determine the amount of product that will be produced? Explain.

7. A new grill has a mass of 30.0 kg. You put 3.0 kg of charcoal in the grill. You burn all the charcoal and the grill has a mass of 30.0 kg. What is the mass of the gases given off? Explain.

8. What happens to the weight of an iron bar when it rusts?
   a. There is no change, since mass is always conserved.
   b. The weight increases.
   c. The weight increases, but if the rust is scraped off, the bar has the original weight.
   d. The weight decreases.
   Justify your choice, and for choices you did not pick, explain what is wrong with them. Make sure to explain what it means for something to rust.

9. You may have noticed that water sometimes drips from the exhaust of a car as it is running. Is this evidence that there is at least a small amount of water originally present in the gasoline? Explain.

Questions 10 and 11 deal with the following situation: You react chemical A with chemical B to make one product. It takes 100 g of A to react completely with 20 g B.

10. What is the mass of the product?
    a. Less than 10 g.
    b. Between 20 and 100 g.
    c. Between 100 and 120 g.
    d. Exactly 120 g.
    e. More than 120 g.

11. What is true about the chemical properties of the product?
    a. The properties are more like chemical A.
    b. The properties are more like chemical B.
    c. The properties are an average of those of chemical A and chemical B.
    d. The properties are not necessarily like either chemical A or chemical B.
    e. The properties are more like chemical A or more like chemical B, but more information is needed.
    Justify your choice, and for choices you did not pick, explain what is wrong with them.

12. Is there a difference between a homogeneous mixture of hydrogen and oxygen in a 2:1 mole ratio and a sample of water vapor? Explain.

13. Chlorine exists mainly as two isotopes, ^{37}Cl and ^{35}Cl. Which is more abundant? How do you know?

14. The average mass of a carbon atom is 12.011. Assuming you could pick up one carbon atom, estimate the chance that you would randomly get one with a mass of 12.011. Support your answer.

15. Can the subscripts in a chemical formula be fractions? Explain. Can the coefficients in a balanced chemical equation be frac-

tions? Explain. Changing the subscripts of chemicals can balance the equations mathematically. Why is this unacceptable?

16. Consider the equation $2A + B \longrightarrow A_2B$. If you mix 1.0 mol of A with 1.0 mol of B, how many moles of A_2B can be produced?

17. According to the law of conservation of mass, mass cannot be gained or destroyed in a chemical reaction. Why can't you simply add the masses of two reactants to determine the total mass of product?

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

Questions

18. The atomic mass of boron (B) is given in the periodic table as 10.81, yet no single atom of boron has a mass of 10.81 amu. Explain.

19. What is the difference between the empirical and molecular formulas of a compound? Can they ever be the same? Explain.

20. Why is the actual yield of a reaction often less than the theoretical yield?

Exercises

In this section similar exercises are paired.

Atomic Masses and the Mass Spectrometer

21. The element magnesium (Mg) has three stable isotopes with the following masses and abundances:

Isotope	Mass (amu)	Abundance
^{24}Mg	23.9850	78.99%
^{25}Mg	24.9858	10.00%
^{26}Mg	25.9826	11.01%

Calculate the average atomic mass (the atomic weight) of magnesium from these data.

22. Assume that element Uus is synthesized and that it has the following stable isotopes:

^{284}Uus (283.4 amu)   34.60%
^{285}Uus (284.7 amu)   21.20%
^{288}Uus (287.8 amu)   44.20%

What is the value of the average atomic mass for Uus that would be listed on the periodic table?

23. An element is a mixture of two isotopes. One isotope of the element has an atomic mass of 34.96885 amu and has a rel-

ative abundance of 75.53%. The other isotope has an atomic mass of 36.96590 amu. Calculate the average atomic mass and identify the element.

24. An element consists of 1.40% of an isotope with mass 203.973 amu, 24.10% of an isotope with mass 205.9745 amu, 22.10% of an isotope with mass 206.9759 amu, and 52.40% of an isotope with mass 207.9766 amu. Calculate the average atomic mass and identify the element.

