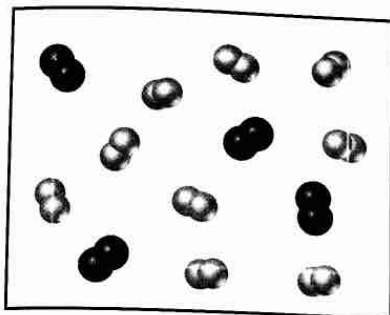
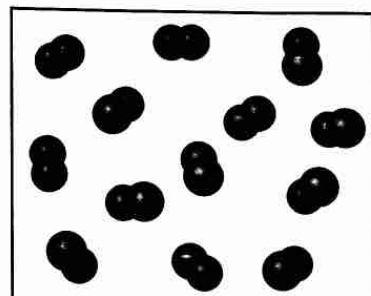


- 3.7 Nitrogen (N_2) and hydrogen (H_2) react to form ammonia (NH_3). Consider the mixture of N_2 and H_2 shown in the accompanying diagram. The blue spheres represent N, and the white ones represent H. Draw a representation of the product mixture, assuming that the reaction goes to completion. How did you arrive at your representation? What is the limiting reactant in this case? [Section 3.7]



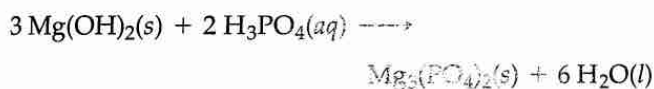
- 3.8 Nitrogen monoxide and oxygen react to form nitrogen dioxide. Consider the mixture of NO and O_2 shown in the accompanying diagram. The blue spheres represent N, and the red ones represent O. (a) Draw a representation of the product mixture, assuming that the reaction goes to completion. What is the limiting reactant in this case? (b) How many NO_2 molecules would you draw as products if the reaction had a percent yield of 75%? [Section 3.7]



EXERCISES

Balancing Chemical Equations

- 3.9 (a) What scientific principle or law is used in the process of balancing chemical equations? (b) In balancing equations, why shouldn't subscripts in chemical formulas be changed? (c) What are the symbols used to represent gases, liquids, solids, and aqueous solutions in chemical equations?
- 3.10 (a) What is the difference between adding a subscript 2 to the end of the formula for CO to give CO_2 and adding a coefficient in front of the formula to give $2 CO$? (b) Is the following chemical equation, as written, consistent with the law of conservation of mass?



Why or why not?

- 3.11 Balance the following equations:
- $CO(g) + O_2(g) \longrightarrow CO_2(g)$
 - $N_2O_5(g) + H_2O(l) \longrightarrow HNO_3(aq)$
 - $CH_4(g) + Cl_2(g) \longrightarrow CCl_4(l) + HCl(g)$
 - $Al_4C_3(s) + H_2O(l) \longrightarrow Al(OH)_3(s) + CH_4(g)$
 - $C_5H_{10}O_2(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$
 - $Fe(OH)_3(s) + H_2SO_4(aq) \longrightarrow Fe_2(SO_4)_3(aq) + H_2O(l)$
 - $Mg_3N_2(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + (NH_4)_2SO_4(aq)$
- 3.12 Balance the following equations:
- $Li(s) + N_2(g) \longrightarrow Li_3N(s)$
 - $La_2O_3(s) + H_2O(l) \longrightarrow La(OH)_3(aq)$
 - $NH_4NO_3(s) \longrightarrow N_2(g) + O_2(g) + H_2O(g)$

- $Ca_3P_2(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq) + PH_3(g)$
- $Ca(OH)_2(aq) + H_3PO_4(aq) \longrightarrow Ca_3(PO_4)_2(s) + H_2O(l)$
- $AgNO_3(aq) + Na_2SO_4(aq) \longrightarrow Ag_2SO_4(s) + NaNO_3(aq)$
- $CH_3NH_2(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g) + N_2(g)$

