Answer Key

Unit 2 Chemical Reactions

Unit Preparation Questions (Assessing Readiness)

(Student textbook pages 106–9)

1. a. corrosive—wear protective equipment and clean up any spills as directed

b. flammable and combustible material—protect substance from heat and flame

c. skin protection safety—gloves should be worn to protect skin from contact with caustic chemicals

d. clothing protection safety—wear apron to protect clothing

e. thermal safety—use tongs and/or thermal gloves when handling hot objects

2. The contents of the container might splash or boil out of the container.

3. Shards of glass can be propelled if the test tubes are dropped or the water causes an explosion.

4. Parts of a Bunsen Burner

Diagram Label	Part	Function
A	barrel	area inside the burner where air and fuel mix
B	air hole	opening through which air enters the barrel
C	zone of burning gases	hotter portion of the flame
D	collar	can be rotated to change the size of the air holes to adjust the rate of air flow into the barrel
E	mixture of unburned fuel and air	cooler portion of the flame
F	base	supports the burner so it is stable

5. Sample answer: I would turn off the gas and leave it off for several minutes to let the gas dissipate. I would make sure that my igniter produces sparks and replace the flint if needed. I would then turn on the gas to a low level and try to light it again.

6. Sample answer: The safe way to see the colour is to lift the test tube away from the heat source and to look at the solution through the side of the test tube.

7. e

8. d

9. a. metals and non-metals

b. non-metals

c. During the formation of an ionic compound, one or more electrons are transferred from one atom to another. During the formation of a molecular compound, atoms share a pair of electrons, forming a covalent bond.

10. a. ionic; LiF

b. molecular; PCl_3

c. molecular; N_2O_3

d. ionic; $Al_2(SO_4)_3$

e. molecular; CBr_4

f. ionic; $CuCl_2$

11. b

12. Prefixes Used in Naming Molecular Compounds

Number of Atoms	Prefix	Number of Atoms	Prefix
1	mono-	2	di-
7	hepta-	5	penta-
3	tri-	8	octa-
6	hexa-	4	tetra-
9	nona-	10	deca-

13. c

14. d

15. The law of conservation of mass says that the mass before and after a chemical reaction must be the same.

16. The mass reading will not change as the reaction continues. All of the materials are sealed in the container, so no material can leave or enter the container. The law of conservation of mass states that the mass of the reactants equals the mass of the products, so the reading on the balance should remain at 50.0 g.

17. Changing a subscript alters the chemical formula for substance. Although the equation might demonstrate the law of conservation of mass, the equation itself would no longer reflect the reaction that is taking place.

18. Yes; one formula unit of $Mg_3Al_2(SiO_4)_3(s)$ contains three atoms of silicon, whereas one formula unit of $Mg_2Si_2O_6(s)$ contains only two atoms of silicon.

19. b

20. a. Light and heat are released.

b. A gas forms.

21. The flame of the burner gives off heat and light.

22. a. The gas shows a change of state, not a new substance.

b. The energy could have been released by a change of state, not the formation of a new substance.

23. I could place the metal into a test tube that contains an acidic solution and observe whether a reaction occurs.

24. Baking soda is not reactive with water but is reactive with vinegar (acid).

25. a. Gold and platinum are not reactive with oxygen.

b. Some parts of the object are discoloured and appear rusty, while other parts are shiny and show no signs of discolouration. The rusted parts are more reactive with oxygen.

26. a. decomposition reaction

b. synthesis reaction

c. single displacement reaction

d. double displacement reaction

27. Indicators allow the identification of products as acidic, basic, or neutral.

28. a. basic **b.** acidic

29. a. When a burning splint is placed into the gas, a popping sound occurs.

b. When a glowing splint is placed into the gas, the splint starts to burn again.

c. When a burning splint is placed into the gas, the flame goes out.

Chapter 3 Synthesis, Decomposition, and Combustion Reactions

Learning Check Questions

(Student textbook page 117)

1. A skeleton equation is a representation of a chemical reaction that does not include the relative quantities of the substances involved.

2. (aq)

3. a. The skeleton equation would show that carbon dioxide and water are the reactants and sugar and oxygen are the products; the equation would show the chemical formula and state for each substance.

b. The skeleton equation would not show the relative number of atoms, molecules, or ions involved in the reaction.

4. The two-way arrow indicates that the reaction is reversible.

5. a. The state of water should be (ℓ) but is shown as (g). The second plus sign (between water and sodium hydroxide) should be an arrow. The formula for sodium hydroxide should be NaOH. The state of sodium hydroxide should be (aq). The formula for hydrogen should have a subscript 2.

b. $Na(s) + H_2O(\ell) \rightarrow NaOH(aq) + H_2(g)$

6. a. $H_2O(\ell) \rightarrow H_2(g) + O_2(g)$

b. $Cl_2(g) + ZnBr_2(aq) \rightarrow Br_2(\ell) + ZnCl_2(s)$

(Student textbook page 125)

7. The general form of a synthesis reaction is $A + B \rightarrow AB$

8. A binary ionic compound is formed.

9. a. A single product is formed from two or more reactants.

b. $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

10. a. $CaCl_2(s)$

b. $Ca(s) + Cl_2(g) \rightarrow CaCl_2(s)$

11. Graphic organizers should show that the first reaction, $S(s) + O_2(g) \rightarrow SO_2(g)$, involves two elements; the second reaction, $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$, involves a compound and an element; and the third reaction, $SO_3(g) + H_2O(\ell) \rightarrow H_2SO_4(aq)$, involves two compounds.

12. No, there must be another product that contains hydrogen. Because there is more than one product, the reaction cannot be a synthesis reaction.

(Student textbook page 132)

13. A metal hydroxide (base) forms when a metal oxide reacts with water.

14. Graphic organizers should show that the solution formed from a metal oxide is basic and that the solution formed from a non-metal oxide is acidic.

15. $AB \rightarrow A + B$; a single reactant breaks down into two or more products.

16. No, the reactant must be a compound because chemical reactions can break a compound into simpler substances but cannot change elements into simpler substances.

17. Electrolysis is possible in the aqueous state. An aqueous solution of an ionic compound can conduct an electric current because when the compound dissolves in water, the ions separate and are free to move.