25. The element europium exists in nature as two isotopes: ^{151}Eu has a mass of 150.9196 amu, and ^{153}Eu has a mass of 152.9209 amu. The average atomic mass of europium is 151.96 amu. Calculate the relative abundance of the two europium isotopes.

26. The element rhenium (Re) has two naturally occurring isotopes, ^{185}Re and ^{187}Re, with an average atomic mass of 186.207 amu. Rhenium is 62.60% ^{187}Re, and the atomic mass of ^{187}Re is 186.956 amu. Calculate the mass of ^{185}Re.

27. The mass spectrum of bromine (Br$_2$) consists of three peaks with the following characteristics:

Mass (amu)	Relative size
157.84	0.2534
159.84	0.5000
161.84	0.2466

How do you interpret these data?

28. Naturally occurring tellurium (Te) has the following isotopic abundances:

Isotope	Abundance	Mass (amu)
^{120}Te	0.09%	119.90
^{122}Te	2.46%	121.90
^{123}Te	0.87%	122.90
^{124}Te	4.61%	123.90
^{125}Te	6.99%	124.90
^{126}Te	18.71%	125.90
^{128}Te	31.79%	127.90
^{130}Te	34.48%	129.91

Draw the mass spectrum of H$_2$Te, assuming that the only hydrogen isotope present is ^{1}H (mass 1.008).

Moles and Molar Masses

29. Calculate the mass of 500. atoms of iron (Fe).

30. How many Fe atoms and how many moles of Fe atoms are in 500.0 g of iron?

31. Diamond is a natural form of pure carbon. How many atoms of carbon are in a 1.00-carat diamond (1.00 carat = 0.200 g)?

32. A diamond contains 5.0×10^{21} atoms of carbon. How many moles of carbon and how many grams of carbon are in this diamond?

33. Aluminum metal is produced by passing an electric current through a solution of aluminum oxide (Al$_2$O$_3$) dissolved in molten cryolite (Na$_3$AlF$_6$). Calculate the molar masses of Al$_2$O$_3$ and Na$_3$AlF$_6$.

34. The Freons are a class of compounds containing carbon, chlorine, and fluorine. While they have many valuable uses, they have been shown to be responsible for depletion of the ozone in the upper atmosphere. In 1991, two replacement compounds for Freons went into production: HFC-134a (CH$_2$FCF$_3$) and HCFC-124 (CHClFCF$_3$). Calculate the molar masses of these two compounds.

35. Calculate the molar mass of the following substances.
   a. NH$_3$
   b. N$_2$H$_4$
   c. (NH$_4$)$_2$Cr$_2$O$_7$

36. Calculate the molar mass of the following substances.
   a. P$_4$O$_6$
   b. Ca$_3$(PO$_4$)$_2$
   c. Na$_2$HPO$_4$

37. How many moles of compound are present in 1.00 g of each of the compounds in Exercise 35?

38. How many moles of compound are present in 1.00 g of each of the compounds in Exercise 36?

39. How many grams of compound are present in 5.00 mol of each of the compounds in Exercise 35?

40. How many grams of compound are present in 5.00 mol of each of the compounds in Exercise 36?

41. How many grams of nitrogen are present in 5.00 mol of each of the compounds in Exercise 35?

42. How many grams of phosphorus are present in 5.00 mol of each of the compounds in Exercise 36?

43. How many molecules (or formula units) are present in 1.00 g of each of the compounds in Exercise 35?

44. How many molecules (or formula units) are present in 1.00 g of each of the compounds in Exercise 36?

45. How many atoms of nitrogen are present in 1.00 g of each of the compounds in Exercise 35?

46. How many atoms of phosphorus are present in 1.00 g of each of the compounds in Exercise 36?

47. Ascorbic acid, or vitamin C (C$_6$H$_8$O$_6$), is an essential vitamin. It cannot be stored by the body and must be present in the diet. What is the molar mass of ascorbic acid? Vitamin C tablets are taken as a dietary supplement. If a typical tablet contains 500.0 mg of vitamin C, how many moles and how many molecules of vitamin C does it contain?

