7. Consider separate aqueous solutions of HCl and H_2SO_4 with the same molar concentrations. You wish to neutralize an aqueous solution of NaOH. For which acid solution would you need to add more volume (in milliliters) to neutralize the base?
   a. the HCl solution
   b. the H_2SO_4 solution
   c. You need to know the acid concentrations to answer this question.
   d. You need to know the volume and concentration of the NaOH solution to answer this question.
   e. c and d
   Explain.
8. Draw molecular-level pictures to differentiate between concentrated and dilute solutions.

A blue question or exercise number indicates that the answer to that question or exercise appears at the back of this book and a solution appears in the *Solutions Guide*.

Questions

9. Differentiate between what happens when the following are dissolved in water.
   a. polar solute versus nonpolar solute
   b. KF versus $C_6H_{12}O_6$
   c. RbCl versus AgCl
   d. HNO_3 versus CO
10. A student wants to prepare 1.00 L of a 1.00 *M* solution of NaOH (molar mass = 40.00 g/mol). If solid NaOH is available, how would the student prepare this solution? If 2.00 *M* NaOH is available, how would the student prepare the solution? To help insure three significant figures in the NaOH molarity, to how many significant figures should the volumes and mass be determined?
11. List the formulas of three soluble bromide salts and three insoluble bromide salts. Do the same exercise for sulfate salts, hydroxide salts, and phosphate salts (list three soluble salts and three insoluble salts). List the formulas for six insoluble Pb^{2+} salts and one soluble Pb^{2+} salt.
12. When 1.0 mol of solid lead nitrate is added to 2.0 mol of aqueous potassium iodide, a yellow precipitate forms. After the precipitate settles to the bottom, does the solution above the precipitate conduct electricity? Explain. Write the complete ionic equation to help you answer this question.
13. What is an acid and what is a base? An acid–base reaction is sometimes called a proton-transfer reaction. Explain.
14. A student had 1.00 L of a 1.00 *M* acid solution. Much to the surprise of the student, it took 2.00 L of 1.00 *M* NaOH solution to react completely with the acid. Explain why it took twice as much NaOH to react with all of the acid.

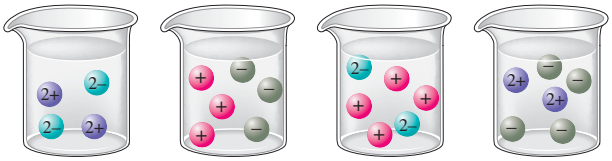
    In a different experiment, a student had 10.0 mL of 0.020 *M* HCl. Again, much to the surprise of the student, it took only 5.00 mL of 0.020 *M* strong base to react completely with the HCl. Explain why it took only half as much strong base to react with all of the HCl.
15. Differentiate between the following terms.
   a. species reduced versus the reducing agent
   b. species oxidized versus the oxidizing agent
   c. oxidation state versus actual charge
16. When balancing reactions in Chapter 3, we did not mention that reactions must be charge balanced as well as mass balanced. What do *charge balanced* and *mass balanced* mean? How are redox reactions charge balanced?

Exercises

In this section similar exercises are paired.

Aqueous Solutions: Strong and Weak Electrolytes

17. Show how each of the following strong electrolytes "breaks up" into its component ions upon dissolving in water by drawing molecular-level pictures.
   a. NaBr
   b. $MgCl_2$
   c. $Al(NO_3)_3$
   d. $(NH_4)_2SO_4$
   e. NaOH
   f. $FeSO_4$
   g. $KMnO_4$
   h. $HClO_4$
   i. $NH_4C_2H_3O_2$ (ammonium acetate)
18. Match each name below with the following microscopic pictures of that compound in aqueous solution.



   a. barium nitrate
   b. sodium chloride
   c. potassium carbonate
   d. magnesium sulfate
   Which picture best represents $HNO_3(aq)$? Why aren't any of the pictures a good representation of $HC_2H_3O_2(aq)$?

19. Calcium chloride is a strong electrolyte and is used to "salt" streets in the winter to melt ice and snow. Write a reaction to show how this substance breaks apart when it dissolves in water.
20. Commercial cold packs and hot packs are available for treating athletic injuries. Both types contain a pouch of water and a dry chemical. When the pack is struck, the pouch of water breaks, dissolving the chemical, and the solution becomes either hot or cold. Many hot packs use magnesium sulfate, and many cold packs use ammonium nitrate. Write reactions to show how these strong electrolytes break apart when they dissolve in water.

Solution Concentration: Molarity

21. Calculate the molarity of each of these solutions.
   a. A 5.623-g sample of $NaHCO_3$ is dissolved in enough water to make 250.0 mL of solution.
   b. A 184.6-mg sample of $K_2Cr_2O_7$ is dissolved in enough water to make 500.0 mL of solution.
   c. A 0.1025-g sample of copper metal is dissolved in 35 mL of concentrated HNO_3 to form Cu^{2+} ions and then water is added to make a total volume of 200.0 mL. (Calculate the molarity of Cu^{2+}.)
22. A solution of ethanol (C_2H_5OH) in water is prepared by dissolving 75.0 mL of ethanol (density = 0.79 g/cm^3) in enough water to make 250.0 mL of solution. What is the molarity of the ethanol in this solution?

