CHAPTERS
18-22   BRINGING IT TOGETHER

Again you have an opportunity to test your understanding of concepts, your knowledge of scientific terms, and your skills at solving chemistry problems. Read through the following questions carefully, and answer each as fully as possible. Review topics when necessary.

1. What is meant by the term *spontaneous change*?
2. Which of these are state functions: E, H, q, S, G, w, T ?
3. How is entropy related to statistical probability?
4. What would be the algebraic signs of ΔS for the following reactions?
   (a) $Br_2(l) + Cl_2(g) \longrightarrow 2BrCl(g)$
   (b) $CaO(s) + CO_2(g) \longrightarrow CaCO_3(s)$
5. Which of the following states has the greatest entropy?
   (a) $2H_2O(l)$ (c) $2H_2(l) + O_2(g)$ (e) $4H(g) + 2O(g)$
   (b) $2H_2O(s)$ (d) $2H_2(g) + O_2(g)$
6. Calculate $\Delta S°$ (in $J\ K^{-1}$) for the following reactions.
   (a) $H_2O(l) + SO_3(g) \longrightarrow H_2SO_4(l)$
   (b) $2KCl(s) + H_2SO_4(l) \longrightarrow K_2SO_4(s) + 2HCl(g)$
   (c) $C_2H_4(g) + H_2O(g) \longrightarrow C_2H_5OH(l)$
7. Calculate $\Delta G°$ (in kJ) for the following reactions.
   (a) $CaSO_4 \cdot \frac{1}{2}H_2O(s) + \frac{3}{2}H_2O(l) \longrightarrow$
   $$CaSO_4 \cdot 2H_2O(s)$$
   (b) $CH_4(g) + Cl_2(g) \longrightarrow CH_3Cl(g) + HCl(g)$
   (c) $CaSO_4(s) + CO_2(s) \longrightarrow CaCO_3(s) + SO_3(g)$
8. Which of the reactions in the preceding question would appear to be spontaneous?
9. Calculate $\Delta S°$, $\Delta H°$, and $\Delta G°_T$ (at 400 °C) using energy units of joules or kilojoules for these reactions.
   (a) $CaSO_4 \cdot 2H_2O(s) \longrightarrow CaSO_4 \cdot \frac{1}{2}H_2O(s) + \frac{3}{2}H_2O(g)$
   (b) $NaOH(s) + NH_4Cl(s) \longrightarrow$
   $$NaCl(s) + NH_3(g) + H_2O(g)$$
   (c) $SO_3(g) \longrightarrow SO_2(g) + \frac{1}{2}O_2(g)$
10. For the reaction $3NO(g) \rightleftharpoons NO_2(g) + N_2O(g)$, calculate K_P at 25 °C using values of $\Delta G°_f$ from Table 18.2. Calculate the value of K_c at 25 °C for the reaction.
11. Consider the reaction

    $$CH_4(g) + Cl_2(g) \rightleftharpoons CH_3Cl(g) + HCl(g)$$

    (a) Calculate $\Delta G°_{473}$ for the reaction at 200 °C.
    (b) What is the value of K_P for the reaction at 200 °C?
    (c) What is the value of K_c for the reaction at 200 °C?
12. Glycine, one of the important amino acids, has the structure

    $$\begin{array}{ccccc} & H & O & & \\ & | & \| & & \\ H-N- & C- & C- & O-H \\ & | & | & & \\ & H & H & & \end{array}$$

    Calculate the atomization energy of the glycine molecule in units of $kJ\ mol^{-1}$ from the data in Table 18.4.
13. Use bond energies in Table 18.4 to calculate the approximate energy that would be absorbed or given off in the formation of 25.0 g of C_2H_6 by the following reaction in the gas phase.

    $$H-C\equiv C-H + 2H_2 \longrightarrow H-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-\underset{\underset{H}{|}}{\overset{\overset{H}{|}}{C}}-H$$

