K/U Knowledge/Understanding T/I Thinking/Investigation C Communication A Application

Knowledge

For each question, select the best answer from the four alternatives.

1. Which of the following is present in a chemical reaction system that has reached equilibrium? (7.1) K/U
   (a) equal concentrations of reactants and products
   (b) constant concentrations of reactants and products
   (c) no conversion among reactants and products
   (d) all of the above
2. Which of the following is an example of a homogeneous equilibrium? (7.2) K/U
   (a) $C(s) + CO_2(g) \rightleftharpoons 2\,CO(g)$
   (b) $H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$
   (c) $Ni(CO)_4(g) \rightleftharpoons Ni(s) + 4\,CO(g)$
   (d) all of the above
3. Which of the following occurs if a product is added to a chemical reaction system at equilibrium? (7.4) K/U
   (a) The equilibrium shifts left, toward reactants.
   (b) The equilibrium shifts right, toward products.
   (c) The equilibrium shifts both left and right equally.
   (d) The equilibrium undergoes no change.
4. Which of the following would not affect the position of equilibrium of the chemical reaction system represented by the following chemical equation? (7.4) K/U
   $SbCl_5(g) \rightleftharpoons SbCl_3(g) + Cl_2(g)$
   (a) removing $Cl_2(g)$
   (b) increasing the volume of the reaction vessel
   (c) adding a catalyst
   (d) reducing the temperature
5. When is a chemical reaction system at equilibrium? (7.5) K/U
   (a) when $Q > K$
   (b) when $Q < K$
   (c) when $Q = K$
   (d) when $Q = \dfrac{1}{K}$
6. Which concentrations are used to calculate the value of the reaction quotient, Q, of a chemical reaction system? (7.5) K/U
   (a) equilibrium concentrations of reactants and products
   (b) concentrations of reactants and products at a particular instant in time
   (c) initial concentrations of reactants and equilibrium concentrations of products
   (d) equilibrium concentrations of reactants and initial concentrations of products
7. Consider the chemical reaction system represented by the following balanced chemical equation:
   $MgF_2(s) \rightleftharpoons Mg^{2+}(aq) + 2\,F^-(aq)$
   Identify the correct expression for the solubility product constant, K_{sp}, for this chemical reaction system. (7.6) K/U
   (a) $K_{sp} = [Mg^{2+}(aq)]^2[F^-(aq)]$
   (b) $K_{sp} = [Mg^{2+}(aq)][F^-(aq)]$
   (c) $K_{sp} = [Mg^{2+}(aq)][F^-(aq)]^2$
   (d) $K_{sp} = [Mg^{2+}(aq)]^2[F^-(aq)]^2$

Indicate whether each statement is true or false. If you think the statement is false, rewrite it to make it true.

8. A chemical reaction system is at equilibrium when the rate at which products form is equal to the rate at which reactants form. (7.1) K/U
9. A reversible chemical reaction produces a different set of equilibrium concentrations of reactants and products in the forward direction than in the reverse direction. (7.1) K/U
10. The equilibrium constant for any chemical reaction system does not vary with temperature. (7.2) K/U
11. When writing the equilibrium expression for the following chemical reaction system, liquid methanol, $CH_3OH(l)$, is not included:
    $2\,H_2(g) + CO(g) \rightleftharpoons CH_3OH(l)$ (7.2) K/U
12. Fritz Haber was able to increase the rate of synthesis of ammonia gas, $NH_3(g)$, from gaseous hydrogen, $H_2(g)$, and nitrogen, $N_2(g)$, by adjusting the pressure and temperature of the reaction. (7.3) K/U
13. If an exothermic chemical reaction is allowed to reach equilibrium at one temperature and then the temperature is lowered, the equilibrium will shift in the direction of the products. (7.4) K/U
14. If the reaction quotient, Q, is equal to the equilibrium constant, K, the system is at equilibrium. (7.5) K/U
15. If the reaction quotient, Q, is less than the equilibrium constant, K, the system will shift toward reactants to achieve equilibrium. (7.5) K/U
16. At 25 °C, a substance with a solubility product constant, K_{sp}, of 2.9×10^{-3} is more soluble than a substance with a solubility product constant of 7.2×10^{-5}. (7.6) K/U

Match each term on the left with the most appropriate description on the right.