23. Calculate the concentration of all ions present in each of the following solutions of strong electrolytes.
a. 0.100 mol of $Ca(NO_3)_2$ in 100.0 mL of solution
b. 2.5 mol of Na_2SO_4 in 1.25 L of solution
c. 5.00 g of NH_4Cl in 500.0 mL of solution
d. 1.00 g K_3PO_4 in 250.0 mL of solution

24. Calculate the concentration of all ions present in each of the following solutions of strong electrolytes.
a. 0.0200 mol of sodium phosphate in 10.0 mL of solution
b. 0.300 mol of barium nitrate in 600.0 mL of solution
c. 1.00 g of potassium chloride in 0.500 L of solution
d. 132 g of ammonium sulfate in 1.50 L of solution

25. Which of the following solutions of strong electrolytes contains the largest number of moles of chloride ions: 100.0 mL of 0.30 *M* $AlCl_3$, 50.0 mL of 0.60 *M* $MgCl_2$, or 200.0 mL of 0.40 *M* NaCl?

26. Which of the following solutions of strong electrolytes contains the largest number of ions: 100.0 mL of 0.100 *M* NaOH, 50.0 mL of 0.200 *M* $BaCl_2$, or 75.0 mL of 0.150 *M* Na_3PO_4?

27. What mass of NaOH is contained in 250.0 mL of a 0.400 *M* sodium hydroxide solution?

28. If 10. g of $AgNO_3$ is available, what volume of 0.25 *M* $AgNO_3$ solution can be prepared?

29. Describe how you would prepare 2.00 L of each of the following solutions.
a. 0.250 *M* NaOH from solid NaOH
b. 0.250 *M* NaOH from 1.00 *M* NaOH stock solution
c. 0.100 *M* K_2CrO_4 from solid K_2CrO_4
d. 0.100 *M* K_2CrO_4 from 1.75 *M* K_2CrO_4 stock solution

30. How would you prepare 1.00 L of a 0.50 *M* solution of each of the following?
a. H_2SO_4 from "concentrated" (18 *M*) sulfuric acid
b. HCl from "concentrated" (12 *M*) reagent
c. $NiCl_2$ from the salt $NiCl_2 \cdot 6H_2O$
d. HNO_3 from "concentrated" (16 *M*) reagent
e. Sodium carbonate from the pure solid

31. A solution is prepared by dissolving 10.8 g ammonium sulfate in enough water to make 100.0 mL of stock solution. A 10.00-mL sample of this stock solution is added to 50.00 mL of water. Calculate the concentration of ammonium ions and sulfate ions in the final solution.

32. Calculate the sodium ion concentration when 70.0 mL of 3.0 *M* sodium carbonate is added to 30.0 mL of 1.0 *M* sodium bicarbonate.

33. A standard solution is prepared for the analysis of fluoxymesterone ($C_{20}H_{29}FO_3$), an anabolic steroid. A stock solution is first prepared by dissolving 10.0 mg of fluoxymesterone in enough water to give a total volume of 500.0 mL. A 100.0-μL aliquot (portion) of this solution is diluted to a final volume of 100.0 mL. Calculate the concentration of the final solution in terms of molarity.

34. A stock solution containing Mn^{2+} ions was prepared by dissolving 1.584 g pure manganese metal in nitric acid and diluting to a final volume of 1.000 L. The following solutions were then prepared by dilution:

For solution *A*, 50.00 mL of stock solution was diluted to 1000.0 mL.
For solution *B*, 10.00 mL of solution *A* was diluted to 250.0 mL.
For solution *C*, 10.00 mL of solution *B* was diluted to 500.0 mL.

Calculate the concentrations of the stock solution and solutions *A*, *B*, and *C*.

Precipitation Reactions

35. On the basis of the general solubility rules given in Table 4.1, predict which of the following substances are likely to be soluble in water.
a. aluminum nitrate
b. magnesium chloride
c. rubidium sulfate
d. nickel(II) hydroxide
e. lead(II) sulfide
f. magnesium hydroxide
g. iron(III) phosphate

36. On the basis of the general solubility rules given in Table 4.1, predict which of the following substances are likely to be soluble in water.
a. zinc chloride
b. lead(II) nitrate
c. lead(II) sulfate
d. sodium iodide
e. cobalt(III) sulfide
f. chromium(III) hydroxide
g. magnesium carbonate
h. ammonium carbonate

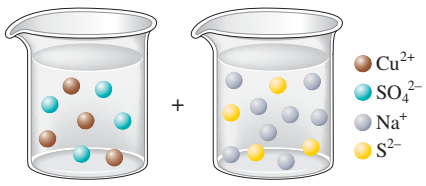
37. When the following solutions are mixed together, what precipitate (if any) will form?
a. $FeSO_4(aq) + KCl(aq)$
b. $Al(NO_3)_3(aq) + Ba(OH)_2(aq)$
c. $CaCl_2(aq) + Na_2SO_4(aq)$
d. $K_2S(aq) + Ni(NO_3)_2(aq)$

38. When the following solutions are mixed together, what precipitate (if any) will form?
a. $Hg_2(NO_3)_2(aq) + CuSO_4(aq)$
b. $Ni(NO_3)_2(aq) + CaCl_2(aq)$
c. $K_2CO_3(aq) + MgI_2(aq)$
d. $Na_2CrO_4(aq) + AlBr_3(aq)$

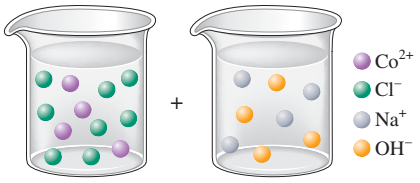
39. For the reactions in Exercise 37, write the balanced formula equation, complete ionic equation, and net ionic equation. If no precipitate forms, write "No reaction."