- 3.13 Write balanced chemical equations to correspond to each of the following descriptions: (a) Solid calcium carbide, CaC_2 , reacts with water to form an aqueous solution of calcium hydroxide and acetylene gas, C_2H_2 . (b) When solid potassium chlorate is heated, it decomposes to form solid potassium chloride and oxygen gas. (c) Solid zinc metal reacts with sulfuric acid to form hydrogen gas and an aqueous solution of zinc sulfate. (d) When liquid phosphorus trichloride is added to water, it reacts to form aqueous phosphorous acid, $H_3PO_3(aq)$, and aqueous hydrochloric acid. (e) When hydrogen sulfide gas is passed over solid hot iron(III) hydroxide, the resultant reaction produces solid iron(III) sulfide and gaseous water.
- 3.14 Convert these descriptions into balanced equations: (a) When sulfur trioxide gas reacts with water, a solution of sulfuric acid forms. (b) Boron sulfide, $B_2S_3(s)$, reacts violently with water to form dissolved boric acid, H_3BO_3 , and hydrogen sulfide gas. (c) Phosphine, $PH_3(g)$, combusts in oxygen gas to form gaseous water and solid tetraphosphorus decoxide. (d) When solid mercury(II) nitrate is heated, it decomposes to form solid mercury(II) oxide, gaseous nitrogen dioxide, and oxygen. (e) Copper metal reacts with hot concentrated sulfuric acid solution to form aqueous copper(II) sulfate, sulfur dioxide gas, and water.

Patterns of Chemical Reactivity

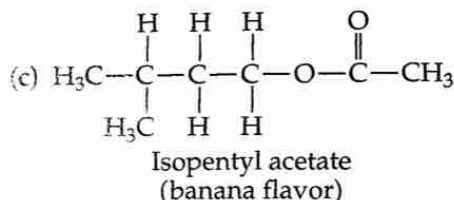
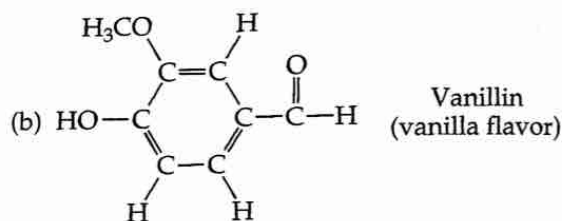
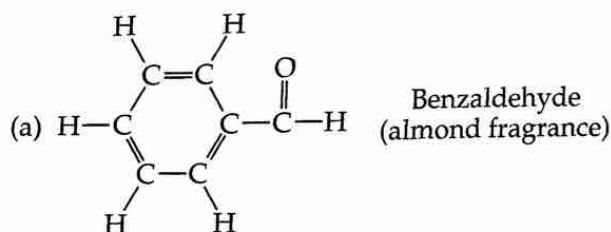
- 3.15 (a) When the metallic element sodium combines with the nonmetallic element bromine, $Br_2(l)$, how can you determine the chemical formula of the product? How do you know whether the product is a solid, liquid, or gas at room temperature? Write the balanced chemical

equation for the reaction. (b) When a hydrocarbon burns in air, what reactant besides the hydrocarbon is involved in the reaction? What products are formed? Write a balanced chemical equation for the combustion of benzene, $C_6H_6(l)$, in air.

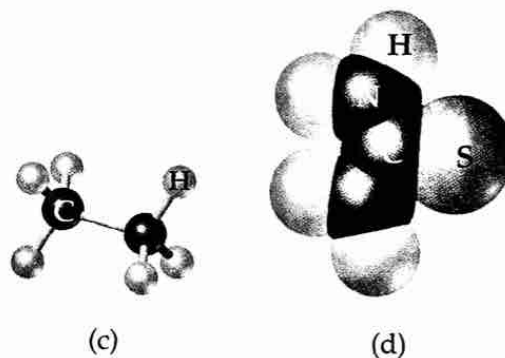
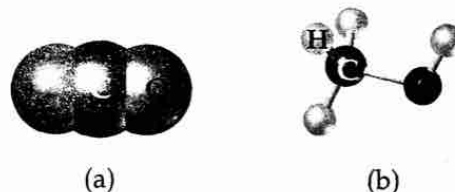
- 3.16 (a) Determine the chemical formula of the product formed when the metallic element calcium combines with the nonmetallic element oxygen, O_2 . Write the balanced chemical equation for the reaction. (b) What products form when a compound containing C, H, and O is completely combusted in air? Write a balanced chemical equation for the combustion of acetone, $C_3H_6O(l)$, in air.
- 3.17 Write a balanced chemical equation for the reaction that occurs when (a) $Mg(s)$ reacts with $Cl_2(g)$; (b) barium carbonate decomposes into barium oxide and carbon dioxide gas when heated; (c) the hydrocarbon styrene, $C_8H_8(l)$, is combusted in air; (d) dimethylether, $CH_3OCH_3(g)$, is combusted in air.
- 3.18 Write a balanced chemical equation for the reaction that occurs when (a) aluminum metal undergoes a combination reaction with $O_2(g)$; (b) copper(II) hydroxide decomposes into copper(II) oxide and water when heated;
- (c) heptane, $C_7H_{16}(l)$, burns in air; (d) the gasoline additive MTBE (methyl tert-butyl ether), $C_5H_{12}O(l)$, burns in air.
- 3.19 Balance the following equations, and indicate whether they are combination, decomposition, or combustion reactions:
- (a) $Al(s) + Cl_2(g) \longrightarrow AlCl_3(s)$
 (b) $C_2H_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$
 (c) $Li(s) + N_2(g) \longrightarrow Li_3N(s)$
 (d) $PbCO_3(s) \longrightarrow PbO(s) + CO_2(g)$
 (e) $C_7H_8O_2(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$
- 3.20 Balance the following equations, and indicate whether they are combination, decomposition, or combustion reactions:
- (a) $C_3H_6(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$
 (b) $NH_4NO_3(s) \longrightarrow N_2O(g) + H_2O(g)$
 (c) $C_5H_6O(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$
 (d) $N_2(g) + H_2(g) \longrightarrow NH_3(g)$
 (e) $K_2O(s) + H_2O(l) \longrightarrow KOH(aq)$