17. (a) equilibrium constant
    (b) equilibrium shift
    (c) equilibrium position
    (d) reaction quotient

    (i) determined by initial concentrations of reactants and products
    (ii) determined by relative amounts of reactants and products
    (iii) determined by equilibrium concentrations of reactants and products
    (iv) determined by the addition or removal of a reactant or product

    (7.1, 7.2, 7.4, 7.5) K/U

Understanding

Write a short answer to each question.

18. **Figure 1** shows the reaction progress of two different chemical reactions. Describe the equilibrium position of each system in terms of whether reactants or products are favoured. (7.1) T/I

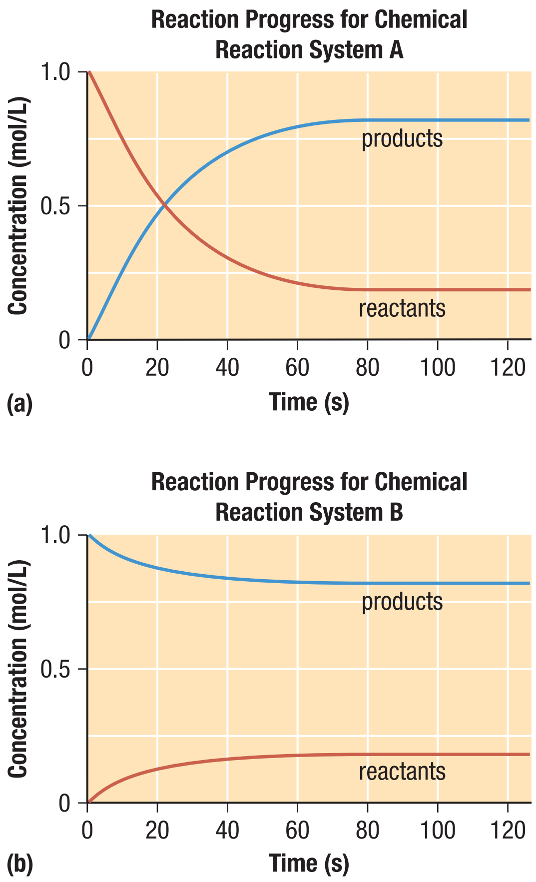

Figure 1

19. Explain what is meant by the equilibrium position of a chemical reaction. (7.1) K/U

20. Suppose that 3.00 mol of nitric oxide gas, NO(g), is introduced into a 1.00 L evacuated flask. When the system comes to equilibrium, 1.00 mol of dinitrogen monoxide gas, $N_2O(g)$, has formed.

    $$2\,N_2O(g) + O_2(g) \rightleftharpoons 4\,NO(g)$$

    Use an ICE table to determine the equilibrium concentrations of each substance. (7.1) T/I C

21. A chemist places 2.00 mol of diatomic bromine gas, $Br_2(g)$, in a 2.00 L reaction flask and allows the gas to decompose to monatomic bromine gas, Br(g):

    $$Br_2(g) \rightleftharpoons 2\,Br(g)$$

    At equilibrium, 0.064 mol of monatomic bromine gas is present in the flask. Calculate the equilibrium concentration of diatomic bromine gas. (7.1) T/I

22. Explain the difference between a homogeneous equilibrium and a heterogeneous equilibrium. (7.2) K/U

23. Write the equilibrium law equation for the chemical reaction systems represented by the following balanced chemical equations:
    (a) $2\,O_3(g) \rightleftharpoons 3\,O_2(g)$
    (b) $3\,Fe(s) + 4\,H_2O(g) \rightleftharpoons Fe_3O_4(s) + 4\,H_2(g)$
    (c) $NH_4NO_2(s) \rightleftharpoons N_2(g) + 2\,H_2O(g)$
    (d) $2\,NOCl(g) \rightleftharpoons 2\,NO(g) + Cl_2(g)$ (7.2) K/U