40. For the reactions in Exercise 38, write the balanced formula equation, complete ionic equation, and net ionic equation. If no precipitate forms, write "No reaction."

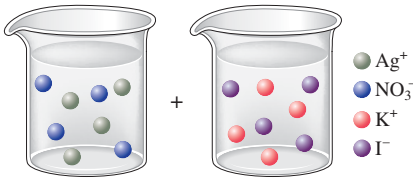
41. Write the balanced formula and net ionic equation for the reaction that occurs when the contents of the two beakers are added together. What colors represent the spectator ions in each reaction?



a.



b.



c.

42. Give an example how each of the following insoluble ionic compounds could be produced using a precipitation reaction. Write the balanced formula equation for each reaction.

a. $Fe(OH)_3(s)$ **c.** $PbSO_4(s)$

b. $Hg_2Cl_2(s)$ **d.** $BaCrO_4(s)$

43. Write net ionic equations for the reaction, if any, that occurs when aqueous solutions of the following are mixed.

a. ammonium sulfate and barium nitrate

b. lead(II) nitrate and sodium chloride

c. sodium phosphate and potassium nitrate

d. sodium bromide and rubidium chloride

e. copper(II) chloride and sodium hydroxide

44. Write net ionic equations for the reaction, if any, that occurs when aqueous solutions of the following are mixed.

a. chromium(III) chloride and sodium hydroxide

b. silver nitrate and ammonium carbonate

c. copper(II) sulfate and mercury(I) nitrate

d. strontium nitrate and potassium iodide

45. Separate samples of a solution of an unknown soluble ionic compound are treated with KCl, Na_2SO_4, and NaOH. A precipitate forms only when Na_2SO_4 is added. Which cations could be present in the unknown soluble ionic compound?

46. A sample may contain any or all of the following ions: Hg_2^{2+}, Ba^{2+}, and Mn^{2+}.

a. No precipitate formed when an aqueous solution of NaCl was added to the sample solution.

b. No precipitate formed when an aqueous solution of Na_2SO_4 was added to the sample solution.

c. A precipitate formed when the sample solution was made basic with NaOH.

Which ion or ions are present in the sample solution?

47. What mass of Na_2CrO_4 is required to precipitate all of the silver ions from 75.0 mL of a 0.100 *M* solution of $AgNO_3$?

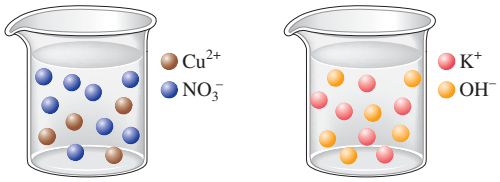
48. What volume of 0.100 *M* Na_3PO_4 is required to precipitate all the lead(II) ions from 150.0 mL of 0.250 *M* $Pb(NO_3)_2$?

49. What mass of solid aluminum hydroxide can be produced when 50.0 mL of 0.200 *M* $Al(NO_3)_3$ is added to 200.0 mL of 0.100 *M* KOH?

50. What mass of barium sulfate can be produced when 100.0 mL of a 0.100 *M* solution of barium chloride is mixed with 100.0 mL of a 0.100 *M* solution of iron(III) sulfate?

51. How many grams of silver chloride can be prepared by the reaction of 100.0 mL of 0.20 *M* silver nitrate with 100.0 mL of 0.15 *M* calcium chloride? Calculate the concentrations of each ion remaining in solution after precipitation is complete.

52. The drawings below represent aqueous solutions. Solution A is 2.00 L of a 2.00 *M* aqueous solution of copper(II) nitrate. Solution B is 2.00 L of a 3.00 *M* aqueous solution of potassium hydroxide.



A B

a. Draw a picture of the solution made by mixing solutions A and B together after the precipitation reaction takes place. Make sure this picture shows the correct relative volume compared to solutions A and B, and the correct relative number of ions, along with the correct relative amount of solid formed.

b. Determine the concentrations (in *M*) of all ions left in solution (from part a) and the mass of solid formed.

53. A 1.42-g sample of a pure compound, with formula M_2SO_4, was dissolved in water and treated with an excess of aqueous calcium chloride, resulting in the precipitation of all the sulfate ions as calcium sulfate. The precipitate was collected, dried, and found to weigh 1.36 g. Determine the atomic mass of M, and identify M.

54. You are given a 1.50-g mixture of sodium nitrate and sodium chloride. You dissolve this mixture into 100 mL of water and then add an excess of 0.500 *M* silver nitrate solution. You produce a white solid, which you then collect, dry, and measure. The white solid has a mass of 0.641 g.

a. If you had an extremely magnified view of the solution (to the atomic-molecular level), list the species you would see (include charges, if any).

b. Write the balanced net ionic equation for the reaction that produces the solid. Include phases and charges.

c. Calculate the percent sodium chloride in the original unknown mixture.