18. Thermal decomposition can be used to isolate elemental mercury by heating solid mercury(II) oxide, according to the following equation: $2HgO(s) \rightarrow 2Hg(\ell) + O_2(g)$. Uses of mercury include (any two of the following) thermometers, barometers, and dental fillings.

(Student textbook page 140)

19. thermal energy (light and heat)

20. A hydrocarbon is a compound composed of only carbon and hydrogen.

a. Hydrocarbons can take part in complete or incomplete combustion reactions.

b. The products of complete combustion are carbon dioxide and water.

21. a. No, because energy in the form of heat is absorbed, not released.

b. synthesis

22. a. A blue flame indicates complete combustion is occurring, and a yellow flame indicates incomplete combustion.

b. The blue flame indicates complete combustion, so the flame is generating much more heat than light.

c. In Figure 3.23, carbon dioxide and water are produced. In Figure 3.24, carbon dioxide, water, elemental carbon, and possibly carbon monoxide are produced.

23. A gas stove is designed to be hot, so it should be designed to allow complete combustion to occur. In addition, because gas stoves are used indoors, it is important for the combustion to be complete to avoid the production of toxic carbon monoxide.

24. A combustion reaction requires oxygen, which is not present in space. The antenna array could not burn (unless it contained self-oxidizing material).

(Student textbook page 143)

25. Incomplete combustion is a chemical reaction in which a substance reacts with oxygen but there is too little oxygen for complete combustion to occur. In addition to the carbon dioxide and water that are produced during complete combustion reactions, elemental carbon and carbon monoxide are produced during incomplete combustion reactions.

26. Carbon monoxide (a poisonous gas) is formed during incomplete combustion.

27. Sample answer: Carbon monoxide production can occur in pulp and paper production, petroleum refineries, and steel production.

28. The amount of oxygen present determines whether complete or incomplete combustion will occur.

29. If the synthesis reaction involves an element or compound reacting with oxygen, and releasing energy in the form of heat and light, it can also be classified as a combustion reaction.

30. This process is cellular respiration, because it occurs at fairly low temperatures and is mediated by living organisms.

Caption Questions

Figure 3.4 (Student textbook page 116): There is one aluminum atom in both the reactants and the product; however, there are two bromine atoms in the reactants and three in the product.

Figure 3.5 (Student textbook page 117): In the reactants, there are three molecules of bromine, each containing two atoms for a total of six bromine atoms. In the products, there are two formula units of aluminum bromide, each containing three bromine atoms, for a total of six. The number of bromine atoms in the reactants and products is balanced, with six on each side.

Figure 3.8 (Student textbook page 123): Both the general form of a synthesis reaction and the reaction shown illustrate two separate substances joining to form one substance.

Figure 3.10 (Student textbook page 125): Manganese and copper are both multivalent metals. Like copper, manganese can form different binary compounds, depending on the reaction that occurs.

Figure 3.14 (Student textbook page 130): The nitrogen gas causes the air bag to inflate.

Figure 3.24 (Student textbook page 139): Elemental carbon forms dark soot deposits on surfaces.

Figure 3.25 (Student textbook page 142): This reaction is a combustion reaction because hydrogen reacts with oxygen to form an oxide, and noticeable heat and light are produced.

Figure 3.26 (Student textbook page 142): Each product is an oxide of the element undergoing combustion.

Quirks and Quarks: Power, Sweet Power Questions

(Student textbook page 144)

1. $C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$; cellular respiration is a type of combustion reaction

2. Because the sugar fuel cell does not require toxic metals, discarded sugar fuel cells would not release toxic metals into the environment.

3. Sample answer: An artist or jeweller might use electrochemistry to place a thin coating of gold over a less expensive metal, such as copper or silver, in a process called electroplating.

Practice Problems

(Student textbook page 115)

1. $H_2(g) + O_2(g) \rightarrow H_2O(g)$

2. $Na(s) + H_2O(\ell) \rightarrow NaOH(aq) + H_2(g)$

3. $KClO_3(s) \rightarrow KCl(s) + O_2(g)$

4. $Cu(s) + O_2(g) \rightarrow CuO(s)$

5. $AgNO_3(aq) + NaCl(aq) \rightarrow NaNO_3(aq) + AgCl(s)$

6. $C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$

7. $SO_3(g) + H_2O(\ell) \rightarrow H_2SO_4(aq)$

8. $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$

9. $AlF_3(s) \rightarrow Al(s) + F_2(g)$

10. $Hg(\ell) + O_2(g) \rightarrow HgO(s)$

(Student textbook page 120)

11. $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

12. $3Mg(s) + 2AlCl_3(aq) \rightarrow 2Al(s) + 3MgCl_2(aq)$

13. $2NaOH(aq) + CuCl_2(aq) \rightarrow 2NaCl(aq) + Cu(OH)_2(s)$

14. $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$

15. $Cu(s) + 2AgNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$

16. $4Al(s) + 3MnO_2(s) \rightarrow 2Al_2O_3(s) + 3Mn(s)$

17. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

18. $4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(\ell)$

19. $K_2S(aq) + CoCl_2(aq) \rightarrow 2KCl(aq) + CoS(s)$

20. $2HCl(g) + Na_2CO_3(aq) \rightarrow CO_2(g) + H_2O(\ell) + 2NaCl(aq)$

(Student textbook page 127)

21. lithium oxide; $4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$

22. strontium fluoride; $Sr(s) + F_2(g) \rightarrow SrF_2(s)$

23. iron(II) bromide or iron(III) bromide; $Fe(s) + Br_2(\ell) \rightarrow FeBr_2(s)$ or $2Fe(s) + 3Br_2(\ell) \rightarrow 2FeBr_3(s)$

24. phosphorus trihydride; $2P(s) + 3H_2(g) \rightarrow 2PH_3(g)$

25. calcium iodide; $Ca(s) + I_2(s) \rightarrow CaI_2(s)$

26. tin(II) oxide or tin(IV) oxide; $2Sn(s) + O_2(g) \rightarrow 2SnO(s)$ or $Sn(s) + O_2(g) \rightarrow SnO_2(s)$

27. bismuth(III) sulfide or bismuth(V) sulfide; $2Bi(s) + 3S(s) \rightarrow Bi_2S_3(s)$ or $2Bi(s) + 5S(s) \rightarrow Bi_2S_5(s)$