48. The molecular formula of acetylsalicylic acid (aspirin), one of the most commonly used pain relievers, is $C_9H_8O_4$.
  a. Calculate the molar mass of aspirin.
  b. A typical aspirin tablet contains 500. mg of $C_9H_8O_4$. How many moles of $C_9H_8O_4$ molecules and how many molecules of acetylsalicylic acid are in a 500.-mg tablet?

49. How many moles are represented by each of these samples?
  a. 100 molecules (exactly) of H_2O
  b. 100.0 g H_2O
  c. 150 molecules (exactly) of O_2

50. How many moles are represented by each of these samples?
  a. 150.0 g Fe_2O_3 **c.** 1.5×10^{16} molecules of BF_3
  b. 10.0 mg NO_2

51. Determine the mass in grams of the following:
  a. 3.00×10^{20} N_2 molecules   **e.** 2.00×10^{-15} mol N_2
  b. 3.00×10^{-3} mol N_2 **f.** 18.0 picomoles of N_2
  c. 1.5×10^2 mol N_2 **g.** 5.0 nanomoles of N_2
  d. A single N_2 molecule

52. How many atoms of nitrogen are present in 5.00 g of each of the following?
  a. glycine, $C_2H_5O_2N$ **c.** calcium nitrate
  b. magnesium nitride   **d.** dinitrogen tetroxide

53. Aspartame is an artificial sweetener that is 160 times sweeter than sucrose (table sugar) when dissolved in water. It is marketed as Nutra-Sweet. The molecular formula of aspartame is $C_{14}H_{18}N_2O_5$.
  a. Calculate the molar mass of aspartame.
  b. How many moles of molecules are present in 10.0 g aspartame?
  c. Calculate the mass in grams of 1.56 mol aspartame.
  d. How many molecules are in 5.0 mg aspartame?
  e. How many atoms of nitrogen are in 1.2 g aspartame?
  f. What is the mass in grams of 1.0×10^9 molecules of aspartame?
  g. What is the mass in grams of one molecule of aspartame?

54. Humulone, $C_{21}H_{30}O_5$, is one of the flavor components that gives a bitter taste to the hops used in making beer.
  a. What is the molar mass of humulone?
  b. How many moles of $C_{21}H_{30}O_5$ molecules are in 275 mg of humulone?
  c. What is the mass of 0.600 mol of humulone?
  d. How many atoms of hydrogen are in 1.00 pg of humulone?
  e. What is the mass of 1.00×10^9 molecules of humulone?
  f. What is the mass of one molecule of humulone?

Percent Composition

55. Photocells use a semiconducting material that produces an electric current or a change in resistance on exposure to light. Compounds of cadmium (Cd) combined with an element from Group 6A of the periodic table are used in many common photocells. Calculate the mass percent of Cd in CdS, CdSe, and CdTe.

56. Calculate the percent composition by mass of the following compounds that are important starting materials for synthetic polymers:
  a. $C_3H_4O_2$ (acrylic acid, from which acrylic plastics are made)
  b. $C_4H_6O_2$ (methyl acrylate, from which Plexiglas is made)
  c. C_3H_3N (acrylonitrile, from which Orlon is made)

57. In 1987 the first substance to act as a superconductor at a temperature above that of liquid nitrogen (77 K) was discovered. The approximate formula of this substance is $YBa_2Cu_3O_7$. Calculate the percent composition by mass of this material.

58. There are several important compounds that contain only nitrogen and oxygen. Calculate the mass percent of nitrogen in each of the following:
  a. NO, a gas formed by the reaction of N_2 with O_2 in internal combustion engines
  b. NO_2, a brown gas mainly responsible for the brownish color of photochemical smog
  c. N_2O_4, a colorless liquid used as a fuel in space shuttles
  d. N_2O, a colorless gas sometimes used as an anesthetic by dentists (known as laughing gas)

59. Arrange the following substances in order of increasing mass percent of carbon.
  a. caffeine, $C_8H_{10}N_4O_2$
  b. sucrose, $C_{12}H_{22}O_{11}$
  c. ethanol, C_2H_5OH

60. Arrange the substances in Exercise 58 in order of the increasing mass percent of nitrogen.

61. Vitamin B_{12}, cyanocobalamin, is essential for human nutrition. It is concentrated in animal tissue but not in higher plants. Although nutritional requirements for the vitamin are quite low, people who abstain completely from animal products may develop a deficiency anemia. Cyanocobalamin is the form used in vitamin supplements. It contains 4.34% cobalt by mass. Calculate the molar mass of cyanocobalamin, assuming that there is one atom of cobalt in every molecule of cyanocobalamin.