Acid–Base Reactions

55. Write the balanced formula, complete ionic, and net ionic equations for each of the following acid–base reactions.

a. $HClO_4(aq) + Mg(OH)_2(s) \rightarrow$

b. $HCN(aq) + NaOH(aq) \rightarrow$

c. $HCl(aq) + NaOH(aq) \rightarrow$

56. Write the balanced formula, complete ionic, and net ionic equations for each of the following acid–base reactions.

a. $HNO_3(aq) + Al(OH)_3(s) \rightarrow$

b. $HC_2H_3O_2(aq) + KOH(aq) \rightarrow$

c. $Ca(OH)_2(aq) + HCl(aq) \rightarrow$

57. Write the balanced formula, complete ionic, and net ionic equations for the reactions that occur when the following are mixed.

a. potassium hydroxide (aqueous) and nitric acid

b. barium hydroxide (aqueous) and hydrochloric acid

c. perchloric acid [$HClO_4(aq)$] and solid iron(III) hydroxide

58. Write the balanced formula, complete ionic, and net ionic equations for the reactions that occur when the following are mixed.
a. solid silver hydroxide and hydrobromic acid
b. aqueous strontium hydroxide and hydroiodic acid
c. solid chromium(III) hydroxide and nitric acid

59. What volume of each of the following acids will react completely with 50.00 mL of 0.200 *M* NaOH?
a. 0.100 *M* HCl
b. 0.150 *M* HNO_3
c. 0.200 *M* $HC_2H_3O_2$ (1 acidic hydrogen)

60. What volume of each of the following bases will react completely with 25.00 mL of 0.200 *M* HCl?
a. 0.100 *M* NaOH
b. 0.0500 *M* $Ba(OH)_2$
c. 0.250 *M* KOH

61. Hydrochloric acid (75.0 mL of 0.250 *M*) is added to 225.0 mL of 0.0550 *M* $Ba(OH)_2$ solution. What is the concentration of the excess H^+ or OH^- ions left in this solution?

62. A student mixes four reagents together, thinking that the solutions will neutralize each other. The solutions mixed together are 50.0 mL of 0.100 *M* hydrochloric acid, 100.0 mL of 0.200 *M* of nitric acid, 500.0 mL of 0.0100 *M* calcium hydroxide, and 200.0 mL of 0.100 *M* rubidium hydroxide. Is the resulting solution neutral? If not, calculate the concentration of excess H^+ or OH^- ions left in solution.

63. A 25.00-mL sample of hydrochloric acid solution requires 24.16 mL of 0.106 *M* sodium hydroxide for complete neutralization. What is the concentration of the original hydrochloric acid solution?

64. What volume of 0.0200 *M* calcium hydroxide is required to neutralize 35.00 mL of 0.0500 *M* nitric acid?

65. A student titrates an unknown amount of potassium hydrogen phthalate ($KHC_8H_4O_4$, often abbreviated KHP) with 20.46 mL of a 0.1000 *M* NaOH solution. KHP (molar mass = 204.22 g/mol) has one acidic hydrogen. What mass of KHP was titrated (reacted completely) by the sodium hydroxide solution?

66. The concentration of a certain sodium hydroxide solution was determined by using the solution to titrate a sample of potassium hydrogen phthalate (abbreviated as KHP). KHP is an acid with one acidic hydrogen and a molar mass of 204.22 g/mol. In the titration, 34.67 mL of the sodium hydroxide solution was required to react with 0.1082 g KHP. Calculate the molarity of the sodium hydroxide.

Oxidation–Reduction Reactions

67. Assign oxidation states for all atoms in each of the following compounds.
a. $KMnO_4$
b. NiO_2
c. $Na_4Fe(OH)_6$
d. $(NH_4)_2HPO_4$
e. P_4O_6
f. Fe_3O_4
g. $XeOF_4$
h. SF_4
i. CO
j. $C_6H_{12}O_6$

68. Assign oxidation states for all atoms in each of the following compounds.
a. UO_2^{2+}
b. As_2O_3
c. $NaBiO_3$
d. As_4
e. $HAsO_2$
f. $Mg_2P_2O_7$
g. $Na_2S_2O_3$
h. Hg_2Cl_2
i. $Ca(NO_3)_2$

69. Assign the oxidation state for nitrogen in each of the following.
a. Li_3N
b. NH_3
c. N_2H_4
d. NO
e. N_2O
f. NO_2
g. NO_2^-
h. NO_3^-
i. N_2

70. Assign oxidation numbers to all the atoms in each of the following.
a. $SrCr_2O_7$
b. $CuCl_2$
c. O_2
d. H_2O_2
e. $MgCO_3$
f. Ag
g. $PbSO_3$
h. PbO_2
i. $Na_2C_2O_4$
j. CO_2
k. $(NH_4)_2Ce(SO_4)_3$
l. Cr_2O_3

71. Specify which of the following are oxidation–reduction reactions, and identify the oxidizing agent, the reducing agent, the substance being oxidized, and the substance being reduced.
a. $Cu(s) + 2Ag^+(aq) \rightarrow 2Ag(s) + Cu^{2+}(aq)$
b. $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$
c. $SiCl_4(l) + 2H_2O(l) \rightarrow 4HCl(aq) + SiO_2(s)$
d. $SiCl_4(l) + 2Mg(s) \rightarrow 2MgCl_2(s) + Si(s)$
e. $Al(OH)_4^-(aq) \rightarrow AlO_2^-(aq) + 2H_2O(l)$