14. Sketch a diagram of an electrolysis cell in which a concentrated solution of NaCl is undergoing electrolysis.
    (a) Label the cathode and anode, including their charges.
    (b) Write half-reactions for the changes taking place at the electrodes.
    (c) Write a balanced equation for the net cell reaction.
15. Suppose that the electrolysis cell described in the previous question contains 250 mL of brine.
    (a) What will be the pH of the solution if the electrolysis is carried out for 20.0 minutes using a current of 1.00 A?
    (b) How many milliliters of H_2, measured at STP, would be evolved if the cell were operated at 5.00 A for 10.0 minutes?
16. What current would be required to deposit 0.100 g of nickel in 20.0 minutes from a solution of $NiSO_4$?
17. A large electrolysis cell can produce as much as 900 lb of aluminum in 1 day from Al_2O_3. What current is required to accomplish this? (Assume three significant figures.)
18. Sketch a diagram of a galvanic cell consisting of a copper electrode dipping into 1.00 M $CuSO_4$ solution and an iron electrode dipping into 1.00 M $FeSO_4$ solution.
    (a) Identify the cathode and the anode. Indicate the charge carried by each.
    (b) Write the equation for the net cell reaction.
    (c) Describe the cell by writing its standard cell notation.
    (d) What is the potential of the cell?
19. What is the purpose of a salt bridge in a galvanic cell?
20. Suppose the cell described in Question 18 contains 100 mL of each solution and is operated for a period of 50.0 hr at a constant current of 0.10 A. At the end of that time, what will be the concentrations of Cu^{2+} and Fe^{2+} in their respective solutions? What will the cell potential be at that point?
21. Use data from Table 19.1 to calculate the value of K_c at 25 °C for the reaction

    $$O_2(g) + 4Br^-(aq) + 4H^+(aq) \longrightarrow 2Br_2(aq) + 2H_2O$$

22. A galvanic cell was assembled as follows. In one compartment, a copper electrode was immersed in a 1.00 M solution of $CuSO_4$. In the other compartment, a manganese electrode was immersed in a 1.00 M solution of $MnSO_4$. The potential of the cell was measured to be 1.52 V, with the Mn electrode as the negative electrode. What is the value of $E°$ for the following half-reaction?

    $$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$$
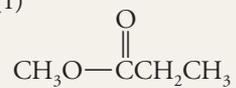
23. Calculate $E°_{cell}$ for the reaction

    $$3Cu(s) + 2NO_3^-(aq) + 8H^+(aq) \longrightarrow$$
    $$2NO(g) + 4H_2O + 3Cu^{2+}(aq)$$

24. What is the value of K_c for the reaction described in the preceding question?

25. Consider a galvanic cell formed by using the half-reactions

$$NiO_2(s) + 2H_2O + 2e^- \rightleftharpoons Ni(OH)_2(s) + 2OH^-(aq)$$
$$E° = +0.49 \text{ V}$$

$$PbO_2(s) + H_2O + 2e^- \rightleftharpoons PbO(s) + 2OH^-(aq)$$
$$E° = +0.25 \text{ V}$$

(a) Write the equation for the spontaneous cell reaction.
(b) Calculate the value of $E°_{cell}$ for the system.
(c) Calculate $\Delta G°$ for the spontaneous cell reaction.

26. A galvanic cell was constructed in which one half-cell consists of a silver electrode coated with silver chloride dipping into a solution that contains chloride ion and the second half-cell consists of a nickel electrode dipping into a solution that contains Ni^{2+}. The half-cell reactions and their reduction potentials are

$$AgCl(s) + e^- \rightleftharpoons Ag(s) + Cl^-(aq) \qquad E° = +0.222 \text{ V}$$

$$Ni^{2+}(aq) + 2e^- \rightleftharpoons Ni(s) \qquad E° = -0.257 \text{ V}$$

(a) Write the equation for the spontaneous cell reaction.
(b) Calculate $E°_{cell}$ for the cell reaction.
(c) Write the Nernst equation for the cell.
(d) Calculate the cell potential if $[Cl^-] = 0.020 \; M$ and $[Ni^{2+}] = 0.10 \; M$.
(e) The galvanic cell was used to measure an unknown chloride ion concentration. The Ni^{2+} concentration was $0.200 \; M$ and the measured cell potential was 0.388 V. What was the chloride ion concentration?

27. Describe how a nickel–metal hydride cell works.

28. Describe how a lithium ion cell works. What does *intercalation* mean?

29. What factors involving the nucleus of helium might be responsible for the large abundance of helium in the universe?

30. What is the symbol for (a) an alpha particle, (b) a beta particle, (c) a positron?

31. What is the rest mass of a particle of gamma radiation?

32. Suppose that the total mass of the reactants in a chemical reaction was 100.00000 g. How many kilojoules of energy would have to evolve from this reaction if the total mass of the products could be no greater than 99.99900 g? If all this energy were used to heat water, how many liters of water could have its temperature raised from 10 °C to 100 °C?

33. Calculate the binding energy in joules per nucleon for the nucleus of the deuterium atom, ^2_1H. The mass of an atom of deuterium, including its electron, is 2.014102 u.

34. Which nuclear force acts over the longer distance, the electrostatic force or the nuclear strong force?

35. Why is an isotope of hydrogen a better candidate for nuclear fusion than an isotope of helium?

36. When an atom of uranium-238 absorbs a neutron, it can ultimately change to an atom of plutonium-239. Write a nuclear equation for the reaction. If the reaction occurs in two steps, what intermediate nucleus is formed?