62. Fungal laccase, a blue protein found in wood-rotting fungi, is 0.390% Cu by mass. If a fungal laccase molecule contains 4 copper atoms, what is the molar mass of fungal laccase?

Empirical and Molecular Formulas

63. Express the composition of each of the following compounds as the mass percents of its elements.
  a. formaldehyde, CH_2O
  b. glucose, $C_6H_{12}O_6$
  c. acetic acid, $HC_2H_3O_2$

64. Considering your answer to Exercise 63, which type of formula, empirical or molecular, can be obtained from elemental analysis that gives percent composition?

65. Give the empirical formula for each of the following compounds (for which the common names are given).
   a. vitamin C, $C_6H_8O_6$
   b. benzene, C_6H_6
   c. acetylene, C_2H_2
   d. phosphorus pentoxide, P_4O_{10}
   e. glucose, $C_6H_{12}O_6$
   f. acetic acid, $HC_2H_3O_2$

66. Determine the molecular formulas to which the following empirical formulas and molar masses pertain.
   a. SNH (188.35 g/mol)
   b. $NPCl_2$ (347.64 g/mol)
   c. CoC_4O_4 (341.94 g/mol)
   d. SN (184.32 g/mol)

67. One of the most commonly used white pigments in paint is a compound of titanium and oxygen that contains 59.9% Ti by mass. Determine the empirical formula of this compound.

68. The compound adrenaline contains 56.79% C, 6.56% H, 28.37% O, and 8.28% N by mass. What is the empirical formula for adrenaline?

69. There are two binary compounds of mercury and oxygen. Heating either of them results in the decomposition of the compound, with oxygen gas escaping into the atmosphere while leaving a residue of pure mercury. Heating 0.6498 g of one of the compounds leaves a residue of 0.6018 g. Heating 0.4172 g of the other compound results in a mass loss of 0.016 g. Determine the empirical formula of each compound.

70. A sample of urea contains 1.121 g N, 0.161 g H, 0.480 g C, and 0.640 g O. What is the empirical formula of urea?

71. A compound that contains only nitrogen and oxygen is 30.4% N by mass; the molar mass of the compound is 92 g/mol. What is the empirical formula of the compound? What is the molecular formula of the compound?

72. A compound containing only sulfur and nitrogen is 69.6% S by mass; the molar mass is 184 g/mol. What are the empirical and molecular formulas of the compound?

73. Benzene contains only carbon and hydrogen and is 7.74% H by mass; the molar mass of benzene is 78.1 g/mol. Determine the empirical and molecular formulas of benzene.

74. Adipic acid is an organic compound composed of 49.31% C, 43.79% O, and the rest hydrogen. If the molar mass of adipic acid is 146.1 g/mol, what are the empirical and molecular formulas for adipic acid?

75. Many homes in rural America are heated by propane gas, a compound that contains only carbon and hydrogen. Complete combustion of a sample of propane produced 2.641 g of carbon dioxide and 1.442 g of water as the only products. Find the empirical formula of propane.

76. A compound contains only C, H, and N. Combustion of 35.0 mg of the compound produces 33.5 mg CO_2 and 41.1 mg H_2O. What is the empirical formula of the compound?

77. Cumene is a compound containing only carbon and hydrogen that is used in the production of acetone and phenol in the chemical industry. Combustion of 47.6 mg cumene produces some CO_2 and 42.8 mg water. The molar mass of cumene is between 115 and 125 g/mol. Determine the empirical and molecular formulas.

78. A compound contains only carbon, hydrogen, and oxygen. Combustion of 10.68 mg of the compound yields 16.01 mg CO_2 and 4.37 mg H_2O. The molar mass of the compound is 176.1 g/mol. What are the empirical and molecular formulas of the compound?