72. Specify which of the following equations represent oxidation–reduction reactions, and indicate the oxidizing agent, the reducing agent, the species being oxidized, and the species being reduced.
a. $CH_4(g) + H_2O(g) \rightarrow CO(g) + 3H_2(g)$
b. $2AgNO_3(aq) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$
c. $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
d. $2H^+(aq) + 2CrO_4^{2-}(aq) \rightarrow Cr_2O_7^{2-}(aq) + H_2O(l)$

73. Balance the following oxidation–reduction reactions that occur in acidic solution.
a. $Zn(s) + HCl(aq) \rightarrow Zn^{2+}(aq) + H_2(g) + Cl^-(aq)$
b. $I^-(aq) + ClO^-(aq) \rightarrow I_3^-(aq) + Cl^-(aq)$
c. $As_2O_3(s) + NO_3^-(aq) \rightarrow H_3AsO_4(aq) + NO(g)$
d. $Br^-(aq) + MnO_4^-(aq) \rightarrow Br_2(l) + Mn^{2+}(aq)$
e. $CH_3OH(aq) + Cr_2O_7^{2-}(aq) \rightarrow CH_2O(aq) + Cr^{3+}(aq)$

74. Balance the following oxidation–reduction reactions that occur in acidic solution using the half-reaction method.
a. $Cu(s) + NO_3^-(aq) \rightarrow Cu^{2+}(aq) + NO(g)$
b. $Cr_2O_7^{2-}(aq) + Cl^-(aq) \rightarrow Cr^{3+}(aq) + Cl_2(g)$
c. $Pb(s) + PbO_2(s) + H_2SO_4(aq) \rightarrow PbSO_4(s)$
d. $Mn^{2+}(aq) + NaBiO_3(s) \rightarrow Bi^{3+}(aq) + MnO_4^-(aq)$
e. $H_3AsO_4(aq) + Zn(s) \rightarrow AsH_3(g) + Zn^{2+}(aq)$

75. Balance the following oxidation–reduction reactions that occur in basic solution.
a. $Al(s) + MnO_4^-(aq) \rightarrow MnO_2(s) + Al(OH)_4^-(aq)$
b. $Cl_2(g) \rightarrow Cl^-(aq) + OCl^-(aq)$
c. $NO_2^-(aq) + Al(s) \rightarrow NH_3(g) + AlO_2^-(aq)$

76. Balance the following oxidation–reduction reactions that occur in basic solution.
a. $Cr(s) + CrO_4^{2-}(aq) \rightarrow Cr(OH)_3(s)$
b. $MnO_4^-(aq) + S^{2-}(aq) \rightarrow MnS(s) + S(s)$
c. $CN^-(aq) + MnO_4^-(aq) \rightarrow CNO^-(aq) + MnO_2(s)$

77. Chlorine gas was first prepared in 1774 by C. W. Scheele by oxidizing sodium chloride with manganese(IV) oxide. The reaction is

$$NaCl(aq) + H_2SO_4(aq) + MnO_2(s) \longrightarrow Na_2SO_4(aq) + MnCl_2(aq) + H_2O(l) + Cl_2(g)$$

Balance this equation.

78. Gold metal will not dissolve in either concentrated nitric acid or concentrated hydrochloric acid. It will dissolve, however, in aqua regia, a mixture of the two concentrated acids. The products of the reaction are the $AuCl_4^-$ ion and gaseous NO. Write a balanced equation for the dissolution of gold in aqua regia.

Additional Exercises

79. Which of the following statements is (are) true? For the false statements, correct them.
a. A concentrated solution in water will always contain a strong or weak electrolyte.
b. A strong electrolyte will break up into ions when dissolved in water.
c. An acid is a strong electrolyte.
d. All ionic compounds are strong electrolytes in water.

80. A 230.-mL sample of a 0.275 *M* $CaCl_2$ solution is left on a hot plate overnight; the following morning, the solution is 1.10 *M*. What volume of water evaporated from the 0.275 *M* $CaCl_2$ solution?

81. Using the general solubility rules given in Table 4.1, name three reagents that would form precipitates with each of the following ions in aqueous solution. Write the net ionic equation for each of your suggestions.
a. chloride ion
b. calcium ion
c. iron(III) ion
d. sulfate ion
e. mercury(I) ion, Hg_2^{2+}
f. silver ion

82. Consider a 1.50-g mixture of magnesium nitrate and magnesium chloride. After dissolving this mixture in water, 0.500 *M* silver nitrate is added dropwise until precipitate formation is complete. The mass of the white precipitate formed is 0.641 g.
a. Calculate the mass percent of magnesium chloride in the mixture.
b. Determine the minimum volume of silver nitrate that must have been added to ensure complete formation of the precipitate.

83. A 1.00-g sample of an alkaline earth metal chloride is treated with excess silver nitrate. All of the chloride is recovered as 1.38 g of silver chloride. Identify the metal.

84. A mixture contains only NaCl and $Al_2(SO_4)_3$. A 1.45-g sample of the mixture is dissolved in water and an excess of NaOH is added, producing a precipitate of $Al(OH)_3$. The precipitate is filtered, dried, and weighed. The mass of the precipitate is 0.107 g. What is the mass percent of $Al_2(SO_4)_3$ in the sample?