24. Write a balanced chemical equation that describes the chemical reaction system represented by each of the following equilibrium expressions: (7.2) K/U
    (a) $K = \dfrac{[NO(g)]^2}{[N_2(g)][O_2(g)]}$
    (b) $K = \dfrac{[NO(g)]^2[Br_2(g)]}{[NOBr(g)]^2}$
    (c) $K = \dfrac{[H_2O(g)][CH_4(g)]}{[CO(g)][H_2(g)]^3}$
    (d) $K = \dfrac{[CH_4(g)][H_2S(g)]^2}{[CS_2(g)][H_2(g)]^4}$

25. The chemical reaction system represented by the equation below is at equilibrium with the concentrations shown.

    $$Cl_2(g) + CO(g) \rightleftharpoons COCl_2(g)$$

    Equilibrium concentrations:

    $[CO] = 1.11 \times 10^{-1}$ mol/L;
    $[Cl_2] = 1.03 \times 10^{-1}$ mol/L;
    $[COCl_2] = 1.17 \times 10^{-1}$ mol/L

    Determine the value of the equilibrium constant, *K*. (7.2) T/I

26. For the chemical reaction system represented by the equation below, $K = 3.72 \times 10^{-2}$:

$$2\ ClF_3(g) \rightleftharpoons Cl_2(g) + 3\ F_2(g)$$

At equilibrium, the concentration of chlorine gas, $Cl_2(g)$, is 1.62×10^{-1} mol/L and of fluorine gas, $F_2(g)$, is 1.85×10^{-1} mol/L. Calculate the equilibrium concentration of chlorine trifluoride gas, $ClF_3(g)$. (7.2) T/I

27. Consider the chemical reaction system represented by the following equation:

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

In an investigation, the initial concentrations were $[SO_2(g)] = 0.40$ mol/L; $[O_2(g)] = 1.6$ mol/L; and $[SO_3(g)] = 29.7$ mol/L. The equilibrium concentration of $[SO_2(g)]$ was 1.2 mol/L. Determine the value of the equilibrium constant, K, for this chemical reaction system. (7.2) T/I

28. The chemical reaction system represented by the following equation has an equilibrium constant, K, equal to 1.24×10^{-1}:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

Concentrations at equilibrium are observed to be $[PCl_5(g)] = 4.06 \times 10^{-1}$ mol/L and $[PCl_3(g)] = 1.17 \times 10^{-1}$ mol/L. What is the equilibrium concentration of chlorine gas, $Cl_2(g)$? (7.2) T/I A

29. In a closed vessel, elemental phosphorus, P(s), combines with elemental chlorine, $Cl_2(g)$, to form phosphorus trichloride gas, $PCl_3(g)$:

$$2\ P(s) + 3\ Cl_2(g) \rightleftharpoons 2\ PCl_3(g)$$

If the equilibrium constant is equal to 2.74×10^{-2} and the concentration of phosphorus trichloride gas at equilibrium is 1.09×10^{-1} mol/L, what is the equilibrium concentration of chlorine? (7.2) T/I

30. Consider the chemical reaction system represented by the equation below:

$$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g); \quad K = 626 \text{ at } 200\ °C$$

If the equilibrium concentrations of gaseous hydrogen, $H_2(g)$, and ammonia, $NH_3(g)$, are 0.50 mol/L and 0.46 mol/L respectively, calculate the equilibrium concentration of nitrogen gas, $N_2(g)$. (7.2) T/I

31. Gaseous hydrogen, $H_2(g)$, and iodine, $I_2(g)$, combine in a reversible reaction to form hydrogen iodide gas, HI(g). The forward reaction is exothermic. (7.4) K/U T/I
    (a) Write a balanced chemical equation for this chemical reaction system.
    (b) If more iodine gas is added after the reaction reaches equilibrium, predict whether the reaction will shift to the right or the left. Explain.
    (c) If thermal energy is added after the reaction reaches equilibrium, is the reaction likely to shift to the left or the right? Explain.