28. aluminum iodide; $2Al(s) + 3I_2(s) \rightarrow 2AlI_3(s)$

29. silver oxide; $4Ag(s) + O_2(g) \rightarrow 2Ag_2O(s)$

30. nitrogen dioxide; $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$

(Student textbook page 134)

31. potassium and bromine; $2KBr(\ell) \rightarrow 2K(\ell) + Br_2(\ell)$

32. aluminum and oxygen; $2Al_2O_3(\ell) \rightarrow 4Al(\ell) + 3O_2(g)$

33. magnesium oxide and water; $Mg(OH)_2(s) \rightarrow MgO(s) + H_2O(g)$

34. calcium nitrite and oxygen; $Ca(NO_3)_2(s) \rightarrow Ca(NO_2)_2(s) + O_2(g)$

35. copper(II) oxide and carbon dioxide; $CuCO_3(s) \rightarrow CuO(s) + CO_2(g)$

36. chromium and chlorine; $2CrCl_3(\ell) \rightarrow 2Cr(\ell) + 3Cl_2(g)$

37. barium oxide and carbon dioxide; $BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$

38. rubidium nitrite and oxygen; $2RbNO_3(s) \rightarrow 2RbNO_2(s) + O_2(g)$

39. lithium oxide and water; $2LiOH(s) \rightarrow Li_2O(s) + H_2O(g)$

40. magnesium and chlorine; $MgCl_2(\ell) \rightarrow Mg(\ell) + Cl_2(g)$

(Student textbook page 141)

41. $C_7H_{16}(\ell) + 11O_2(g) \rightarrow 7CO_2(g) + 8H_2O(g)$

42. $C_9H_{20}(\ell) + 14O_2(g) \rightarrow 9CO_2(g) + 10H_2O(g)$

43. $2C_2H_2(\ell) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g)$

44. $2C_6H_6(\ell) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(g)$

45. $2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

46. $2C_8H_{18}(\ell) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$

47. $2C_5H_{12}(\ell) + 11O_2(g) \rightarrow 10CO(g) + 12H_2O(g)$

48. $C_3H_8(g) + 2O_2(g) \rightarrow 3C(s) + 4H_2O(g)$

49. $4C_7H_{16}(\ell) + 37O_2(g) \rightarrow 14CO_2(g) + 14CO(g) + 32H_2O(g)$

50. a. $C_6H_{12}(\ell) + 6O_2(g) \rightarrow 6CO(g) + 6H_2O(g)$

b. $C_6H_{12}(\ell) + 3O_2(g) \rightarrow 6C(s) + 6H_2O(g)$

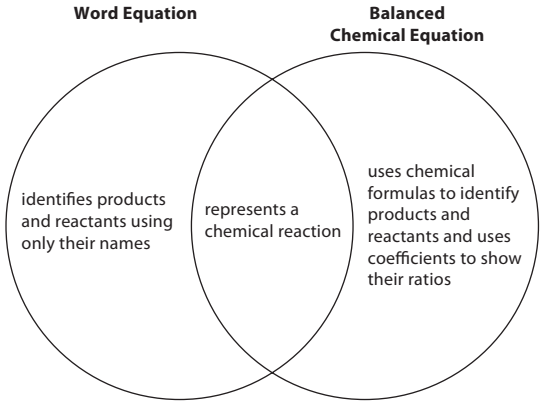
Section 3.1 Review Questions

(Student textbook page 121)

1. word equation, skeleton equation, and balanced chemical equation

2. No, the reactants would have to include phosphorus for $POCl_3(\ell)$ to be produced.

3. Sample answer:



4. Liquid water is indicated by (ℓ), and an aqueous solution is indicated by (aq).

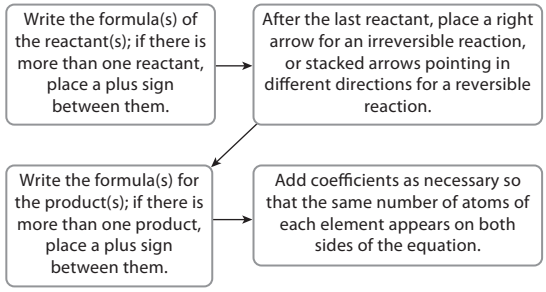
5. $Cl_2(g)$

6. A skeleton equation does not indicate the relative number of atoms, molecules, or ions involved in a chemical reaction.

7. (g)

8. Coefficients are placed in front of chemical formulas when balancing chemical equations.

9. Sample answer:



10. Changing a subscript changes the chemical formula so that it would describe a chemical different from the one involved in the reaction.

11. a. $2K(s) + Cl_2(g) \rightarrow 2KCl(s)$

b. $2Al(s) + 3CuSO_4(aq) \rightarrow 3Cu(s) + Al_2(SO_4)_3(aq)$

c. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

d. $CaCl_2(aq) + F_2(g) \rightarrow CaF_2(aq) + Cl_2(g)$

12. a. The polyatomic ions are hydroxide ion OH^- and the phosphate ion PO_4^{3-}.

b. A polyatomic ion can be balanced as a unit when it appears on both sides of the equation.

c. $Ba(OH)_2(s) + H_3PO_4(aq) \rightarrow BaHPO_4(s) + 2H_2O(\ell)$

13. The coefficients are not in the lowest possible ratio. The correct equation is: $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(\ell)$.

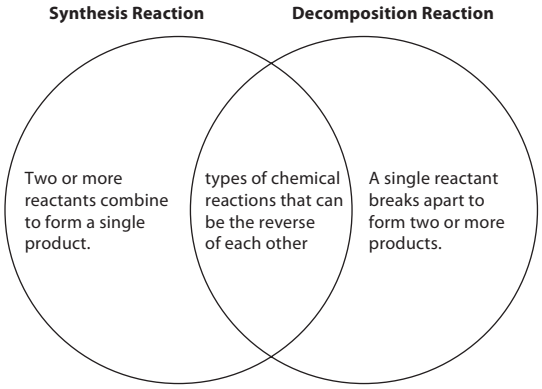
14. The equation is not correct. The chemical formulas for chlorine gas and aluminum chloride are incorrect and the state of each species should be shown.
$2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$

Section 3.2 Review Questions

(Student textbook page 136)

1. In a synthesis reaction, two or more reactants combine to form a single product, while in a decomposition reaction, a single reactant breaks apart to form two or more products.

