. For the reaction given below, 2.00 moles of A and 3.00 moles of B are placed in a 6.00-L container.

$$A(g) + 2B(g) \rightleftharpoons C(g)$$

26. At equilibrium, the concentration of A is 0.300 mol/L. What is the concentration of B at equilibrium?

a) 0.300 mol/L
b) 0.433 mol/L
c) 0.500 mol/L
d) 0.600 mol/L
e) none of these

ANS: b) 0.433 mol/L **PAGE:** 13.2

27. At equilibrium, the concentration of A is 0.300 mol/L. What is the value of *K*?

a) 0.146
b) 0.253
c) 0.300
d) 0.589
e) 1.043

ANS: d) 0.589 **PAGE:** 13.5

28. A 10.0-g sample of solid NH_4Cl is heated in a 5.00-L container to 900°C. At equilibrium the pressure of $NH_3(g)$ is 1.20 atm.

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$$

The equilibrium constant, K_p, for the reaction is:

a) 1.20
b) 1.44
c) 2.40
d) 31.0
e) none of these

ANS: b) 1.44 **PAGE:** 13.5

29. The following reaction is investigated (assume an ideal gas mixture):

$$2N_2O(g) + N_2H_4(g) \rightleftharpoons 3N_2(g) + 2H_2O(g)$$

Initially there are 0.10 moles of N_2O and 0.25 moles of N_2H_4, in a 10.0-L container. If there are 0.06 moles of N_2O at equilibrium, how many moles of N_2 are present at equilibrium?

a) 0.9
b) 0.04
c) 0.06
d) 0.02
e) none of these

ANS: c) 0.06 **PAGE:** 13.5

30. At a certain temperature *K* for the reaction

$$2NO_2 \rightleftharpoons N_2O_4$$

is 7.5 liters/mole. If 2.0 moles of NO_2 are placed in a 2.0-liter container and permitted to react at this temperature, calculate the concentration of N_2O_4 at equilibrium.

a) 0.39 moles/liter
b) 0.65 moles/liter
c) 0.82 moles/liter
d) 7.5 moles/liter
e) none of these

ANS: a) 0.39 moles/liter **PAGE:** 13.5,6

31. Initially 2.0 moles of $N_2(g)$ and 4.0 moles of $H_2(g)$ were added to a 1.0-liter container and the following reaction then occurred:

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

The equilibrium concentration of $NH_3(g)$ = 0.68 moles/liter at 700°C. The value for *K* at 700°C for the formation of ammonia is:

a) 3.6×10^{-3}
b) 1.4×10^{-1}
c) 1.1×10^{-2}
d) 5.0×10^{-2}
e) none of these

ANS: c) 1.1×10^{-2} **PAGE:** 13.5

32. Consider the reaction $C(s) + CO_2(g) \rightleftharpoons 2CO(g)$. At 1273 K the K_p value is 167.5. What is the P_{CO} at equilibrium if the P_{CO_2} is 0.10 atm at this temperature?

a) 16.7 atm
b) 2.0 atm
c) 1.4 atm
d) 4.1 atm
e) 250 atm

ANS: c) 4.1 atm **PAGE:** 13.4

33. Which of the following is true for a system whose equilibrium constant is relatively small?

a) It will take a short time to reach equilibrium.
b) It will take a long time to reach equilibrium.
c) The equilibrium lies to the left.
d) The equilibrium lies to the right.
e) Two of these.

ANS: c) The equilibrium lies to the left. **PAGE:** 13.5

34. The reaction quotient for a system is 7.2×10^2. If the equilibrium constant for the system is 36, what will happen as equilibrium is approached?

a) There will be a net gain in product.
b) There will be a net gain in reactant.
c) There will be a net gain in both product and reactant.
d) There will be no net gain in either product or reactant.
e) The equilibrium constant will decrease until it equals the reaction quotient.