Formula Weights

- 3.21 Determine the formula weights of each of the following compounds: (a) N_2O_5 , (b) $CuSO_4$, (c) $(NH_4)_3PO_4$, (d) $Ca(HCO_3)_2$, (e) aluminum sulfide, (f) iron(III) sulfate, (g) disilicon hexabromide.
- 3.22 Determine the formula weights of each of the following compounds: (a) nitrous oxide, N_2O , known as laughing gas and used as an anesthetic in dentistry; (b) benzoic acid, $HC_7H_5O_2$, a substance used as a food preservative; (c) $Mg(OH)_2$, the active ingredient in milk of magnesia; (d) urea, $(NH_2)_2CO$, a compound used as a nitrogen fertilizer; (e) isopentyl acetate, $CH_3CO_2C_5H_{11}$, responsible for the odor of bananas.
- 3.23 Calculate the percentage by mass of oxygen in the following compounds: (a) SO_3 ; (b) CH_3COOCH_3 ; (c) $Cr(NO_3)_3$; (d) sodium sulfate; (e) ammonium nitrate.
- 3.24 Calculate the percentage by mass of the indicated element in the following compounds: (a) carbon in acetylene, C_2H_2 , a gas used in welding; (b) hydrogen in ascorbic acid, $HC_6H_7O_6$, also known as vitamin C; (c) hydrogen in ammonium sulfate, $(NH_4)_2SO_4$, a substance used as a nitrogen fertilizer; (d) platinum in $PtCl_2(NH_3)_2$, a chemotherapy agent called cisplatin; (e) oxygen in the female sex hormone estradiol, $C_{18}H_{24}O_2$; (f) carbon in capsaicin, $C_{18}H_{27}NO_3$, the compound that gives the hot taste to chili peppers.
- 3.25 Based on the following structural formulas, calculate the percentage of carbon by mass present in each compound:



- 3.26 Calculate the percentage of carbon by mass in each of the compounds represented by the following models:



Avogadro's Number and the Mole

- 3.27 (a) What is Avogadro's number, and how is it related to the mole? (b) What is the relationship between the formula weight of a substance and its molar mass?
- 3.28 (a) What is the mass, in grams, of a mole of ^{12}C ? (b) How many carbon atoms are present in a mole of ^{12}C ?
- 3.29 Without doing any detailed calculations (but using a periodic table to give atomic weights), rank the following samples in order of increasing number of atoms: 0.50 mol H_2O , 23 g Na, 6.0×10^{23} N_2 molecules.
- 3.30 Without doing any detailed calculations (but using a periodic table to give atomic weights), rank the following samples in order of increasing number of atoms: 3.0×10^{23} molecules of H_2O_2 , 2.0 mol CH_4 , 32 g O_2 .
- 3.31 What is the mass, in kilograms, of an Avogadro's number of Olympic shot-put balls if each one has a mass of 16 lb? How does this compare with the mass of Earth, 5.98×10^{24} kg?
- 3.32 If Avogadro's number of pennies is divided equally among the 292 million men, women, and children in the United States, how many dollars would each receive? How does this compare with the national debt of the United States, which was \$7.0 trillion at the time of the writing of this text?
- 3.33 Calculate the following quantities:
 (a) mass, in grams, of 0.773 mol CaH_2
 (b) moles of $\text{Mg}(\text{NO}_3)_2$ in 5.35 g of this substance
 (c) number of molecules in 0.0305 mol CH_3OH
 (d) number of C atoms in 0.585 mol C_4H_{10}
- 3.34 Calculate the following quantities:
 (a) mass, in grams, of 1.906×10^{-2} mol BaI_2
 (b) number of moles of NH_4Cl in 48.3 g of this substance
 (c) number of molecules in 0.05752 mol HCHO_2
 (d) number of O atoms in 4.88×10^{-3} mol $\text{Al}(\text{NO}_3)_3$
- 3.35 (a) What is the mass, in grams, of 2.50×10^{-3} mol of ammonium phosphate?
 (b) How many moles of chloride ions are in 0.2550 g of aluminum chloride?
 (c) What is the mass, in grams, of 7.70×10^{20} molecules of caffeine, $\text{C}_8\text{H}_{10}\text{N}_4\text{O}_2$?
 (d) What is the molar mass of cholesterol if 0.00105 mol weighs 0.406 g?
- 3.36 (a) What is the mass, in grams, of 0.0714 mol of iron(III) sulfate?
 (b) How many moles of ammonium ions are in 8.776 g of ammonium carbonate?
 (c) What is the mass, in grams, of 6.52×10^{21} molecules of aspirin, $\text{C}_9\text{H}_8\text{O}_4$?
 (d) What is the molar mass of diazepam (Valium[®]) if 0.05570 mol weighs 15.86 g?
- 3.37 The molecular formula of allicin, the compound responsible for the characteristic smell of garlic, is $\text{C}_6\text{H}_{10}\text{OS}_2$.
 (a) What is the molar mass of allicin? (b) How many moles of allicin are present in 5.00 mg of this substance? (c) How many molecules of allicin are in 5.00 mg of this substance? (d) How many S atoms are present in 5.00 mg of allicin?
- 3.38 The molecular formula of aspartame, the artificial sweetener marketed as NutraSweet[®], is $\text{C}_{14}\text{H}_{18}\text{N}_2\text{O}_5$.
 (a) What is the molar mass of aspartame? (b) How many moles of aspartame are present in 1.00 mg of aspartame? (c) How many molecules of aspartame are present in 1.00 mg of aspartame? (d) How many hydrogen atoms are present in 1.00 mg of aspartame?
- 3.39 A sample of glucose, $\text{C}_6\text{H}_{12}\text{O}_6$, contains 1.250×10^{21} atoms of carbon. (a) How many atoms of hydrogen does it contain? (b) How many molecules of glucose does it contain? (c) How many moles of glucose does it contain? (d) What is the mass of this sample in grams?
- 3.40 A sample of the male sex hormone testosterone, $\text{C}_{19}\text{H}_{28}\text{O}_2$, contains 7.08×10^{20} atoms of hydrogen. (a) How many atoms of carbon does it contain? (b) How many molecules of testosterone does it contain? (c) How many moles of testosterone does it contain? (d) What is the mass of this sample in grams?
- 3.41 The allowable concentration level of vinyl chloride, $\text{C}_2\text{H}_3\text{Cl}$, in the atmosphere in a chemical plant is 2.0×10^{-6} g/L. How many moles of vinyl chloride in each liter does this represent? How many molecules per liter?
- 3.42 At least 25 μg of tetrahydrocannabinol (THC), the active ingredient in marijuana, is required to produce intoxication. The molecular formula of THC is $\text{C}_{21}\text{H}_{30}\text{O}_2$. How many moles of THC does this 25 μg represent? How many molecules?

Empirical Formulas

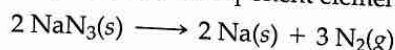
- 3.43 Give the empirical formula of each of the following compounds if a sample contains (a) 0.0130 mol C, 0.0390 mol H, and 0.0065 mol O; (b) 11.66 g iron and 5.01 g oxygen; (c) 40.0% C, 6.7% H, and 53.3% O by mass.
- 3.44 Determine the empirical formula of each of the following compounds if a sample contains (a) 0.104 mol K, 0.052 mol C, and 0.156 mol O; (b) 5.28 g Sn and 3.37 g F; (c) 87.5% N and 12.5% H by mass.
- 3.45 Determine the empirical formulas of the compounds with the following compositions by mass:
 (a) 10.4% C, 27.8% S, and 61.7% Cl
 (b) 21.7% C, 9.6% O, and 68.7% F
 (c) 32.79% Na, 13.02% Al, and 54.19% F
- 3.46 Determine the empirical formulas of the compounds with the following compositions by mass:
 (a) 55.3% K, 14.6% P, and 30.1% O
 (b) 24.5% Na, 14.9% Si, and 60.6% F
 (c) 62.1% C, 5.21% H, 12.1% N, and 20.7% O
- 3.47 What is the molecular formula of each of the following compounds?
 (a) empirical formula CH_2 , molar mass = 84 g/mol
 (b) empirical formula NH_2Cl , molar mass = 51.5 g/mol
- 3.48 What is the molecular formula of each of the following compounds?
 (a) empirical formula HCO_2 , molar mass = 90.0 g/mol
 (b) empirical formula $\text{C}_2\text{H}_4\text{O}$, molar mass = 88 g/mol