2. Sample answer:



3. The sulfur undergoes a series of three synthesis reactions that eventually form compounds that can combine with atmospheric water vapour and result in acid precipitation. Using low-sulfur coal reduces the amount of sulfur compounds that are formed as a result of burning the coal.

4. a metal and a non-metal

5. $2Al(s) + 3S(s) \rightarrow Al_2S_3(s)$

6. Look at the periodic table to determine the charge(s) of the metal ion. Write the chemical formula for the ionic compound(s) by balancing the charges of the metal and non-metal ions.

7. a. acid **b.** base **c.** acid **d.** base

8. Techniques that are used to combat acid precipitation remove the non-metal oxide rather than the other reactant because the other reactant is water, which is common in the atmosphere and could not be removed without causing environmental damage.

9. a binary compound

10. a metal carbonate

11. a. mercury

b. oxygen

c. Place a glowing splint into the test tube. The presence of oxygen will cause the splint to reignite.

12. Graphic organizers should show that the reaction between sulfur and oxygen, $S(s) + O_2(g) \rightarrow SO_2(g)$, involves two elements; the reaction between sulfur dioxide and oxygen, $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$, involves a compound and an element; and the reaction between sulfur trioxide, $SO_3(g) + H_2O(\ell) \rightarrow H_2SO_4(aq)$, involves two compounds.

13. a nitrite-containing compound and oxygen gas

14. Diagrams should show that compounds that are composed of three or more elements do not usually break down into their elements. Sodium carbonate breaks down into sodium oxide and carbon dioxide.

15. Heat solid lithium carbonate:
$Li_2CO_3(s) \rightarrow Li_2O(s) + CO_2(g)$
Heat solid lithium hydroxide:
$2LiOH(s) \rightarrow Li_2O(s) + H_2O(g)$

16. Sample answer: TNT decomposes much more explosively, while ammonium dichromate decomposes more slowly and produces a lot of light.

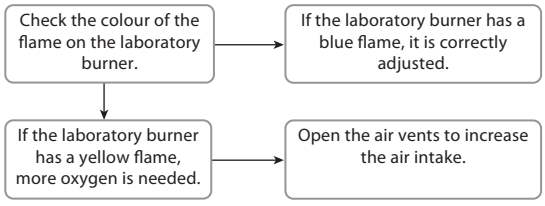
Section 3.3 Review Questions

(Student textbook page 145)

1. the release of energy in the form of heat and light

2. Sample answer: methane, propane, butane

3. Sample answer:



4. No, the substance contains oxygen, but hydrocarbons are made up of only carbon and hydrogen atoms.

5. $5CO_2(g)$

6. a. $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$

b. $2C_{10}H_{22}(\ell) + 31O_2(g) \rightarrow 20CO_2(g) + 22H_2O(g)$

c. $C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$

d. $2C_6H_{14}(\ell) + 19O_2(g) \rightarrow 12CO_2(g) + 14H_2O(g)$

7. Low oxygen levels can result in producing carbon monoxide. An excess of oxygen should allow for complete combustion and the formation of only carbon dioxide and water vapour.

8. No; the blue flame indicates that complete combustion is occurring, so only carbon dioxide and water are being produced.

9. a. heat and light energy

b. oxides

10. a. incomplete combustion

b. headache, dizziness, nausea

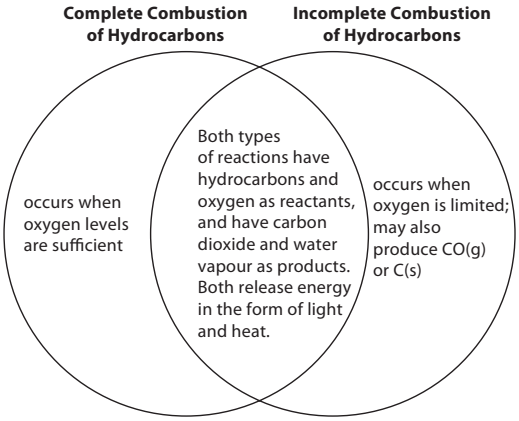
c. Carbon monoxide reduces the amount of oxygen that blood can carry, which can lead to unconsciousness. Without help, the unconscious person continues breathing carbon monoxide and eventually suffocates.

11. a. carbon monoxide

b. incomplete combustion of a hydrocarbon

12. The products vary depending upon the temperature and amount of oxygen available. Either or both CO(g) and C(s) may form. $CO_2(g)$ may be produced. $H_2O(g)$ will be produced.

13. Sample answer:



14. Glowing particles of carbon give the flame a yellow colour.

15. a. The reaction is a synthesis reaction (also combustion of a metal) since two elements combine to form a compound. It is a combustion reaction since oxygen combines with the metal (could also be called oxidation). This combustion is different from hydrocarbon combustion.

b. The reaction is complete combustion of a hydrocarbon since the products are $CO_2(g)$ and $H_2O(g)$.

c. The reaction is a synthesis reaction since two elements combine to form a compound.

16. The organism would die.

Chapter 3 Review Questions

(Student textbook pages 155–7)

1. c

2. a

3. e

4. c

5. c

6. a

7. d

8. e

9. hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine, and iodine

10. 1

11. A solution formed from a metal oxide is basic, and a solution formed from a non-metal oxide is acidic.

12. An electric current is used to cause a chemical reaction.

13. carbon dioxide, water vapour, soot (elemental carbon), carbon monoxide

14. One of the products of incomplete combustion is carbon monoxide, which is a toxic gas.

15. Decomposition reactions that produce gases are used in explosives.

16. When a multivalent metal reacts with a non-metal or when two non-metals react, more than one product is possible.

17. Sample answer: hydrogen, sodium, and chlorine

18. a. $Mg_3N_2(s) \rightarrow 3Mg(s) + N_2(g)$

b. $4Mn(s) + 3O_2(g) \rightarrow 2Mn_2O_3(s)$

c. $CO_2(g) + 4H_2(g) \rightarrow CH_4(g) + 2H_2O(g)$

d. $2PbO(s) \rightarrow 2Pb(s) + O_2(g)$

e. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$

f. $Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$

g. $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

h. $3PbCl_4(aq) + 4K_3PO_4(aq) \rightarrow 12KCl(aq) + Pb_3(PO_4)_4(s)$

19. There may be several intermediary reactions and/or processes represented by the arrow.

20. a. potassium sulfide; $2K(s) + S(s) \rightarrow K_2S(s)$

b. chromium(III) chloride; $2Cr(s) + 3Cl_2(g) \rightarrow 2CrCl_3(s)$; chromium(II) chloride; $Cr(s) + Cl_2(g) \rightarrow CrCl_2(s)$

c. silver oxide; $4Ag(s) + O_2(g) \rightarrow 2Ag_2O(s)$

d. sulfur hexachloride; $S(s) + 3Cl_2(g) \rightarrow SCl_6(g)$

21. a. magnesium and iodine; $MgI_2(\ell) \rightarrow Mg(s) + I_2(g)$

b. copper(II) nitrite and oxygen; $Cu(NO_3)_2(s) \rightarrow Cu(NO_2)_2(s) + O_2(g)$

c. barium oxide and carbon dioxide; $BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$

22. This reaction should not produce multiple products. The ions of alkaline-earth metals have a single charge (2+) and would form a single compound in a synthesis reaction with a halogen.