32. In a closed container, the chemical reaction system represented by the following equation progresses to equilibrium:

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

The volume of the container is decreased. Predict the direction in which the equilibrium will shift and explain why. (7.4) K/U T/I

33. Sulfur dioxide gas, $SO_2(g)$, and oxygen gas, $O_2(g)$, combine in a reversible reaction to form sulfur trioxide gas, $SO_3(g)$. If more sulfur trioxide gas is added after the reaction reaches equilibrium, predict whether the equilibrium will shift and, if so, in which direction. Give reasons for your prediction. (7.4) K/U T/I

34. **Figure 2** shows the changes in concentrations of three substances, X, Y, and Z, as they take part in a chemical reaction that reaches equilibrium. All three substances are gases. (7.4) T/I C

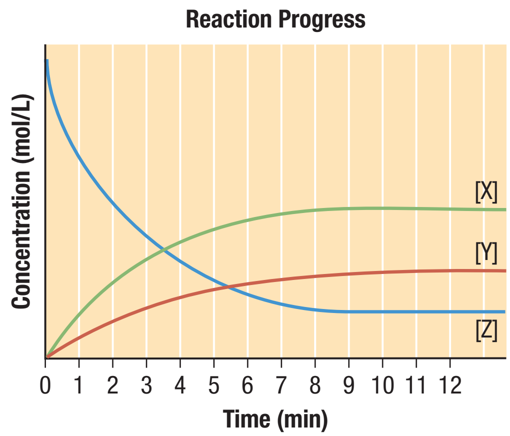

Figure 2

    (a) Write an equation to describe the equilibrium.
    (b) Predict how the graph will change if more of compound Z is added at 10 min. Give reasons for your prediction.

35. Why are catalysts added to some industrial processes that involve an equilibrium? (7.4) K/U

36. Suppose that the chemical reaction system represented by the equation below is at equilibrium. How will the addition of argon, Ar(g), affect the chemical reaction system? (7.4) K/U T/I

$$2\ H_2S(g) \rightleftharpoons 2\ H_2(g) + S_2(g)$$

37. The following are the values of the equilibrium constant, K, for four different chemical reaction systems. For each of the chemical reaction systems, describe the equilibrium position of the given temperature as mostly products, mostly reactants, or equal concentrations of reactants and products. (7.5) K/U
    (a) $K = 10^{-12}$ at 25 °C
    (b) $K = 10^{3}$ at −109 °C
    (c) $K = 10^{21}$ at −5 °C
    (d) $K = 10^{-1}$ at 554 °C

38. Explain the difference between the reaction quotient, Q, and the equilibrium constant, K. (7.5) K/U T/I

39. The chemical reaction system that can be used to produce the biofuel methanol, $CH_3OH(g)$, is represented by the following equation:

$$2\ H_2(g) + CO(g) \rightleftharpoons CH_3OH(g)$$
$$K = 10.5 \text{ at } 500\text{ K}$$

When the concentrations of hydrogen, $H_2(g)$; carbon monoxide, $CO(g)$; and methanol are 0.25 mol/L, 0.25 mol/L, and 0.040 mol/L, respectively, is the system at equilibrium? If not, predict the direction in which the equilibrium will shift and explain why. (7.5) T/I

40. A chemist is investigating the chemical reaction system by which nitric oxide, $NO(g)$, is converted to nitrogen, $N_2(g)$, and oxygen, $O_2(g)$:

$$2\ NO(g) \rightleftharpoons N_2(g) + O_2(g)$$

Initially she places 1.6 mol nitric oxide, 1.6 mol nitrogen, and 0.60 mol oxygen in a 1.00 L vessel. At equilibrium, she finds that the concentration of nitric oxide is 1.4 mol/L. Calculate the equilibrium constant, K, for this chemical reaction system. (7.5) T/I