ANS: b) There will be a net gain in reactant. **PAGE:** 13.5

35. Consider the following equilibrated system: $2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$. If the K_p value is 0.860, find the equilibrium pressure of the O_2 gas if the NO_2 gas pressure is 0.520 atm and the P_{NO} is 0.300 atm at equilibrium.

a) 1.49 atm
b) 0.78 atm
c) 0.40 atm
d) 0.99 atm
e) 2.58 atm

ANS: e) 2.58 atm **PAGE:** 13.5

36–37. Consider the following reaction (assume an ideal gas mixture):

$$2NOBr(g) \rightleftharpoons 2NO(g) + Br_2(g)$$

A 1.0-liter vessel was initially filled with pure NOBr, at a pressure of 4.0 atm, at 300 K.

36. After equilibrium was established, the partial pressure of NOBr was 2.5 atm. What is K_p for the reaction?

a) 0.45
b) 0.27
c) 0.18
d) 0.75
e) none of these

ANS: b) 0.27 **PAGE:** 13.5,6

37. After equilibrium was reached, the volume was increased to 2.0 liters, while the temperature was kept at 300 K. This will result in:

a) an increase in K_p.
b) a decrease in K_p.
c) a shift in the equilibrium position to the right.
d) a shift in the equilibrium position to the left.
e) none of these

ANS: c) a shift in the equilibrium position to the right. **PAGE:** 13.7

38–39. Nitric oxide, an important pollutant in air, is formed from the elements nitrogen and oxygen at high temperatures, such as those obtained when gasoline burns in an automobile engine. At 2000°C, K for the reaction

$$N2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

is 0.01.

38. Predict the direction in which the system will move to reach equilibrium at 2000°C if 0.4 moles of N_2, 0.1 moles of O_2, and 0.08 moles of NO are placed in a 1.0-liter container.

a) The system remains unchanged.
b) The concentration of NO will decrease; the concentrations of N_2 and O_2 will increase.
c) The concentration of NO will increase; the concentrations of N_2 and O_2 will decrease.
d) The concentration of NO will decrease; the concentrations of N_2 and O_2 will remain unchanged.
e) More information is necessary.

ANS: b) The concentration of NO will decrease; the concentrations of N_2 and O_2 will increase. **PAGE:** 13.5

39. A 1-L container originally holds 0.4 mol of N_2, 0.1 mol of O_2, and 0.08 mole of NO. If the volume of the container holding the equilibrium mixture of N_2, O_2, and NO is decreased to 0.5 L without changing the quantities of the gases present, how will their concentrations change?

a) The concentration of NO will increase; the concentrations of N_2 and O_2 will decrease.
b) The concentrations of N_2 and O_2 will increase; and the concentration of NO will decrease.
c) The concentrations of N_2, O_2, and NO will increase.
d) The concentrations of N_2, O_2, and NO will decrease.
e) There will be no change in the concentrations of N_2, O_2, and NO.

ANS: c) The concentrations of N_2, O_2, and NO will increase. **PAGE:** 13.5,7

40. A sample of solid NH_4NO_3 was placed in an evacuated container and then heated so that it decomposed explosively according to the following equation:

$$NH_4NO_3(s) \rightleftharpoons N_2O(g) + 2H_2O(g)$$

At equilibrium the total pressure in the container was found to be 3.20 atm at a temperature of 500°C. Calculate K_p.

a) 4.10
b) 1.23
c) 2.56
d) 4.85
e) 1.14

ANS: d) 4.85 **PAGE:** 13.5

41. Consider the following reaction:

$$2HF(g) \rightleftharpoons H_2(g) + F_2(g) \quad (K = 1.00 \times 10^{-2})$$

Given 1.00 mole of HF(g), 0.500 mole of $H_2(g)$, and 0.750 mole of $F_2(g)$ are mixed in a 5.00-L flask, determine the reaction quotient, Q, and the net direction to achieve equilibrium.

a) $Q = 0.150$; the equilibrium shifts to the right.
b) $Q = 0.375$; the equilibrium shifts to the left.
c) $Q = 0.150$; the equilibrium shifts to the left.
d) $Q = 0.375$; the equilibrium shifts to the right.
e) $Q = 0.150$; the system is at equilibrium.