23. a. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$

b. $C_5H_{12}(\ell) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(g)$

c. $2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

24. a decomposition reaction, because it can be used to produce elements from compounds

25. Maintenance includes cleaning air filters, cleaning debris from the system, checking for gas leaks, checking for leaks in the flue system, and checking the ignition system and safety controls. Hazards associated with improperly maintained systems include the risk of fire, exposure to carbon monoxide, and inefficient use of fuel.

26. Diagrams should clearly show the distinction between synthesis, decomposition, and combustion reactions.

For the synthesis reaction, in which a single compound is produced, see Figure 3.8 on page 123 of the student textbook.

For the decomposition reaction, in which a single compound breaks down, see Figure 3.14 on page 130 of the student textbook.

For the combustion reaction, in which oxygen combines with another substance and releases energy in the form of heat and light, see Figure 3.21 on page 137 of the student textbook.

27. Diagrams should include: $Ca(s) + Br_2(\ell) \rightarrow CaBr_2(s)$; $Mg(s) + Br_2(\ell) \rightarrow MgBr_2(s)$; $Sr(s) + Br_2(\ell) \rightarrow SrBr_2(s)$

28. E-mails should express that coal-burning power plants are a major source of acid-forming compounds, including sulfur compounds. Sulfur dioxide can combine with water in the air, leading to acid precipitation that can damage structures, acidify bodies of water, kill aquatic life, and damage or kill vegetation including crops and trees.

29. Types of Synthesis Reactions

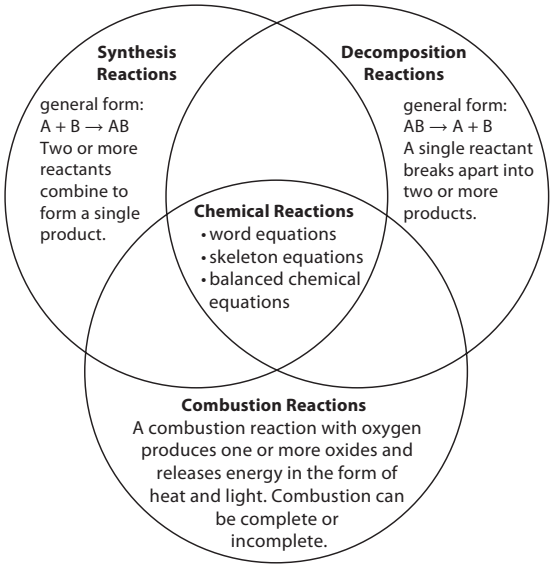
Reactants	Likely product
metal and non-metal	binary ionic compound
non-metal and non-metal	binary molecular compound
non-metal oxide and water	acid
metal oxide and water	metal hydroxide; base

30. Types of Decomposition Reactions

Reactants	Likely products
binary compound	two elements that compose the compound
hydrate	ionic compound + water
metal nitrate	metal nitrite + oxygen
metal carbonate	metal oxide + carbon dioxide
metal hydroxide	metal oxide + water

31. The chemical formulas for nitrogen gas and hydrogen gas are incorrect, so the chemical equation is not correctly balanced; in addition, the arrow should show that the chemical reaction is reversible. The correct chemical equation is $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$.

32. Sample answer:



33. Batteries provide electric current, which is needed for electrolysis. Electrolysis can be used to decompose a compound into its elements, so it is reasonable to think that the development of the technology of batteries provided the equipment and energy needed to advance the scientific knowledge of known elements.

34. a. synthesis reaction

b. $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$

c. A decomposition reaction takes place because the compound nitrogen dioxide is broken apart into the separate elements nitrogen and oxygen.

35. a. $2H_2O_2(\ell) \rightarrow 2H_2O(\ell) + O_2(g)$

b. Although made up of only two elements, hydrogen peroxide contains the polyatomic ion peroxide. Compounds that have polyatomic ions do not generally break apart into their elements.

36. a. soot

b. The presence of soot indicates that incomplete combustion occurs in the fireplace.

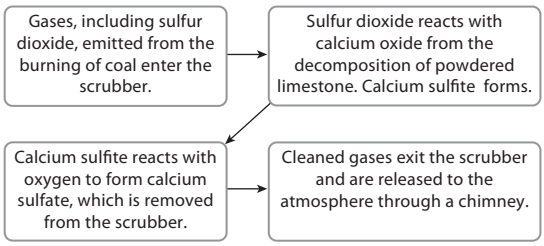
c. A build-up of soot can block proper airflow and provide fuel for a chimney fire.

37. a. decomposition; $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

b. synthesis; $CaO(s) + SO_2(g) \rightarrow CaSO_3(s)$

c. synthesis; $2CaSO_3(s) + O_2(g) \rightarrow 2CaSO_4(s)$

d. Sample answer:



e. Sample answer: In general, scrubbing sulfur from emissions using powdered limestone is effective and efficient. However, the physical and chemical properties of the limestone being used affect its reactivity. Limestone must be powdered to a specific size for use in a particular scrubber. If the powder is not optimum for the scrubber, sulfur will be removed less efficiently. Chemical composition, such as the percentage of magnesium present, also affects the reactivity of the limestone.

38. Sample answer: A person who works in swimming-pool or saltwater aquarium maintenance must use balanced chemical equations to inhibit bacterial growth and keep the water suitable for swimming or for the health of aquarium organisms.

39. The compound must be able to conduct an electric current. An ionic compound is not a good conductor in the solid state.