41. A team of researchers is investigating the effect of temperature on the reversible reaction in which carbon monoxide gas, $CO(g)$, and water vapour, $H_2O(g)$, are converted to hydrogen gas, $H_2(g)$, and carbon dioxide gas, $CO_2(g)$. In one trial, the initial concentrations of reactants and products they place in a sealed vessel are carbon monoxide gas, 0.80 mol/L; water vapour, 2.40 mol/L; carbon dioxide, 0.62 mol/L; and hydrogen, 0.50 mol/L. The temperature in the vessel is maintained at 1000 °C and the reaction is allowed to come to equilibrium. They determine that the equilibrium concentration of carbon dioxide gas is 0.92 mol/L. Find the value of the equilibrium constant, K, for this chemical reaction system. (7.5) T/I

42. Initially, 1.00 mol each of gaseous carbon dioxide, $CO_2(g)$, and hydrogen, $H_2(g)$, is injected into a 10.0 L reaction chamber at 986 °C. What is the predicted concentration of each entity at equilibrium? The balanced equation for the chemical reaction system is

$$CO_2(g) + H_2(g) \rightleftharpoons CO(g) + H_2O(g)$$
$$K = 1.60 \text{ at } 986\text{ °C (7.5)}$$ T/I

43. At the beginning of an investigation, 0.50 mol of iodine gas, $I_2(g)$, and 0.50 mol of chlorine gas, $Cl_2(g)$, are placed into a 2.00 L reaction vessel at 25 °C. Find the concentrations of all entities at equilibrium for the chemical reaction system given by the following balanced equation:

$$I_2(g) + Cl_2(g) \rightleftharpoons 2\ ICl(g)$$
$$K = 81.9 \text{ at } 25\text{ °C (7.5)}$$ T/I

44. The equilibrium constant, K, is 4.20×10^{-6} at a temperature of 1100 K for the chemical reaction system represented by the following equation:

$$2\ H_2S(g) \rightleftharpoons 2\ H_2(g) + S_2(g)$$

What is the predicted equilibrium concentration of $S_2(g)$ if an initial quantity of 0.200 mol of $H_2S(g)$ is added to a sealed 1.00 L vessel at 1100 K? (7.5) T/I

45. Hydrogen chloride gas, $HCl(g)$, decomposes into its elements according to the balanced equation

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

The equilibrium constant, K, is 3.2×10^{-34} at 25 °C. Calculate the equilibrium concentrations of all entities if 2.00 mol hydrogen chloride gas is initially placed in a closed 1.00 L vessel. (7.5) T/I

46. Solid zinc hydroxide, $Zn(OH)_2(s)$, dissolves in water to form zinc ions, $Zn^{2+}(aq)$, and hydroxide ions, $OH^-(aq)$:

$$Zn(OH)_2(aq) \rightleftharpoons Zn^{2+}(aq) + 2\ OH^-(aq)$$

(a) Write the expression for the solubility product constant, K_{sp}, of zinc hydroxide.

(b) If the value of the solubility product constant, K_{sp}, for zinc hydroxide is 7.7×10^{-17} at 25 °C, calculate the molar solubility of zinc hydroxide at 25 °C. (7.6) T/I

47. A student mixes two solutions: 10.0 mL of 0.0040 mol/L lead(II) nitrate, $Pb(NO_3)_2(aq)$, and 15.0 mL of 0.25 mol/L potassium chloride, $KCl(aq)$. If the solubility product constant, K_{sp}, for lead(II) chloride, $PbCl_2$, is 1.2×10^{-5} at 25 °C, will a precipitate form when these two solutions are mixed? Why? (7.6) T/I