Balancing Chemical Equations

79. Write a balanced chemical equation that describes each of the following.
   a. Iron metal reacts with oxygen to form rust, iron(III) oxide.
   b. Calcium metal reacts with water to produce aqueous calcium hydroxide and hydrogen gas.
   c. Aqueous barium hydroxide reacts with aqueous sulfuric acid to produce solid barium sulfate and water.

80. Give the balanced equation for each of the following chemical reactions:
   a. Glucose ($C_6H_{12}O_6$) reacts with oxygen gas to produce gaseous carbon dioxide and water vapor.
   b. Solid iron(III) sulfide reacts with gaseous hydrogen chloride to form solid iron(III) chloride and hydrogen sulfide gas.
   c. Carbon disulfide liquid reacts with ammonia gas to produce hydrogen sulfide gas and solid ammonium thiocyanate (NH_4SCN).

81. Balance the following equations:
   a. $Cu(s) + AgNO_3(aq) \rightarrow Ag(s) + Cu(NO_3)_2(aq)$
   b. $Zn(s) + HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$
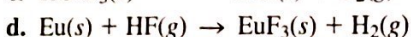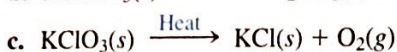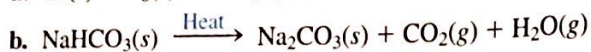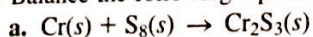   c. $Au_2S_3(s) + H_2(g) \rightarrow Au(s) + H_2S(g)$

82. Balance the following equations:
   a. $Ca(OH)_2(aq) + H_3PO_4(aq) \rightarrow H_2O(l) + Ca_3(PO_4)_2(s)$
   b. $Al(OH)_3(s) + HCl(aq) \rightarrow AlCl_3(aq) + H_2O(l)$
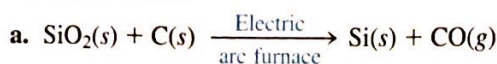   c. $AgNO_3(aq) + H_2SO_4(aq) \rightarrow Ag_2SO_4(s) + HNO_3(aq)$

83. Balance the following equations representing combustion reactions:
   a. $C_{12}H_{22}O_{11}(s) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
   b. $C_6H_6(l) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
   c. $Fe(s) + O_2(g) \rightarrow Fe_2O_3(s)$
   d. $C_4H_{10}(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$
   e. $FeO(s) + O_2(g) \rightarrow Fe_2O_3(s)$

84. Balance the following equations:
    a. $Cr(s) + S_8(s) \rightarrow Cr_2S_3(s)$
    b. $NaHCO_3(s) \xrightarrow{Heat} Na_2CO_3(s) + CO_2(g) + H_2O(g)$
    c. $KClO_3(s) \xrightarrow{Heat} KCl(s) + O_2(g)$
   d. $Eu(s) + HF(g) \rightarrow EuF_3(s) + H_2(g)$

85. Silicon is produced for the chemical and electronics indus-
   tries by the following reactions. Give the balanced equation
    for each reaction.
    a. $SiO_2(s) + C(s) \xrightarrow[\text{arc furnace}]{Electric} Si(s) + CO(g)$
    b. Silicon tetrachloride is reacted with very pure magnesium,
       producing silicon and magnesium chloride.
    c. $Na_2SiF_6(s) + Na(s) \rightarrow Si(s) + NaF(s)$
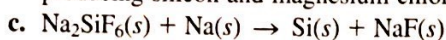
86. Phosphorus occurs naturally in the form of fluorapatite,
    $CaF_2 \cdot 3Ca_3(PO_4)_2$, the dot indicating 1 part CaF_2 to 3 parts
    $Ca_3(PO_4)_2$. This mineral is reacted with an aqueous solution
    of sulfuric acid in the preparation of a fertilizer. The prod-
    ucts are phosphoric acid, hydrogen fluoride, and gypsum,
    $CaSO_4 \cdot 2H_2O$. Write and balance the chemical equation de-
    scribing this process.