40. a. Sample answer: Depending on the materials that are burning, toxic chemicals that form during fires include dioxins, volatile organic compounds, metals, hydrogen chloride, and polychlorinated biphenyls. These chemicals cause respiratory distress and long-term damage to living tissues.

b. The local community is exposed to harmful chemicals during the fire, and in the resulting runoff.

Chapter 3 Self-Assessment Questions

(Student textbook pages 158–9)

1. e

2. b

3. c

4. e

5. d

6. a

7. a NOTE: Technically, both c and d would also form acids when they react with water. These other answers would be acceptable as long as the student understands the reactions that would occur.

8. d

9. b

10. b

11. $CO_2(g)$

12. a. $Na_2CO_3(s) \rightarrow Na_2O(s) + CO_2(g)$

b. After the reaction, measure the mass of the sodium oxide that remains. The difference between the mass of the sodium oxide and the original 10 g of sodium carbonate is the mass of the carbon dioxide gas.

13. Sample answer: If I wanted to light a dark room, I would want incomplete combustion because the carbon that forms glows and gives off a yellow light. If I were trying to stay warm, complete combustion would be better because it releases the maximum amount of heat from the fuel.

14. Procedures should reflect an understanding of the basic process of connecting the burner to the gas line, starting the flow of gas, and lighting the burner. Answers should also indicate that a yellow flame indicates incomplete combustion of methane and requires opening the air vents to allow more oxygen into the mix. A blue flame indicates complete combustion and is the preferred flame to use.

15. a. $Cr(ClO_3)_2(s) \rightarrow CrCl_2(s) + 3O_2(g)$

b. $4Rb(s) + O_2(g) \rightarrow 2Rb_2O(s)$

c. $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$

d. $2KOH(s) \rightarrow K_2O(s) + H_2O(g)$

16. a. combustion; $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

b. decomposition; $2KBrO_3(s) \rightarrow 2KBr(s) + 3O_2(g)$

c. synthesis; $CaO(s) + SO_2(g) \rightarrow CaSO_3(s)$

d. decomposition; $Ca(NO_3)_2(s) \rightarrow Ca(NO_2)_2(s) + O_2(g)$

e. decomposition; $C_{12}H_{22}O_{11}(s) \rightarrow 12C(s) + 11H_2O(\ell)$

f. combustion; $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$

17. a. aluminum chloride; $2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$

b. barium hydroxide; $BaO(s) + H_2O(\ell) \rightarrow Ba(OH)_2(s)$

18. a. calcium and nitrogen; $Ca_3N_2(s) \rightarrow 3Ca(s) + N_2(g)$

b. sulfur dioxide and water; $H_2SO_3(aq) \rightarrow SO_2(g) + H_2O(\ell)$

19. a. $C_5H_{12}(\ell) + 8O_2(g) \rightarrow 5CO_2(g) + 6H_2O(g)$

b. $2C_3H_6(g) + 9O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$

20. Iron is a metal that has more than one possible charge, so a synthesis reaction with chlorine could form one of two possible iron chlorides. Zinc has only one charge, so there is only one binary compound that it would form with chlorine.

21. power plants that burn sulfur-containing coal; car exhaust

22. a metal carbonate

23. a. Nitrogen compounds in the atmosphere can combine with moisture in the air to produce nitric acid, leading to increased acidity of precipitation.

b. Hydrazine decomposes to produce either ammonia and nitrogen or nitrogen and hydrogen. Because its decomposition does not produce oxides, it does not have the same potential as the combustion of hydrocarbons does to release acid-forming compounds into the atmosphere.

24. Diagrams should contain the following information: reactants, $2HCl(g) + Na_2CO_3(aq)$; products, $CO_2(g) + H_2O(\ell) + 2NaCl(aq)$; yields sign, $\rightarrow$; coefficient, the 2 in front of HCl and NaCl; states, HCl and CO_2 are gas, Na_2CO_3 and NaCl are aqueous, H_2O is liquid.

25. a. LiOH(s): decomposition; $H_2SO_4(aq)$: decomposition; $H_2(g) + O_2(g)$: synthesis; $CH_4(g)$: combustion

b. Sample answer: Even though both LiOH(s) and $H_2SO_4(aq)$ are corrosive, LiOH(s) would probably be the best to include in the kit because, as a solid, it is easier to package and transport, and because concentrated $H_2SO_4(aq)$ can react violently with water. The gases $O_2(g)$ and $CH_4(g)$ would be difficult to package and are potentially explosive.

Chapter 4 Displacement Reactions

Learning Check Questions

(Student textbook page 165)

1. A + BX → AX + B, where A and B represent metals

2. An element displaces a different element from a compound, forming a new compound and the replaced element as products.

3. Scientists perform experiments to determine the relative reactivity of a series of elements.

4. Platinum and gold, which are at the bottom of the reactivity series of metals, are the least reactive metals. A platinum or gold coating can prevent another (more reactive) metal underneath it from reacting with any substances the metal object might come into contact with.

5. a. No reaction

b. Copper is not reactive enough to displace lead.

6. a. Titanium would appear closer to the bottom of the series.

b. Its use in medical implants indicates that titanium is not very reactive.

(Student textbook page 173)

7. AX + BY → AY + BX

8. They are in aqueous solution.

9. Cations are positive ions, so describing a double displacement reaction as the exchange of cations is correct.

10. The ions in each reactant switch partners, so knowing which ions are involved makes it possible to correctly pair them up and determine the reaction products.

11. No, the products of a double displacement reaction are generally two compounds, not elements.

12. a. potassium nitrate and silver bromide; $KNO_3(aq)$ and $AgBr(s)$

b. $KBr(aq) + AgNO_3(aq) \rightarrow KNO_3(aq) + AgBr(s)$

(Student textbook page 177)

13. A precipitate is an insoluble solid that forms as a result of a chemical reaction between two soluble compounds.

14. The other compounds are in aqueous solution, but the silver chloride is a solid precipitate.

15. No, the solubility rules in the table are for the solubility of compounds in water only.

16. Either carbon dioxide or ammonia could be produced. The general forms of these reactions are: acid + compound containing carbonate ion → ionic compound + water + carbon dioxide; compound containing ammonium ions + compound containing hydroxide ions → ionic compound + water + ammonia

17. a. $Ba(OH)_2(s)$ **b.** $MgS(s)$ **c.** $H_3PO_4(s)$ **d.** $Na_2SO_3(s)$

18. $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(\ell) + CO_2(g)$

(Student textbook page 183)

19. single displacement; aluminum displaces iron from iron oxide

20. The liquid metal product of a thermite reaction is useful for welding.

21. Solid aluminum reacts with solid copper(II) oxide to produce pure liquid copper and aluminum oxide.

22. Seashells are a source of calcium carbonate, which is decomposed to produce calcium oxide. Calcium oxide is a reactant in a step in the process of magnesium extraction.