ANS: b) $Q = 0.375$; the equilibrium shifts to the left. **PAGE:** 13.5

42. Equilibrium is reached in chemical reactions when:

a) the rates of the forward and reverse reactions become equal.
b) the concentrations of reactants and products become equal.
c) the temperature shows a sharp rise.
d) all chemical reactions stop.
e) the forward reaction stops.

ANS: a) the rates of the forward and reverse reactions become equal. **PAGE:** 13.1

43–46. Consider the following equilibrium:

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

with $K = 1.6 \times 10^{-5}$. 1.00 mole of pure NOCl and 1.00 mole of pure Cl_2 are replaced in a 1.00-L container.

43. If x moles of NOCl react, what is the equilibrium concentration of NO?

a) $+x$
b) $+2x$
c) $-x$
d) $-2x$
e) x^2

ANS: a) $+x$ **PAGE:** 13.6

44. If x moles of NOCl react, what is the equilibrium concentration of Cl_2?

a) $+x$

b) $+\frac{x}{2}$

c) $1 + x$

d) $1 + \frac{x}{2}$

e) $1 + 2x$

ANS: d) $1 + \frac{x}{2}$ **PAGE:** 13.6

45. Calculate the equilibrium concentration of NO(g).

a) 1.0 M
b) 1.6×10^{-5} M
c) 0.50 M
d) 6.2×10^{-4} M
e) 4.0×10^{-3} M

ANS: e) 4.0×10^{-3} M **PAGE:** 13.6

46. Calculate the equilibrium concentration of Cl_2(g).

a) 1.6×10^{-5} M
b) 1.0 M
c) 0.50 M
d) 6.2×10^{-4} M
e) 4.0×10^{-3} M

ANS: b) 1.0 M **PAGE:** 13.6

47–49. The questions below refer to the following system:

A 3.00-liter flask initially contains 1.50 mol of gas A and 0.450 mol of gas B. Gas A decomposes according to the following reaction:

$$3A \rightleftharpoons 2B + C$$

The equilibrium concentration of gas C is 0.100 mol/L.

47. Determine the equilibrium concentration of gas A.

a) 0.100 M
b) 0.200 M
c) 0.300 M
d) 0.500 M
e) none of these

ANS: b) 0.200 M **PAGE:** 13.5

48. Determine the equilibrium concentration of gas B.

a) 0.150 M
b) 0.200 M
c) 0.350 M
d) 0.450 M
e) none of these

ANS: c) 0.350 M **PAGE:** 13.5

49. Determine the value of the equilibrium constant, *K*.

a) 0.117
b) 0.175
c) 0.227
d) 1.53
e) none of these

ANS: d) 1.53 **PAGE:** 13.5

50. Nitrogen gas (N_2) reacts with hydrogen gas (H_2) to form ammonia (NH_3). At 200°C in a closed container, 1.0 atm of nitrogen gas is mixed with 2.0 atm of hydrogen gas. At equilibrium, the total pressure is 2.0 atm. Calculate the partial pressure of hydrogen gas at equilbrium.

a) 2.0 atm
b) 0.50 atm
c) 1.5 atm
d) 0.0 atm
e) none of these

ANS: b) 0.50 atm **PAGE:** 13.6

51. Given the equation $A(aq) + 2B(aq) \rightleftharpoons 3C(aq) + 2D(aq)$. 45.0 mL of 0.050 M A is mixed with 25.0 mL 0.100 M B. At equilibrium the concentration of C is 0.0410 M. Calculate *K*.

a) 7.3
b) 0.34
c) 0.040
d) 0.14
e) none of these

ANS: c) 0.040 **PAGE:** 13.5

52. Given the reaction A(g) + B(g) $\rightleftharpoons$ C(g) + D(g). You have the gases A, B, C, and D at equilibrium. Upon adding gas A, the value of *K*:

    a) increases because by adding A, more products are made, increasing the product to reactant ratio.
    b) decreases because A is a reactant of the product to reactant ratio decreases.
    c) does not change because A does not figure into the product to reactant ratio.
    d) does not change as long as the temperature is constant.
    e) depends on whether the reaction is endothermic or exothermic.