87. Lead hydrogen arsenate, an inorganic insecticide used against
   the potato beetle, is a product in the following reaction:

    $Pb(NO_3)_2(aq) + H_3AsO_4(aq) \longrightarrow$
    $\qquad\qquad\qquad\qquad PbHAsO_4(s) + HNO_3(aq)$
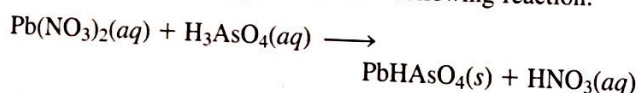
    Balance this equation.

88. The electrolysis of concentrated brine solutions is an impor-
    tant source of NaOH, H_2, and Cl_2 for the chemical industry.
   The reaction is

    $NaCl(aq) + H_2O(l) \xrightarrow{Electricity}$
    $\qquad\qquad\qquad Cl_2(g) + H_2(g) + NaOH(aq)$
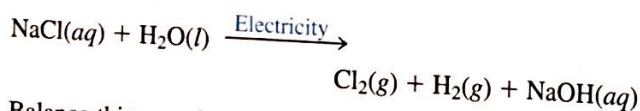
    Balance this equation.

Reaction Stoichiometry

89. Calculate the masses of Cr_2O_3, N_2, and H_2O produced from
    10.8 g $(NH_4)_2Cr_2O_7$ in an ammonium dichromate volcano re-
    action as described in Sample Exercise 3.14.

90. Over the years, the thermite reaction has been used for weld-
    ing railroad rails, in incendiary bombs, and to ignite solid-
    fuel rocket motors. The reaction is

    $Fe_2O_3(s) + 2Al(s) \longrightarrow 2Fe(l) + Al_2O_3(s)$
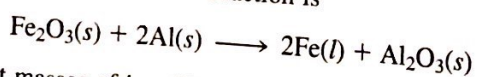
    What masses of iron(III) oxide and aluminum must be used
    to produce 15.0 g iron? What is the maximum mass of alu-
    minum oxide that could be produced?

91. The reusable booster rockets of the U.S. space shuttle em-
    ploy a mixture of aluminum and ammonium perchlorate for
    fuel. A possible equation for this reaction is

$3Al(s) + 3NH_4ClO_4(s) \longrightarrow$
$\qquad Al_2O_3(s) + AlCl_3(s) + 3NO(g) + 6H_2O(g)$
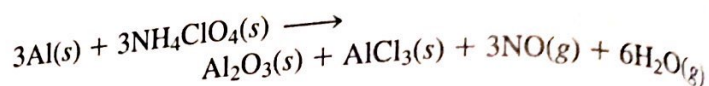
What mass of NH_4ClO_4 should be used in the fuel mixture
for every kilogram of Al?

92. One of relatively few reactions that takes place directly be-
    tween two solids at room temperature is

$Ba(OH)_2 \cdot 8H_2O(s) + NH_4SCN(s) \longrightarrow$
$\qquad Ba(SCN)_2(s) + H_2O(l) + NH_3(g)$
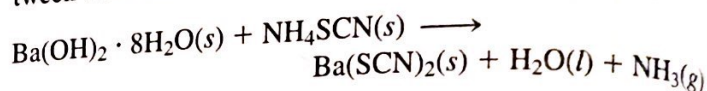
In this equation, the $\cdot 8H_2O$ in $Ba(OH)_2 \cdot 8H_2O$ indicates the
presence of eight water molecules. This compound is called
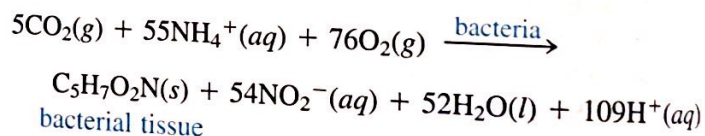barium hydroxide octahydrate.
a. Balance the equation.
b. What mass of ammonium thiocyanate (NH_4SCN) must be
   used if it is to react completely with 6.5 g barium hy-
   droxide octahydrate?