85. Saccharin ($C_7H_5NO_3S$) is sometimes dispensed in tablet form. Ten tablets with a total mass of 0.5894 g were dissolved in water. They were oxidized to convert all the sulfur to sulfate ion, which was precipitated by adding an excess of barium chloride solution. The mass of $BaSO_4$ obtained was 0.5032 g. What is the average mass of saccharin per tablet? What is the average mass percent of saccharin in the tablets?

86. A mixture contains only NaCl and $Fe(NO_3)_3$. A 0.456-g sample of the mixture is dissolved in water, and an excess of NaOH is added, producing a precipitate of $Fe(OH)_3$. The precipitate is filtered, dried, and weighed. Its mass is 0.107 g. Calculate the following.
a. the mass of iron in the sample
b. the mass of $Fe(NO_3)_3$ in the sample
c. the mass percent of $Fe(NO_3)_3$ in the sample

87. A student added 50.0 mL of an NaOH solution to 100.0 mL of 0.400 *M* HCl. The solution was then treated with an excess of aqueous chromium(III) nitrate, resulting in formation of 2.06 g of precipitate. Determine the concentration of the NaOH solution.

88. What acid and what strong base would react in aqueous solution to produce the following salts in the formula equation? Write the balanced formula equation for each reaction.
a. potassium perchlorate
b. cesium nitrate
c. calcium iodide

89. A 10.00-mL sample of vinegar, an aqueous solution of acetic acid ($HC_2H_3O_2$), is titrated with 0.5062 *M* NaOH, and 16.58 mL is required to reach the equivalence point.
a. What is the molarity of the acetic acid?
b. If the density of the vinegar is 1.006 g/cm^3, what is the mass percent of acetic acid in the vinegar?

90. When hydrochloric acid reacts with magnesium metal, hydrogen gas and aqueous magnesium chloride are produced. What volume of 5.0 *M* HCl is required to react completely with 3.00 g of magnesium?

91. A 2.20-g sample of an unknown acid (empirical formula = $C_3H_4O_3$) is dissolved in 1.0 L of water. A titration required 25.0 mL of 0.500 *M* NaOH to react completely with all the acid present. Assuming the unknown acid has one acidic proton per molecule, what is the molecular formula of the unknown acid?

92. Carminic acid, a naturally occurring red pigment extracted from the cochineal insect, contains only carbon, hydrogen, and oxygen. It was commonly used as a dye in the first half of the nineteenth century. It is 53.66% C and 4.09% H by mass. A titration required 18.02 mL of 0.0406 *M* NaOH to neutralize 0.3602 g carminic acid. Assuming that there is only one acidic hydrogen per molecule, what is the molecular formula of carminic acid?

93. A 30.0-mL sample of an unknown strong base is neutralized after the addition of 12.0 mL of a 0.150 *M* HNO_3 solution. If the unknown base concentration is 0.0300 *M*, give some possible identities for the unknown base.

94. Many oxidation–reduction reactions can be balanced by inspection. Try to balance the following reactions by inspection. In each reaction, identify the substance reduced and the substance oxidized.
a. $Al(s) + HCl(aq) \rightarrow AlCl_3(aq) + H_2(g)$
b. $CH_4(g) + S(s) \rightarrow CS_2(l) + H_2S(g)$
c. $C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$
d. $Cu(s) + Ag^+(aq) \rightarrow Ag(s) + Cu^{2+}(aq)$

95. One of the classical methods for the determination of the manganese content in steel is to convert all the manganese to the deeply colored permanganate ion and then to measure the absorption of light. The steel is dissolved in nitric acid, producing the manganese(II) ion and nitrogen dioxide gas. This solution is then reacted with an acidic solution containing periodate ion; the products are the permanganate and iodate ions. Write balanced chemical equations for both these steps.

Challenge Problems

96. The units of parts per million (ppm) and parts per billion (ppb) are commonly used by environmental chemists. In general, 1 ppm means 1 part of solute for every 10^6 parts of solution. Mathematically, by mass:

$$\text{ppm} = \frac{\mu\text{g solute}}{\text{g solution}} = \frac{\text{mg solute}}{\text{kg solution}}$$

In the case of very dilute aqueous solutions, a concentration of 1.0 ppm is equal to 1.0 μg of solute per 1.0 mL, which equals 1.0 g solution. Parts per billion is defined in a similar fashion. Calculate the molarity of each of the following aqueous solutions.

a. 5.0 ppb Hg in H_2O
b. 1.0 ppb $CHCl_3$ in H_2O
c. 10.0 ppm As in H_2O
d. 0.10 ppm DDT ($C_{14}H_9Cl_5$) in H_2O

97. In most of its ionic compounds, cobalt is either Co(II) or Co(III). One such compound, containing chloride ion and waters of hydration, was analyzed, and the following results were obtained. A 0.256-g sample of the compound was dissolved in water, and excess silver nitrate was added. The silver chloride was filtered, dried, and weighed, and it had a mass of 0.308 g. A second sample of 0.416 g of the compound was dissolved in water, and an excess of sodium hydroxide was added. The hydroxide salt was filtered and heated in a flame, forming cobalt(III) oxide. The mass of cobalt(III) oxide formed was 0.145 g.

a. What is the percent composition, by mass, of the compound?
b. Assuming the compound contains one cobalt atom per formula unit, what is the molecular formula?
c. Write balanced equations for the three reactions described.