    ANS: d) does not change as long as the temperature is constant. **PAGE:** 13.2, 7

53. The equilibrium system 2A $\rightleftharpoons$ 2B + C has a very small equilibrium constant: $K = 2.6 \times 10^{-6}$. Initially 3 moles of A are placed in a 1.5-L flask. Determine the concentration of C at equilibrium.

    a) 0.011 M
    b) 0.022 M
    c) 0.033 M
    d) 0.044 M
    e) 2.0 M

    ANS: a) 0.011 M **PAGE:** 13.6

54–57. The questions below refer to the following system:

Cobalt chloride is added to pure water. The Co^{2+} ions hydrate. The hydrated form then reacts with the Cl^- ions to set up the equilibrium shown here:

$$\underset{\text{(pink)}}{Co(H_2O)_6^{2+}} + 4\ Cl^- \rightleftharpoons \underset{\text{(blue)}}{CoCl_4^{2-}} + 6H_2O$$

54. Which statement below describes the change that the system will undergo if hydrochloric acid is added?

    a) It should become more blue.
    b) It should become more pink.
    c) The equilibrium will shift to the right.
    d) The equilibrium will shift to the left.
    e) Two of these.

    ANS: e) Two of these. **PAGE:** 13.7

55. Which statement below describes the change that the system will undergo if water is added?

    a) More chlorine ions will be produced.
    b) More water will be produced.
    c) The equilibrium will shift to the right.
    d) The color will become more blue.
    e) There will be less of the hydrated cobalt ion at the new equilibrium position.

    ANS: a) More chlorine ions will be produced. **PAGE:** 13.7

56. Which statement below describes the change that the system will undergo if silver nitrate is added?

    a) It should become more blue.
    b) It should become more pink.
    c) Water will be produced.
    d) The silver ion will react with the $CoCl_4^{2-}$.
    e) Nothing will change.

    ANS: b) It should become more pink. **PAGE:** 13.7

57. Which statement below describes the change that the system will undergo if acetone (whose density is lower than water and is insoluble in water) is added?

    a) The system will become pink on the top and blue on the bottom.
    b) The system will become blue on the top and pink on the bottom.
    c) The system will become intensely pink in the middle.
    d) The system will become intensely blue on the top and clear on the bottom.
    e) The system will become intensely pink on the top and clear on the bottom.

    ANS: b) The system will become blue on the top and pink on the bottom. **PAGE:** 13.7

58–60. The following questions refer to the equilibrium shown here:

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g)$$

58. What would happen to the system if oxygen were added?

    a) More ammonia would be produced.
    b) More oxygen would be produced.
    c) The equilibrium would shift to the right.
    d) The equilibrium would shift to the left.
    e) Nothing would happen.

    ANS: c) The equilibrium would shift to the right. **PAGE:** 13.7

59. What would happen to the system if the pressure were decreased?

    a) Nothing would happen.
    b) More oxygen would be produced.
    c) The water vapor would become liquid water.
    d) The ammonia concentration would increase.
    e) The NO concentration would increase.

    ANS: e) The NO concentration would increase. **PAGE:** 13.7

60. For a certain reaction at 25.0°C, the value of *K* is 1.2×10^{-3}. At 50.0°C the value of *K* is 3.4×10^{-1}. This means that the reaction is

a) exothermic.
b) endothermic.
c) never favorable.
d) More information is needed.
e) None of these (a-d)

ANS: a) Endothermic **PAGE:** 13.7

61. Ammonia is prepared industrially by the reaction:

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

For the reaction, $\Delta H° = -92.2$ kJ and *K* (at 25°C) = 4.0×10^8. When the temperature of the reaction is increased to 500°C, which of the following is true?

a) *K* for the reaction will be larger at 500°C than at 25°C.
b) At equilibrium, more NH_3 is present at 500°C than at 25°C.
c) Product formation (at equilibrium) is not favored as the temperature is raised.
d) The reaction of N_2 with H_2 to form ammonia is endothermic.
e) None of these is true.