Analysis and Application

48. Use the concept of dynamic equilibrium to explain why a bottle of pop stays carbonated longer if the bottle cap is replaced after opening (**Figure 3**). (7.1) T/I

Figure 3

49. A student mixes two solutions in a dish and notices that bubbles are produced and a colour change occurs. After a few minutes, the bubbles stop and the colour has reached a constant shade. The student concludes that the reaction has reached equilibrium. Do you agree? Explain your reasoning. (7.1) T/I

50. Fluoride toothpastes have been developed to reduce the incidence of dental cavities. These toothpastes supply fluoride ions, F^-, which replace hydroxide ions, OH^-, in solid hydroxyapatite, $Ca_5(PO_4)_3(OH)(s)$, in teeth. The resulting compound is fluorapatite, $Ca_5(PO_4)_3F(s)$. Given this information, do you think the equilibrium constant for the dissolution of fluorapatite is higher or lower than that of hydroxyapatite? Explain your reasoning. (7.2) T/I A

51. A chemist places 1 mol each of nitrogen, $N_2(g)$, and hydrogen, $H_2(g)$, in a sealed vessel. The reactants undergo a reversible reaction:

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

Determine the amount of ammonia, $NH_3(g)$, that would form if x mol of hydrogen, $H_2(g)$, is consumed in the reaction. (7.2) T/I

52. An investigator gathers the data in **Table 1** by carrying out the reaction represented by the following equation:

$$PCl_5\,(g) \rightleftharpoons PCl_3\,(g) + Cl_2\,(g)$$

Table 1 Observed Equilibrium Concentrations

Trial	$[PCl_5(g)]$	$[PCl_3(g)]$	$[Cl_2(g)]$
1	0.023	0.23	0.55
2	0.010	0.15	0.37
3	0.085	0.99	0.47
4	1.00	3.66	1.5

(a) Show that the data in Table 1 are consistent with the equilibrium law.

(b) What is the equilibrium constant for this reaction? (7.2) T/I A

53. The Haber synthesis of ammonia, $NH_3(g)$, is represented by the equation below:

$$N_2(g) + 3\,H_2(g) \rightleftharpoons 2\,NH_3(g);\ \Delta H = -92\ \text{kJ}$$

Le Châtelier's principle predicts that the equilibrium concentration of ammonia, $NH_3(g)$, will be greater at high pressure and low temperature. In industrial production of ammonia, this reaction is typically carried out at 500 °C and 200 atm. Under these conditions, the equilibrium chemical reaction system proceeds to about 15 % completion. Using collision theory, explain why lower temperatures are not used. (7.3, 7.4) T/I

54. In a chemical manufacturing process that involves a system at equilibrium, the reactants are continually added and the products are continually removed to maximize yield. Explain why both steps are necessary, using Le Châtelier's principle. (7.4) T/I A

55. Myoglobin is a protein present in muscle that binds oxygen more tightly than hemoglobin. It functions to store oxygen within muscle to ensure that a sufficient oxygen reserve is readily available. Relate your understanding of the magnitude of the equilibrium constant, K, to the differences in function of hemoglobin (as a transporter of oxygen from lungs) and myoglobin (as an oxygen storage reservoir). Why is the equilibrium constant for hemoglobin binding to oxygen lower than the equilibrium constant for myoglobin binding to oxygen? (7.4) T/I A

56. The reaction between sulfur dioxide, $SO_2(g)$, and oxygen, $O_2(g)$, to form sulfur trioxide, $SO_3(g)$, is reversible. The following equation represents this chemical reaction system:

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g) \quad \Delta H = -196\ \text{kJ}$$

This chemical reaction system is used during the industrial production of sulfuric acid. The reaction is carried out at a temperature of 450 °C and a pressure of 2 atm, and in the presence of a catalyst. A chemical engineer suggests that money might be saved by eliminating the catalyst and raising the temperature of the reaction. Is the engineer's suggestion valid? Explain your reasoning. (7.4) T/I A