23. The precipitation allows for the magnesium to be easily separated from the other ions in seawater.

24. Chlorine is used to produce hydrochloric acid, which is needed for the neutralization reaction.

Caption Questions

Figure 4.2 (Student textbook page 163): Nothing. The nitrate ions do not change during the reaction.

Figure 4.5 (Student textbook page 166): Metals that can displace hydrogen from acids are tin, nickel, cobalt, cadmium, iron, chromium, zinc, aluminum, sodium, calcium, barium, potassium, and lithium. Metals that cannot displace hydrogen from acids are copper, silver, mercury, platinum, and gold.

Figure 4.9 (Student textbook page 173): The positive ions, Ag^+ and Na^+, change places.

Figure 4.13 (Student textbook page 181): The thermite reaction occurs in the solid state, but most double replacement reactions occur in an aqueous solution.

Figure 4.16 (Student textbook page 183): Aluminum-magnesium tubing is strong, light, and more resistant to corrosion than pure aluminum—all of which are valuable properties for a kayak.

Figure 4.17 (Student textbook page 184): The furnaces are built at different elevations, so the material can flow downhill, moving by gravity from one furnace to the next.

Figure 4.19 (Student textbook page 186): A precipitate holds the cyanide in place as a solid, increasing the chance that it can be cleaned up before it is washed into groundwater or a river.

Section 4.1 Review Questions

(Student textbook page 170)

1. Sodium displaces iron from iron(III) oxide. Sodium oxide and metallic iron form.

2. The term single displacement refers to the action of one uncombined element taking the place of another element in a compound, so there is a single, uncombined element in both the reactants and in the products.

3. A reaction will occur if copper metal is added to a solution that contains silver ions, but a reaction will not occur if silver metal is added to a solution that contains copper ions. Therefore, silver will appear below copper in an activity series.

4. Gold is the least reactive metal in the activity series, so it is unlikely to enter into chemical reactions and become corroded or break down into other forms.

5. a. NR

b. Zinc displaces iron.
$Zn(s) + FeCl_2(aq) \rightarrow ZnCl_2(aq) + Fe(s)$.

c. Magnesium displaces aluminum.
$3Mg(s) + Al_2(SO_4)_3(aq) \rightarrow 2Al(s) + 3MgSO_4(aq)$

d. Zinc displaces hydrogen.
$Zn(s) + 2HCl(aq) \rightarrow H_2(g) + ZnCl_2(aq)$

e. NR

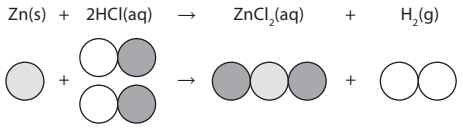
f. Magnesium displaces hydrogen.
$Mg(s) + H_2SO_4(aq) \rightarrow H_2(g) + MgSO_4(aq)$

6. Aluminum is more reactive than iron, making it harder to extract from ores.

7. Hydrogen can form a cation with a 1+ charge, so it can be replaced by metals that also form cations.

8. Hydrogen gas can be produced from the reaction of a metal above sodium in the activity series with cold water or from the reaction of a metal above hydrogen gas in the activity series with a dilute acid.

9. Sample answer:



10. Hydrogen gas and a metal hydroxide form when a metal displaces hydrogen from water.

11. The periodic table lists the halogens from top to bottom in order of decreasing reactivity.

12. We assume that a displacement reaction is shown in the diagram and the gas is hydrogen. If the liquid is water, then the metal cannot be zinc, since zinc metal is below sodium in the activity series. Only metals from sodium and above will react with cold water. If the liquid is an acid, then the metal can be zinc, since zinc is above hydrogen in the activity series (and can therefore displace the hydrogen from the acid to produce hydrogen gas).

13. The bromine in the salt of a metal bromide, and the iodine in the salt of a metal iodide can be displaced by chlorine, $Cl_2(g)$.

14. Concept maps should show characteristics of single displacement reactions, use of activity series in predicting the occurrence of single displacement reactions, metals displacing metals, metals displacing hydrogen, and halogens replacing halogens.

15. a. Iron displaces hydrogen.
$Fe(s) + 2HBr(aq) \rightarrow FeBr_2(aq) + H_2(g)$

b. Bromine displaces iodine.
$Br_2(g) + MgI_2(aq) \rightarrow MgBr_2(aq) + I_2(s)$

c. Potassium displaces aluminum.
$6K(s) + Al_2(SO_4)_3(aq) \rightarrow 2Al(s) + 3K_2SO_4(aq)$

d. Lithium displaces hydrogen.
$2Li(s) + 2H_2O(\ell) \rightarrow 2LiOH(aq) + H_2(g)$

e. NR

f. NR

16. Bromine, $Br_2(\ell)$, will displace iodine and is itself displaced by fluorine and chlorine.

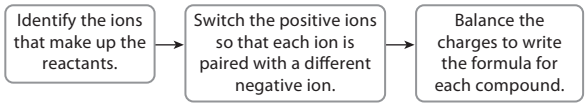
Section 4.2 Review Questions

(Student textbook page 180)

1. a. The error is that the products show two cations and two anions combining.

b. CW + DZ → CZ + DW

2. Sample answer:



3. A precipitate is an insoluble solid that is formed by a chemical reaction between two soluble compounds.

4. Sample answer: When two solutions are mixed and a precipitate forms, I expect to see the resulting mixture become cloudy.

5. nitrate and acetate

6. A reaction would be unlikely to occur. Alkali metal compounds are soluble, so no precipitate would form.

7. A reaction would not occur because if the ions switch partners, the same two compounds would form, and they would remain dissolved.

8. The products of the reaction between sodium nitrate and a lead compound in the water would form a sodium compound and a lead nitrate compound. Compounds that contain sodium ions and compounds that contain nitrate ions are soluble, so no precipitate would form from this reaction.