- 3.49 Determine the empirical and molecular formulas of each of the following substances:
- Styrene, a compound substance used to make Styrofoam® cups and insulation, contains 92.3% C and 7.7% H by mass and has a molar mass of 104 g/mol.
 - Caffeine, a stimulant found in coffee, contains 49.5% C, 5.15% H, 28.9% N, and 16.5% O by mass and has a molar mass about 195 g/mol.
 - Monosodium glutamate (MSG), a flavor enhancer in certain foods, contains 35.51% C, 4.77% H, 37.85% O, 8.29% N, and 13.60% Na, and has a molar mass of 169 g/mol.
- 3.50 Determine the empirical and molecular formulas of each of the following substances:
- Ibuprofen, a headache remedy, contains 75.69% C, 8.80% H, and 15.51% O by mass, and has a molar mass about 206 g/mol.
 - Cadaverine, a foul smelling substance produced by the action of bacteria on meat, contains 58.55% C, 13.81% H, and 27.40% N by mass; its molar mass is 102.2 g/mol.
 - Epinephrine (adrenaline), a hormone secreted into the bloodstream in times of danger or stress, contains 59.0% C, 7.1% H, 26.2% O, and 7.7% N by mass; its MW is about 180 amu.
- 3.51 (a) Combustion analysis of toluene, a common organic solvent, gives 5.86 mg of CO₂ and 1.37 mg of H₂O. If the compound contains only carbon and hydrogen, what is its empirical formula? (b) Menthol, the substance we can smell in mentholated cough drops, is composed of C, H, and O. A 0.1005-g sample of menthol is combusted, producing 0.2829 g of CO₂ and 0.1159 g of H₂O. What is the empirical formula for menthol? If the compound has a molar mass of 156 g/mol, what is its molecular formula?
- 3.52 (a) The characteristic odor of pineapple is due to ethyl butyrate, a compound containing carbon, hydrogen, and oxygen. Combustion of 2.78 mg of ethyl butyrate produces 6.32 mg of CO₂ and 2.58 mg of H₂O. What is the empirical formula of the compound? (b) Nicotine, a component of tobacco, is composed of C, H, and N. A 5.250-mg sample of nicotine was combusted, producing 14.242 mg of CO₂ and 4.083 mg of H₂O. What is the empirical formula for nicotine? If the substance has a molar mass of 60 ± 5 g/mol, what is its molecular formula?
- 3.53 Washing soda, a compound used to prepare hard water for washing laundry, is a hydrate, which means that a certain number of water molecules are included in the solid structure. Its formula can be written as Na₂CO₃·xH₂O, where x is the number of moles of H₂O per mole of Na₂CO₃. When a 2.558-g sample of washing soda is heated at 25°C, all the water of hydration is lost, leaving 0.948 g of Na₂CO₃. What is the value of x?
- 3.54 Epsom salts, a strong laxative used in veterinary medicine, is a hydrate, which means that a certain number of water molecules are included in the solid structure. The formula for Epsom salts can be written as MgSO₄·xH₂O, where x indicates the number of moles of H₂O per mole of MgSO₄. When 5.061 g of this hydrate is heated to 250°C, all the water of hydration is lost, leaving 2.472 g of MgSO₄. What is the value of x?