57. Some equilibria are described as being "weak" because very little product is present in these systems at equilibrium. Predict the magnitude of the values of the equilibrium constant, K, for these chemical reaction systems. (7.5) T/I

58. Water hardness is caused by the presence of Ca^{2+} and Mg^{2+} ions. One way of removing these ions is to add sodium carbonate, $Na_2CO_3(s)$, which causes precipitation of calcium carbonate, $CaCO_3(s)$, and magnesium carbonate, $MgCO_3(s)$. A 5.0 L volume of water has a Ca^{2+} concentration of 0.0040 mol/L. What is the maximum mass of sodium carbonate that can be added to this volume without causing any precipitate to form? The K_{sp} for $CaCO_3(s)$ is 4.8×10^{-9} at 25 °C. (7.6) A

59. Name two examples of compounds that, when added to a solution containing barium sulfate, $BaSO_4(aq)$, will decrease the solubility of barium sulfate. Explain your answer. (7.6) T/I A

60. The temperature of groundwater that circulates through rock near volcanoes may be increased by thermal energy released from the hot rock beneath the volcano. This heated water can flow through rock below the ground and, in the process, dissolve some of the minerals in the rock. When the water rises to the surface and cools, the minerals precipitate out to form deposits around many hot springs (**Figure 4**). Use your understanding of solubility to explain these observations. (7.6) T/I A

Figure 4 The precipitation of minerals gives many hot springs beautiful colours.

Evaluation

61. During a class presentation, a student states that unsaturated solutions are in dynamic equilibrium, but saturated solutions are not. Do you agree or disagree with the student's statement? Make a diagram to support your answer. (7.1, 7.2, 7.6) T/I C
62. Many, but not all, industrial chemical processes involve catalysts. Do you think that chemical engineers should focus on identifying catalysts for all industrial processes? Defend your answer. (7.3) T/I
63. While searching the Internet for information on chemical reactions, you find a website that includes the following statement: "There are many ways to shift a chemical equilibrium toward the products of a reaction. Increasing temperature and decreasing pressure are two examples of changes that will cause equilibrium to shift toward the products." Do you think the person who wrote this website has a complete understanding of chemical equilibria? Defend your answer. (7.4, 7.5, 7.6) T/I

Reflect on Your Learning

64. Which concepts in this chapter did you find most interesting? Why? A
65. Describe three ways the information in this chapter can help you understand things you observe in your everyday life. Do you think that your understanding of chemical equilibrium will change any of your behaviours? If so, which ones? A
66. Identify two concepts from this chapter that you had a hard time understanding. How can you improve your understanding of these concepts? A

Research

WEB LINK

67. Create a poster describing why ammonia is important in maintaining the global food supply. C A
68. As a scuba diver descends, the surrounding water pressure increases. This forces more nitrogen, $N_2(g)$, in the compressed air the diver is breathing to dissolve in the diver's bloodstream:

    $N_2(g) \rightleftharpoons N_2(aq)$

    "The bends," or decompression sickness, can occur if the diver ascends to the surface too quickly. Nitrogen narcosis is another condition that results from the increased solubility of nitrogen in the blood at high pressures. Research the causes, symptoms, and methods used to combat the bends and nitrogen narcosis in divers. Write a short report summarizing your findings. C A
69. Research the equilibrium process involved in stalactite and stalagmite formation in limestone caves. Write a balanced chemical equation to describe what happens during the formation of these structures. Explain how Le Châtelier's principle is involved. C A
70. Research the use of cobalt chloride as an indicator for humidity. Explain the chemical reaction that underlies this process. What property of the system is used to indicate the level of humidity? If possible, find an example of a product that illustrates this application. Present your findings in a short written or oral report. C A
71. According to his Nobel lecture, Fritz Haber wanted to find an economical process for fixing nitrogen to make fertilizer. Compare the amount of ammonia being used today for fertilizer to the other uses of ammonia. What are the five chief uses of ammonia other than fertilizer? A C