ANS: c) Product formation (at equilibrium) is not favored as the temperature is raised. **PAGE:** 13.7

62–65. Consider the following equilibrium:

$$2H_2(g) + X_2(g) \rightleftharpoons 2H_2X(g) + \text{energy}$$

62. Addition of X_2 to a system described by the above equilibrium

a) will cause $[H_2]$ to decrease.
b) will cause $[X_2]$ to decrease.
c) will cause $[H_2X]$ to decrease.
d) will have no effect.
e) cannot possibly be carried out.

ANS: a) will cause $[H_2]$ to decrease. **PAGE:** 13.7

63. Addition of argon to the above equilibrium

a) will cause $[H_2]$ to decrease.
b) will cause $[X_2]$ to increase.
c) will cause $[H_2X]$ to increase.
d) will have no effect.
e) cannot possibly be carried out.

ANS: d) will have no effect. **PAGE:** 13.7

64. Increasing the pressure by decreasing the volume will cause

a) the reaction to occur to produce H_2X.
b) the reaction to occur to produce H_2 and X_2.
c) the reaction to occur to produce H_2 but no more X_2.
d) no reaction to occur.
e) X_2 to dissociate.

ANS: a) the reaction to occur to produce H_2X. **PAGE:** 13.7

65. Increasing the temperature will cause

a) the reaction to occur to produce H_2X.
b) the reaction to occur to produce H_2 and X_2.
c) the reaction to occur to produce H_2 but no more X_2.
d) no reaction to occur.
e) an explosion.

ANS: b) the reaction to occur to produce H_2 and X_2. **PAGE:** 13.7

66. The value of equilibrium constant *K* is dependent on

I. the initial concentrations of the reactants.
II. the initial concentrations of the products.
III. the temperature of the system.
IV. the nature of the reactants and products.

a) I, II
b) II, III
c) III, IV
d) It is dependent on three of these choices.
e) It is not dependent on any of these choices.

ANS: c) III, IV **PAGE:** 13.2

67–72. Given the equation $2A(g) \rightleftharpoons 2B(g) + C(g)$. At a particular temperature, $K = 1.6 \times 10^4$.

67. If you start with 2.0 M of chemical A, calculate the equilibrium concentration of chemical C.

a) 8.3×10^{-3} M
b) 6.25×10^{-5} M
c) 2.0 M
d) 0.99 M
e) none of these

ANS: d) 0.99 M **PAGE:** 13.6

68. If you mixed 5.0 mol B, 0.10 mol C, and 0.0010 mol A in a one-liter container, which direction would the reaction initially proceed?

a) To the left.
b) To the right.
c) The above mixture is the equilibrium mixture.
d) Cannot tell from the information given.
e) None of these (a-d)

ANS: a) To the left. **PAGE:** 13.5

69. At a higher temperature, $K = 1.8 \times 10^{-5}$. If you start with 2.0 M of chemical A, calculate the equilibrium concentration of chemical C.

a) 6.0×10^{-3} M
b) 2.6×10^{-2} M
c) 1.0 M
d) 2.1×10^{-2} M
e) none of these

ANS: b) 2.6×10^{-2} M **PAGE:** 13.6

70. Addition of chemical B to an equilibrium mixture of the above will

a) cause [A] to increase.
b) cause [C] to increase.
c) have no effect.
d) cannot be determined.
e) none of these.

ANS: a) cause [A] to increase. **PAGE:** 13.7

71. Placing the equilibrium mixture in an ice bath (thus lowering the temperature) will

a) cause [A] to increase.
b) cause [B] to increase.
c) have no effect.
d) cannot be determined.
e) none of these.

ANS: b) cause [B] to increase. **PAGE:** 13.7

72. Raising the pressure by lowering the volume of the container will

a) cause [A] to increase.
b) cause [B] to increase.
c) have no effect.
d) cannot be determined.
e) none of these.

ANS: a) cause [A] to increase. **PAGE:** 13.7