93. Coke is an impure form of carbon that is often used in the
    industrial production of metals from their oxides. If a sam-
    ple of coke is 95% carbon by mass, determine the mass of
   coke needed to react completely with 1.0 ton of copper(II)
    oxide.

$$2CuO(s) + C(s) \longrightarrow 2Cu(s) + CO_2(g)$$
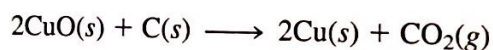
94. Bacterial digestion is an economical method of sewage treat-
    ment. The reaction

$5CO_2(g) + 55NH_4^+(aq) + 76O_2(g) \xrightarrow{bacteria}$
$\underset{\text{bacterial tissue}}{C_5H_7O_2N(s)} + 54NO_2^-(aq) + 52H_2O(l) + 109H^+(aq)$

is an intermediate step in the conversion of the nitrogen in or-
ganic compounds into nitrate ions. How much bacterial tissue
is produced in a treatment plant for every 1.0×10^4 kg of
wastewater containing 3.0% NH_4^+ ions by mass? Assume that
95% of the ammonium ions are consumed by the bacteria.

95. The compound cisplatin, $Pt(NH_3)_2Cl_2$, has been studied ex-
    tensively as an antitumor agent.
    a. Calculate the elemental percent composition by mass of
       cisplatin.
   b. Cisplatin is synthesized as follows:

$K_2PtCl_4(aq) + 2NH_3(aq) \longrightarrow Pt(NH_3)_2Cl_2(s) + 2KCl(aq)$
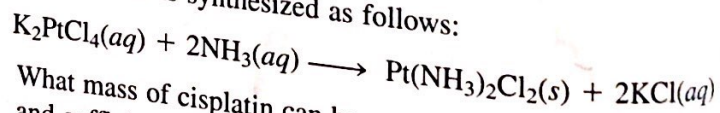
What mass of cisplatin can be made from 100. g of K_2PtCl_4
and sufficient NH_3? What mass of KCl is also produced?

96. Aspirin ($C_9H_8O_4$) is synthesized by reacting salicylic acid
    ($C_7H_6O_3$) with acetic anhydride ($C_4H_6O_3$). The balanced
    equation is

$$C_7H_6O_3 + C_4H_6O_3 \longrightarrow C_9H_8O_4 + HC_2H_3O_2$$
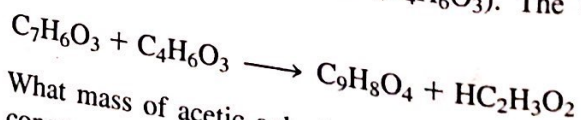
a. What mass of acetic anhydride is needed to completely
   consume 1.00×10^2 g salicylic acid?

b. What is the maximum mass of aspirin (the theoretical yield) that could be produced in this reaction?

Limiting Reactants and Percent Yield

97. Consider the reaction

$$Mg(s) + I_2(s) \longrightarrow MgI_2(s)$$
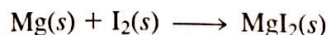
Identify the limiting reagent in each of the reaction mixtures below:
a. 100 atoms of Mg and 100 molecules of I_2
b. 150 atoms of Mg and 100 molecules of I_2
c. 200 atoms of Mg and 300 molecules of I_2
d. 0.16 mol Mg and 0.25 mol I_2
e. 0.14 mol Mg and 0.14 mol I_2
f. 0.12 mol Mg and 0.08 mol I_2
g. 6.078 g Mg and 63.46 g I_2
h. 1.00 g Mg and 2.00 g I_2
i. 1.00 g Mg and 20.00 g I_2

98. Consider the reaction

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$
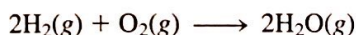
Identify the limiting reagent in each of the reaction mixtures given below:
a. 50 molecules of H_2 and 25 molecules of O_2
b. 100 molecules of H_2 and 40 molecules of O_2
c. 100 molecules of H_2 and 100 molecules of O_2
d. 0.50 mol H_2 and 0.75 mol O_2
e. 0.80 mol H_2 and 0.75 mol O_2
f. 1.0 g H_2 and 0.25 mol O_2
g. 5.00 g H_2 and 56.00 g O_2

99. When a mixture of silver metal and sulfur is heated, silver sulfide is formed:

$$16Ag(s) + S_8(s) \xrightarrow{\text{Heat}} 8Ag_2S(s)$$
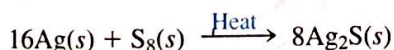
a. What mass of Ag_2S is produced from a mixture of 2.0 g Ag and 2.0 g S_8?
b. What mass of which reactant is left unreacted?