Calculations Based on Chemical Equations

- 3.55 Why is it essential to use balanced chemical equations when determining the quantity of a product formed from a given quantity of a reactant?
- 3.56 What parts of balanced chemical equations give information about the relative numbers of moles of reactants and products involved in a reaction?
- 3.57 Hydrofluoric acid, HF(aq), cannot be stored in glass bottles because compounds called silicates in the glass are attacked by the HF(aq). Sodium silicate (Na₂SiO₃), for example, reacts as follows:
- $$\text{Na}_2\text{SiO}_3(s) + 8 \text{HF}(aq) \longrightarrow \text{H}_2\text{SiF}_6(aq) + 2 \text{NaF}(aq) + 3 \text{H}_2\text{O}(l)$$
- How many moles of HF are needed to react with 0.300 mol of Na₂SiO₃?
 - How many grams of NaF form when 0.500 mol of HF reacts with excess Na₂SiO₃?
 - How many grams of Na₂SiO₃ can react with 0.800 g of HF?
- 3.58 The fermentation of glucose (C₆H₁₂O₆) produces ethyl alcohol (C₂H₅OH) and CO₂:
- $$\text{C}_6\text{H}_{12}\text{O}_6(aq) \longrightarrow 2 \text{C}_2\text{H}_5\text{OH}(aq) + 2 \text{CO}_2(g)$$
- How many moles of CO₂ are produced when 0.400 mol of C₆H₁₂O₆ reacts in this fashion?
 - How many grams of C₆H₁₂O₆ are needed to form 7.50 g of C₂H₅OH?
 - How many grams of CO₂ form when 7.50 g of C₂H₅OH are produced?
- 3.59 Several brands of antacids use Al(OH)₃ to react with stomach acid, which contains primarily HCl:
- $$\text{Al}(\text{OH})_3(s) + \text{HCl}(aq) \longrightarrow \text{AlCl}_3(aq) + \text{H}_2\text{O}(l)$$
- Balance this equation.
 - Calculate the number of grams of HCl that can react with 0.500 g of Al(OH)₃.
 - Calculate the number of grams of AlCl₃ and the number of grams of H₂O formed when 0.500 g of Al(OH)₃ reacts.
 - Show that your calculations in parts (b) and (c) are consistent with the law of conservation of mass.
- 3.60 An iron ore sample contains Fe₂O₃ together with other substances. Reaction of the ore with CO produces iron metal:
- $$\text{Fe}_2\text{O}_3(s) + \text{CO}(g) \longrightarrow \text{Fe}(s) + \text{CO}_2(g)$$
- Balance this equation.
 - Calculate the number of grams of CO that can react with 0.150 kg of Fe₂O₃.
 - Calculate the number of grams of Fe and the number of grams of CO₂ formed when 0.150 kg of Fe₂O₃ reacts.
 - Show that your calculations in parts (b) and (c) are consistent with the law of conservation of mass.

- 3.61 Aluminum sulfide reacts with water to form aluminum hydroxide and hydrogen sulfide. (a) Write the balanced chemical equation for this reaction. (b) How many grams of aluminum hydroxide are obtained from 6.75 g of aluminum sulfide?
- 3.62 Calcium hydride reacts with water to form calcium hydroxide and hydrogen gas. (a) Write a balanced chemical equation for the reaction. (b) How many grams of calcium hydride are needed to form 8.500 g of hydrogen?
- 3.63 Automotive air bags inflate when sodium azide, NaN_3 , rapidly decomposes to its component elements:



- (a) How many moles of N_2 are produced by the decomposition of 1.50 mol of NaN_3 ?
 (b) How many grams of NaN_3 are required to form 10.0 g of nitrogen gas?
 (c) How many grams of NaN_3 are required to produce 10.0 ft³ of nitrogen gas if the gas has a density of 1.25 g/L?
- 3.64 The complete combustion of octane, C_8H_{18} , a component of gasoline, proceeds as follows:

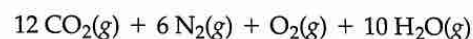


- (a) How many moles of O_2 are needed to burn 1.25 mol of C_8H_{18} ?
 (b) How many grams of O_2 are needed to burn 10.0 g of C_8H_{18} ?
 (c) Octane has a density of 0.692 g/mL at 20°C. How many grams of O_2 are required to burn 1.00 gal of C_8H_{18} ?

- 3.65 A piece of aluminum foil 1.00 cm square and 0.550 mm thick is allowed to react with bromine to form aluminum bromide as shown in the accompanying photo.



- (a) How many moles of aluminum were used? (The density of aluminum is 2.699 g/cm³.) (b) How many grams of aluminum bromide form, assuming that the aluminum reacts completely?
- 3.66 Detonation of nitroglycerin proceeds as follows:



- (a) If a sample containing 2.00 mL of nitroglycerin (density = 1.592 g/mL) is detonated, how many total moles of gas are produced? (b) If each mole of gas occupies 55 L under the conditions of the explosion, how many liters of gas are produced? (c) How many grams of N_2 are produced in the detonation?