98. Polychlorinated biphenyls (PCBs) have been used extensively as dielectric materials in electrical transformers. Because PCBs have been shown to be potentially harmful, analysis for their presence in the environment has become very important. PCBs are manufactured according to the following generic reaction:

$$C_{12}H_{10} + nCl_2 \rightarrow C_{12}H_{10-n}Cl_n + n\text{HCl}$$

This reaction results in a mixture of PCB products. The mixture is analyzed by decomposing the PCBs and then precipitating the resulting Cl^- as AgCl.

a. Develop a general equation that relates the average value of n to the mass of a given mixture of PCBs and the mass of AgCl produced.
b. A 0.1947-g sample of a commercial PCB yielded 0.4791 g of AgCl. What is the average value of n for this sample?

99. You have two 500.0 mL aqueous solutions. Solution A is a solution of silver nitrate, and solution B is a solution of potassium chromate. The masses of the solutes in each of the solutions are the same. When the solutions are added together, a blood-red precipitate forms. After the reaction has gone to completion, you dry the solid and find that it has a mass of 331.8 g.

a. Calculate the concentration of the potassium ions in the original potassium chromate solution.
b. Calculate the concentration of the chromate ions in the final solution.

100. A sample is a mixture of KCl and KBr. When 0.1024 g of the sample is dissolved in water and reacted with excess silver nitrate, 0.1889 g solid is obtained. What is the composition by mass percent of the original mixture?

101. You are given a solid that is a mixture of Na_2SO_4 and K_2SO_4. A 0.205-g sample of the mixture is dissolved in water. An excess of an aqueous solution of $BaCl_2$ is added. The $BaSO_4$ that is formed is filtered, dried, and weighed. Its mass is 0.298 g. What mass of SO_4^{2-} ion is in the sample? What is the mass percent of SO_4^{2-} ion in the sample? What are the percent compositions by mass of Na_2SO_4 and K_2SO_4 in the sample?

102. Zinc and magnesium metal each react with hydrochloric acid according to the following equations:

$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$
$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

A 10.00-g mixture of zinc and magnesium is reacted with the stoichiometric amount of hydrochloric acid. The reaction mixture is then reacted with 156 mL of 3.00 M silver nitrate to produce the maximum possible amount of silver chloride.

a. Determine the percent magnesium by mass in the original mixture.
b. If 78.0 mL of HCl was added, what was the concentration of the HCl?

103. You made 100.0 mL of a lead(II) nitrate solution for lab but forgot to cap it. The next lab session you noticed that there was only 80.0 mL left (the rest had evaporated). In addition, you forgot the initial concentration of the solution. You decide to take 2.00 mL of the solution and add an excess of a concentrated sodium chloride solution. You obtain a solid with a mass of 3.407 g. What was the concentration of the original lead(II) nitrate solution?

104. Consider reacting copper(II) sulfate with iron. Two possible reactions can occur, as represented by the following equations.

$$\text{copper(II) sulfate}(aq) + \text{iron}(s) \longrightarrow \text{copper}(s) + \text{iron(II) sulfate}(aq)$$
$$\text{copper(II) sulfate}(aq) + \text{iron}(s) \longrightarrow \text{copper}(s) + \text{iron(III) sulfate}(aq)$$

You place 87.7 mL of a 0.500 M solution of copper(II) sulfate in a beaker. You then add 2.00 g of iron filings to the copper(II) sulfate solution. After one of the above reactions occurs, you isolate 2.27 g of copper. Which equation above describes the reaction that occurred? Support your answer.

105. Consider an experiment in which two burets, Y and Z, are simultaneously draining into a beaker that initially contained 275.0 mL of 0.300 M HCl. Buret Y contains 0.150 M NaOH and buret Z contains 0.250 M KOH. The stoichiometric point in the titration is reached 60.65 minutes after Y and Z were started simultaneously. The total volume in the beaker at the stoichiometric point is 655 mL. Calculate the flow rates of burets Y and Z. Assume the flow rates remain constant during the experiment.

106. Complete and balance each acid–base reaction.
- **a.** $H_3PO_4(aq) + NaOH(aq) \rightarrow$
  Contains three acidic hydrogens
- **b.** $H_2SO_4(aq) + Al(OH)_3(s) \rightarrow$
  Contains two acidic hydrogens
- **c.** $H_2Se(aq) + Ba(OH)_2(aq) \rightarrow$
  Contains two acidic hydrogens
- **d.** $H_2C_2O_4(aq) + NaOH(aq) \rightarrow$
  Contains two acidic hydrogens

107. What volume of 0.0521 *M* $Ba(OH)_2$ is required to neutralize exactly 14.20 mL of 0.141 *M* H_3PO_4? Phosphoric acid contains three acidic hydrogens.

108. A 10.00-mL sample of sulfuric acid from an automobile battery requires 35.08 mL of 2.12 *M* sodium hydroxide solution for complete neutralization. What is the molarity of the sulfuric acid? Sulfuric acid contains two acidic hydrogens.

109. Some of the substances commonly used in stomach antacids are MgO, $Mg(OH)_2$, and $Al(OH)_3$.
- **a.** Write a balanced equation for the neutralization of hydrochloric acid by each of these substances.
- **b.** Which of these substances will neutralize the greatest amount of 0.10 *M* HCl per gram?