100. Mercury and bromine will react with each other to produce mercury(II) bromide:

$$Hg(l) + Br_2(l) \longrightarrow HgBr_2(s)$$
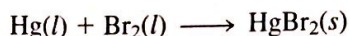
a. What mass of $HgBr_2$ can be produced from the reaction of 10.0 g Hg and 9.00 g Br_2? What mass of which reagent is left unreacted?
b. What mass of $HgBr_2$ can be produced from the reaction of 5.00 mL mercury (density = 13.6 g/mL) and 5.00 mL bromine (density = 3.10 g/mL)?

101. Consider the following unbalanced equation:

$$Ca_3(PO_4)_2(s) + H_2SO_4(aq) \longrightarrow CaSO_4(s) + H_3PO_4(aq)$$
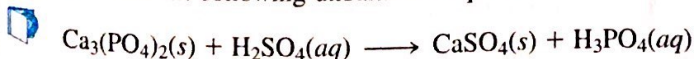
What masses of calcium sulfate and phosphoric acid can be produced from the reaction of 1.0 kg calcium phosphate with 1.0 kg concentrated sulfuric acid (98% H_2SO_4 by mass)?

102. Hydrogen cyanide is produced industrially from the reaction of gaseous ammonia, oxygen, and methane:

$$2NH_3(g) + 3O_2(g) + 2CH_4(g) \longrightarrow 2HCN(g) + 6H_2O(g)$$
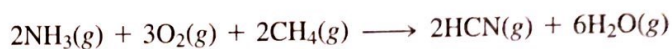
If 5.00×10^3 kg each of NH_3, O_2, and CH_4 are reacted, what mass of HCN and of H_2O will be produced, assuming 100% yield?

103. The reaction of ethane gas (C_2H_6) with chlorine gas produces C_2H_5Cl as its main product (along with HCl). In addition, the reaction invariably produces a variety of other minor products, including $C_2H_4Cl_2$, $C_2H_3Cl_3$, and others. Naturally, the production of these minor products reduces the yield of the main product. Calculate the percent yield of C_2H_5Cl if the reaction of 300. g of ethane with 650. g of chlorine produced 490. g of C_2H_5Cl.

104. A student prepared aspirin in a laboratory experiment using the reaction in Exercise 96. The student reacted 1.50 g salicylic acid with 2.00 g acetic anhydride. The yield was 1.50 g aspirin. Calculate the theoretical yield and the percent yield for this experiment.

105. Aluminum burns in bromine, producing aluminum bromide:

$$2Al(s) + 3Br_2(l) \longrightarrow 2AlBr_3(s)$$
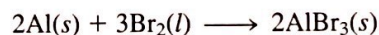
In a certain experiment, 6.0 g aluminum was reacted with an excess of bromine to yield 50.3 g aluminum bromide. Calculate the theoretical and percent yields for this experiment.

106. Consider the following unbalanced reaction:

$$P_4(s) + F_2(g) \longrightarrow PF_3(g)$$
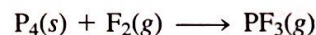
How many grams of F_2 are needed to produce 120. g of PF_3 if the reaction has a 78.1% yield?

Additional Exercises

107. Only one isotope of this element occurs in nature. One atom of this isotope has a mass of 9.123×10^{-23} g. Identify the element and give its atomic mass.

108. Chloral hydrate ($C_2H_3Cl_3O_2$) is a drug formerly used as a sedative and hypnotic. It is the compound used to make "Mickey Finns" in detective stories.
a. Calculate the molar mass of chloral hydrate.
b. How many moles of $C_2H_3Cl_3O_2$ molecules are in 500.0 g chloral hydrate?
c. What is the mass in grams of 2.0×10^{-2} mol chloral hydrate?
d. How many chlorine atoms are in 5.0 g chloral hydrate?
e. What mass of chloral hydrate would contain 1.0 g Cl?
f. What is the mass of exactly 500 molecules of chloral hydrate?