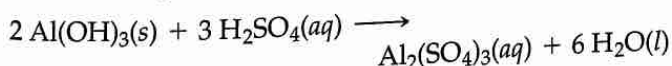
Limiting Reactants; Theoretical Yields

- 3.67 (a) Define the terms *limiting reactant* and *excess reactant*. (b) Why are the amounts of products formed in a reaction determined only by the amount of the limiting reactant?
- 3.68 (a) Define the terms *theoretical yield*, *actual yield*, and *percent yield*. (b) Why is the actual yield in a reaction almost always less than the theoretical yield?
- 3.69 A manufacturer of bicycles has 4815 wheels, 2305 frames, and 2255 handlebars. (a) How many bicycles can be manufactured using these parts? (b) How many parts of each kind are left over? (c) Which part limits the production of bicycles?
- 3.70 A bottling plant has 121,515 bottles with a capacity of 355 mL, 122,500 caps, and 40,875 L of beverage. (a) How many bottles can be filled and capped? (b) How much of each item is left over? (c) Which component limits the production?
- 3.71 Sodium hydroxide reacts with carbon dioxide as follows:



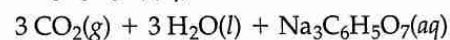
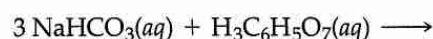
Which reagent is the limiting reactant when 1.85 mol NaOH and 1.00 mol CO_2 are allowed to react? How many moles of Na_2CO_3 can be produced? How many moles of the excess reactant remain after the completion of the reaction?

- 3.72 Aluminum hydroxide reacts with sulfuric acid as follows:

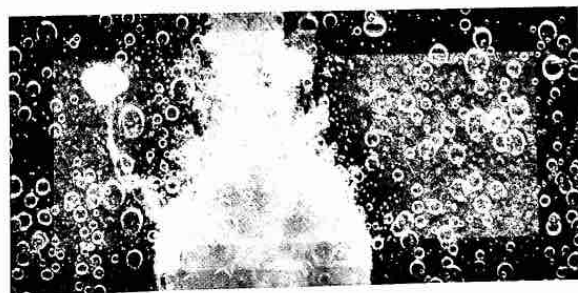


Which reagent is the limiting reactant when 0.500 mol $\text{Al}(\text{OH})_3$ and 0.500 mol H_2SO_4 are allowed to react? How many moles of $\text{Al}_2(\text{SO}_4)_3$ can form under these conditions? How many moles of the excess reactant remain after the completion of the reaction?

- 3.73 The fizz produced when an Alka-Seltzer[®] tablet is dissolved in water is due to the reaction between sodium bicarbonate (NaHCO_3) and citric acid ($\text{H}_3\text{C}_6\text{H}_5\text{O}_7$):



In a certain experiment 1.00 g of sodium bicarbonate and 1.00 g of citric acid are allowed to react. (a) Which is the limiting reactant? (b) How many grams of carbon dioxide form? (c) How many grams of the excess reactant remain after the limiting reactant is completely consumed?



- 3.74 One of the steps in the commercial process for converting ammonia to nitric acid is the conversion of NH_3 to NO :



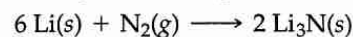
In a certain experiment, 1.50 g of NH_3 reacts with 2.75 g of O_2 . (a) Which is the limiting reactant? (b) How many grams of NO and of H_2O form? (c) How many grams of the excess reactant remain after the limiting reactant is completely consumed? (d) Show that your calculations in parts (b) and (c) are consistent with the law of conservation of mass.

- 3.75 Solutions of sodium carbonate and silver nitrate react to form solid silver carbonate and a solution of sodium nitrate. A solution containing 3.50 g of sodium carbonate is mixed with one containing 5.00 g of silver nitrate. How many grams of sodium carbonate, silver nitrate, silver carbonate, and sodium nitrate are present after the reaction is complete?
- 3.76 Solutions of sulfuric acid and lead(II) acetate react to form solid lead(II) sulfate and a solution of acetic acid. If 7.50 g of sulfuric acid and 7.50 g of lead(II) acetate are mixed, calculate the number of grams of sulfuric acid, lead(II) acetate, lead(II) sulfate, and acetic acid present in the mixture after the reaction is complete.
- 3.77 When benzene (C_6H_6) reacts with bromine (Br_2), bromobenzene ($\text{C}_6\text{H}_5\text{Br}$) is obtained:



(a) What is the theoretical yield of bromobenzene in this reaction when 30.0 g of benzene reacts with 65.0 g of bromine? (b) If the actual yield of bromobenzene was 56.7 g, what was the percentage yield?