37. If an atom of beryllium-7 decays by the capture of a K-electron, into which isotope does it change? Write the equation.

38. An atom of neodymium-144 decays by alpha emission. Write the nuclear equation.

39. Phosphorus-32 decays by beta emission. Write the nuclear equation.

40. The half-life of samarium-149, an alpha emitter, is 4×10^{14} years. The half-life of oxygen-15 is 124 seconds. Assuming that equimolar samples are compared, which is the more intensely radioactive?

41. The half-life of cesium-137 is 30 years. Of an initial 100 g sample, how much cesium-137 will remain after 300 years?

42. What are some "rules of thumb" that can be used to judge if a particular radionuclide might have a long enough half-life to warrant the effort to make it?

43. A particular compound nucleus can form from a variety of combinations of targets and bombarding particles, as in the example of aluminum on page 835. What determines how a compound nucleus breaks up?

44. Strontium-90, a beta emitter, has a half-life of 28.1 yr. If 36.2 mg of ^{90}Sr were incorporated in the bones of a growing child, how many beta particles would the child absorb from this source in 1.00 day?

45. Which kind of radiation poses a greater health risk, beta or alpha radiation? Why?

46. What reaction, if any, will occur when solutions of $KBr(aq)$ and $Cl_2(aq)$ are mixed?

47. Write the equation for the reduction of bismuth(III) oxide by hydrogen.

48. Why can't fluorine be produced by the electrolysis of aqueous NaF? Why can't liquid HF be electrolyzed to give F_2 and H_2?

49. Why doesn't phosphorus form a stable P_2 molecule similar to N_2?

50. Describe the structure of the ozone molecule. What effect does ozone in smog have on the chlorophyll in green plants?

51. What is the molecular structure of diamond? How are the structures of graphite, buckyballs, and carbon nanotubes related?

52. What must be true about the heat of formation of a metal compound if the compound is thermally unstable?

53. Why is carbon used as a reducing agent in industrial metallurgy? Write the equations that take place in a blast furnace during the reduction of Fe_2O_3 to metallic Fe?

54. The reaction

$$Ni(H_2O)_6^{2+} + 6NH_3 \longrightarrow Ni(NH_3)_6^{2+} + 6H_2O$$

can be described as the displacement of one Lewis base by another. Explain. What is the Lewis acid in the reaction?

55. Sketch the structures of the oxalate ion and ethylenediamine. Identify the donor atoms these ligands use when they form chelate complexes.

56. Sketch the chiral isomers of $[Cr(H_2O)_2(en)_2]^{3+}$. Is there a nonchiral isomer of the complex? What is the name of $[Cr(H_2O)_2(en)_2]Cl_3$?

57. Which complex would absorb light of a shorter wavelength, $[V(H_2O)_6]^{3+}$ or $[V(CN)_6]^{3-}$? Justify your answer.

58. Name the following organic compound.

$$CH_3CHCH_2CH_2CH{=}CCH_2CH_3$$

with CH_3 branch on the left carbon and $CH_2CH_2CH_3$ branch on the right.

59. Draw the structure of 2,2-dimethyl-4-ethylheptane.

60. Which of the following compounds (a) neutralizes NaOH, (b) neutralizes HCl, (c) yields an alcohol and an organic acid when hydrolyzed, (d) is easily oxidized to an acid, (e) would
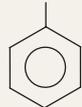
be classified as aromatic, (f) would be oxidized to give a ketone?

(1)

$$CH_3O—\overset{\overset{O}{\|}}{C}CH_2CH_3$$

(2)

$$CH_3CH_2\overset{\overset{O}{\|}}{C}H$$

(3) $O{=}C—OH$

(4)

$$CH_3\overset{\overset{OH}{|}}{C}HCH_2CH_3$$

(5) $CH_3—NH$
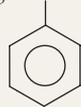
61. What would be the repeating structural unit if a condensation polymer were to form from the following monomers by the elimination of CH_3OH?

$$CH_3O—\overset{\overset{O}{\|}}{C}CH_2CH_2\overset{\overset{O}{\|}}{C}—OCH_3 \qquad H_2NCH_2CH_2CH_2NH_2$$

62. What effect does cross-linking have on the properties of a polymer?

63. What are the monomer units in (a) starch, (b) a polypeptide, and (c) DNA?

64. How do the water solubilities compare for monosaccharides and lipids?

65. How is the folding of a polypeptide chain affected by the hydrophobic and hydrophilic nature of its side chains?

66. Use data in Table 19.1 to calculate the value of K_{sp} for AgCl.