110. A 6.50-g sample of a diprotic acid requires 137.5 mL of a 0.750 *M* NaOH solution for complete reaction. Determine the molar mass of the acid.

111. Citric acid, which can be obtained from lemon juice, has the molecular formula $C_6H_8O_7$. A 0.250-g sample of citric acid dissolved in 25.0 mL of water requires 37.2 mL of 0.105 *M* NaOH for complete neutralization. What number of acidic hydrogens per molecule does citric acid have?

112. Balance the following equations by the half-reaction method.
- **a.** $Fe(s) + HCl(aq) \rightarrow HFeCl_4(aq) + H_2(g)$
- **b.** $IO_3^-(aq) + I^-(aq) \xrightarrow{\text{Acid}} I_3^-(aq)$
- **c.** $Cr(NCS)_6^{4-}(aq) + Ce^{4+}(aq) \xrightarrow{\text{Acid}} Cr^{3+}(aq) + Ce^{3+}(aq) + NO_3^-(aq) + CO_2(g) + SO_4^{2-}(aq)$
- **d.** $CrI_3(s) + Cl_2(g) \xrightarrow{\text{Base}} CrO_4^{2-}(aq) + IO_4^-(aq) + Cl^-(aq)$
- **e.** $Fe(CN)_6^{4-}(aq) + Ce^{4+}(aq) \xrightarrow{\text{Base}} Ce(OH)_3(s) + Fe(OH)_3(s) + CO_3^{2-}(aq) + NO_3^-(aq)$
- **f.** $Fe(OH)_2(s) + H_2O_2(aq) \xrightarrow{\text{Base}} Fe(OH)_3(s)$

113. It took 25.06 ±0.05 mL of a sodium hydroxide solution to titrate a 0.4016-g sample of KHP (see Exercise 65). Calculate the concentration and uncertainty in the concentration of the sodium hydroxide solution. (See Appendix 1.5.) Neglect any uncertainty in the mass.

Integrative Problems

These problems require the integration of multiple concepts to find the solutions.

114. Tris(pentafluorophenyl)borane, commonly known by its acronym BARF, is frequently used to initiate polymerization of ethylene or propylene in the presence of a catalytic transition metal compound. It is composed solely of C, F, and B; it is 42.23% C by mass and 55.66% F by mass.
- **a.** What is the empirical formula of BARF?
- **b.** A 2.251-g sample of BARF dissolved in 347.0 mL of solution produces a 0.01267 *M* solution. What is the molecular formula of BARF?

115. In a 1-L beaker, 203 mL of 0.307 *M* ammonium chromate was mixed with 137 mL of 0.269 *M* chromium(III) nitrite to produce ammonium nitrite and chromium(III) chromate. Write the balanced chemical reaction occurring here. If the percent yield of the reaction was 88.0%, how much chromium(III) chromate was isolated?

116. The vanadium in a sample of ore is converted to VO^{2+}. The VO^{2+} ion is subsequently titrated with MnO_4^- in acidic solution to form $V(OH)_4^+$ and manganese(II) ion. To titrate the solution, 26.45 mL of 0.02250 *M* MnO_4^- was required. If the mass percent of vanadium in the ore was 58.1%, what was the mass of the ore sample? Which of the four transition metal ions in this titration has the highest oxidation state?

117. The unknown acid H_2X can be neutralized completely by OH^- according to the following (unbalanced) equation:

$$H_2X(aq) + OH^- \longrightarrow X^{2-} + H_2O$$

The ion formed as a product, X^{2-}, was shown to have 36 total electrons. What is element X? Propose a name for H_2X? To completely neutralize a sample of H_2X, 35.6 mL of 0.175 *M* OH^- solution was required. What was the mass of the H_2X sample used?

Marathon Problems

These problems are designed to incorporate several concepts and techniques into one situation. Marathon Problems can be used in class by groups of students to help facilitate problem-solving skills.

118. Three students were asked to find the identity of the metal in a particular sulfate salt. They dissolved a 0.1472-g sample of the salt in water and treated it with excess barium chloride, resulting in the precipitation of barium sulfate. After the precipitate had been filtered and dried, it weighed 0.2327 g.

Each student analyzed the data independently and came to different conclusions. Pat decided that the metal was titanium. Chris thought it was sodium. Randy reported that it was gallium. What formula did each student assign to the sulfate salt?

Look for information on the sulfates of gallium, sodium, and titanium in this text and reference books such as the *CRC Handbook of Chemistry and Physics*. What further tests would you suggest to determine which student is most likely correct?

119. You have two 500.0-mL aqueous solutions. Solution A is a solution of a metal nitrate that is 8.246% nitrogen by mass. The ionic compound in solution B consists of potassium, chromium, and oxygen; chromium has an oxidation state of +6 and there are 2 potassiums and 1 chromium in the formula. The masses of the solutes in each of the solutions are the same. When the solutions are added together, a blood-red precipitate forms. After the reaction has gone to completion, you dry the solid and find that it has a mass of 331.8 g.
- **a.** Identify the ionic compounds in solution A and solution B.
- **b.** Identify the blood-red precipitate.
- **c.** Calculate the concentration (molarity) of all ions in the original solutions.
- **d.** Calculate the concentration (molarity) of all ions in the final solution.

Get help understanding core concepts and visualizing molecular-level interactions, and practice problem solving, by visiting the Online Study Center at **college.hmco.com/PIC/zumdahl7e.**