- 3.78 When ethane (C_2H_6) reacts with chlorine (Cl_2), the main product is $\text{C}_2\text{H}_5\text{Cl}$; but other products containing Cl, such as $\text{C}_2\text{H}_4\text{Cl}_2$, are also obtained in small quantities. The formation of these other products reduces the yield of $\text{C}_2\text{H}_5\text{Cl}$. (a) Calculate the theoretical yield of $\text{C}_2\text{H}_5\text{Cl}$ when 125 g of C_2H_6 reacts with 255 g of Cl_2 , assuming that C_2H_6 and Cl_2 react only to form $\text{C}_2\text{H}_5\text{Cl}$ and HCl . (b) Calculate the percent yield of $\text{C}_2\text{H}_5\text{Cl}$ if the reaction produces 206 g of $\text{C}_2\text{H}_5\text{Cl}$.
- 3.79 Lithium and nitrogen react to produce lithium nitride:



If 5.00 g of each reactant undergoes a reaction with a 88.5% yield, how many grams of Li_3N are obtained from the reaction?

- 3.80 When hydrogen sulfide gas is bubbled into a solution of sodium hydroxide, the reaction forms sodium sulfide and water. How many grams of sodium sulfide are formed if 1.50 g of hydrogen sulfide is bubbled into a solution containing 2.00 g of sodium hydroxide, assuming that the sodium sulfide is made in 92.0% yield?

Additional Exercises

- 3.81 Write the balanced chemical equation for (a) the complete combustion of butyric acid, $\text{HC}_4\text{H}_7\text{O}_2(\text{l})$, a compound produced when butter becomes rancid; (b) the decomposition of solid nickel(II) hydroxide into solid nickel(II) oxide and water vapor; (c) the combination reaction between zinc metal and chlorine gas.
- 3.82 The effectiveness of nitrogen fertilizers depends on both their ability to deliver nitrogen to plants and the amount of nitrogen they can deliver. Four common nitrogen-containing fertilizers are ammonia, ammonium nitrate, ammonium sulfate, and urea [$(\text{NH}_2)_2\text{CO}$]. Rank these fertilizers in terms of the mass percentage nitrogen they contain.
- 3.83 (a) Diamond is a natural form of pure carbon. How many moles of carbon are in a 1.25-carat diamond (1 carat = 0.200 g)? How many atoms are in this diamond? (b) The molecular formula of acetylsalicylic acid (aspirin), one of the most common pain relievers, is $\text{HC}_9\text{H}_7\text{O}_4$. How many moles of $\text{HC}_9\text{H}_7\text{O}_4$ are in a 0.500-g tablet of aspirin? How many molecules of $\text{HC}_9\text{H}_7\text{O}_4$ are in this tablet?
- 3.84 (a) One molecule of the antibiotic known as penicillin G has a mass of 5.342×10^{-21} g. What is the molar mass of penicillin G? (b) Hemoglobin, the oxygen-carrying protein in red blood cells, has four iron atoms per molecule and contains 0.340% iron by mass. Calculate the molar mass of hemoglobin.
- 3.85 Very small crystals composed of 1000 to 100,000 atoms, called quantum dots, are being investigated for use in electronic devices.
- (a) Calculate the mass in grams of a quantum dot consisting of 10,000 atoms of silicon.
- (b) Assuming that the silicon in the dot has a density of 2.3 g/cm^3 , calculate its volume.
- (c) Assuming that the dot has the shape of a cube, calculate the length of each edge of the cube.
- 3.86 Serotonin is a compound that conducts nerve impulses in the brain. It contains 68.2 mass percent C, 6.86 mass percent H, 15.9 mass percent N, and 9.08 mass percent O. Its molar mass is 176 g/mol. Determine its molecular formula.
- 3.87 The koala dines exclusively on eucalyptus leaves. Its digestive system detoxifies the eucalyptus oil, a poison to other animals. The chief constituent in eucalyptus oil is a substance called eucalyptol, which contains 77.87% C, 11.76% H, and the remainder O. (a) What is the empirical formula for this substance? (b) A mass spectrum of eucalyptol shows a peak at about 154 amu. What is the molecular formula of the substance?
- 3.88 Vanillin, the dominant flavoring in vanilla, contains C, H, and O. When 1.05 g of this substance is completely combusted, 2.43 g of CO_2 and 0.50 g of H_2O are produced. What is the empirical formula of vanillin?
- [3.89] An organic compound was found to contain only C, H, and Cl. When a 1.50-g sample of the compound was completely combusted in air, 3.52 g of CO_2 was formed. In a separate experiment the chlorine in a 1.00-g sample of the compound was converted to 1.27 g of AgCl . Determine the empirical formula of the compound.
- [3.90] An oxybromate compound, KBrO_x , where x is unknown, is analyzed and found to contain 52.92% Br. What is the value of x ?