9. a. The geologist is looking for bubbles of $CO_2(g)$.

b. $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(\ell) + CO_2(g)$

10. Sample answer: I could use an acid-base indicator to test whether the pH of the solution has changed.

11. a. formation of a precipitate

b. sodium chloride and copper(II) hydroxide

c. Copper(II) hydroxide is the precipitate. Sodium is an alkali metal, so sodium chloride dissolves in water.

d. $2NaOH(aq) + CuCl_2(aq) \rightarrow 2NaCl(aq) + Cu(OH)_2(s)$

12. The gas that forms is ammonia, $NH_3(g)$:
$NH_4Br(aq) + NaOH(aq) \rightarrow NaBr(aq) + H_2O(\ell) + NH_3(g)$

13. an acid and a base

14. A hydrogen ion and a hydroxide ion

15. calcium chloride and water;
$Ca(OH)_2(aq) + 2HCl(aq) \rightarrow CaCl_2(aq) + 2H_2O(\ell)$

16. The states of the products are incorrect, and the equation is not balanced. Balanced equation showing the correct phases of the products:
$3NaOH(aq) + H_3PO_4(aq) \rightarrow 3H_2O(\ell) + Na_3PO_4(aq)$

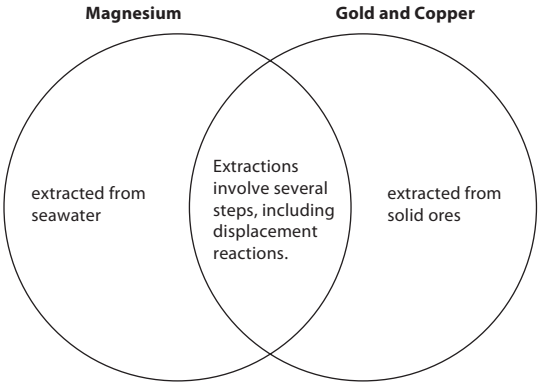
Section 4.3 Review Questions

(Student textbook page 187)

1. The larger surface area in the powdered form allows the reactants to be in better contact with one another and helps the reaction occur faster.

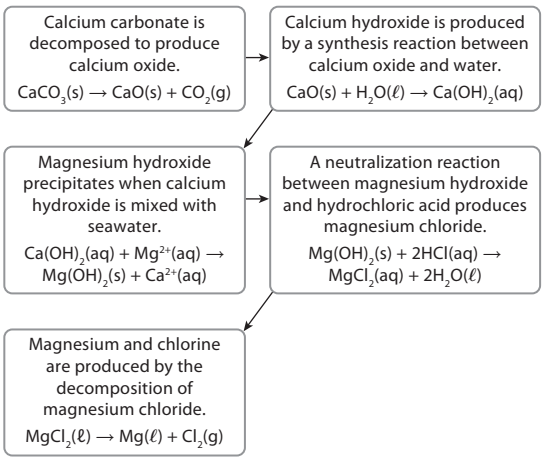
2. Sample answer: Most single displacement reactions studied so far have been in aqueous solution. Solid reactants are easier to transport and do not react immediately upon mixing.

3. Sample answer:



4. The decomposition of calcium carbonate provides the calcium oxide needed.

5. Sample answer:



6. The key process is the precipitation of magnesium ions in magnesium hydroxide and the filtering of the solid precipitate from seawater.

7. The neutralization step changes an insoluble precipitate into a soluble compound that will eventually be electrolysed.

8. a. The final stage of magnesium production uses electrical energy to produce the magnesium metal. The high energy requirement of this stage might benefit from a nearby source of electrical energy that the power plant could provide.

b. $MgCl(\ell) \rightarrow Mg(\ell) + Cl(g)$

9. $Cu_2S(\ell) + 2FeO(\ell) + 3SO_2(g)$

10. Matte is an impure copper sulfide, so it contains the desired element. Slag is the material that also forms and is mostly made up of materials other than the desired element.

11. Zinc is more reactive than gold is and can displace gold from an aqueous solution.

12. Making coffee is a model for cyanide leaching of gold. The water dissolves substances from the coffee grounds like the cyanide solution dissolves gold from the ore.

13. a. Reduced air pollution

b. The acid can be re-used (in the refining process) or sold.

c. $2CuFeS_2(s) + 4O_2(g) \rightarrow Cu_2S(\ell) + 2FeO(\ell) + 3SO_2(g)$

$2Cu_2S(\ell) + 3O_2(g) \rightarrow 2Cu_2O(\ell) + 2SO_2(g)$

$Cu_2S(\ell) + 2Cu_2O(\ell) \rightarrow 6Cu(\ell) + SO_2(g)$

14. sodium hypochlorite and iron(II) sulfate

15. Sample answer: Because the solution is contained, treatment with sodium hypochlorite would be preferred because the final products are non-toxic. Having the solution contained would allow the clean-up team to calculate the amount of the sodium hypochlorite needed and make sure that all of the cyanide reacted.

16. The iron(II) cyanide ions (hexacyanoferrate(II) ions) are non-toxic ions that helps to bind the toxic cyanide ions. The iron(II) cyanide ions also form precipitates with many metal ions, which helps to prevent the spread of the cyanide ions.

Case Study: Smelting Emissions Questions

(Student textbook pages 198–9)

1. Answers should show an understanding of the health effects of some of the chemicals released from base metal smelters, including the effects of varying levels of exposure on human health and the increased vulnerability of certain segments of the population, such as children.

2. Answers should include a list of metals commonly produced by Ontario smelters, the locations of major smelters, an estimate of the money they contribute to Ontario's economy on an annual basis, and a summary of positive and negative effects of specific smelters.

3. Answers should show an understanding of the risks of exposure to smelter emissions at various concentrations, the government's role in protecting people from exposure to toxic substances, and positive and negative effects on a community if a smelter closes.

Practice Problems

(Student textbook page 169)

1. $Mg(s) + CrSO_4(aq) \rightarrow MgSO_4(aq) + Cr(s)$

2. NR

3. $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$

4. $F_2(g) + MgI_2(aq) \rightarrow MgF_2(aq) + I_2(s)$

5. $Cl_2(g) + 2NaI(aq) \rightarrow 2NaCl(aq) + I_2(s)$

6. NR

7. NR

8. $2K(s) + 2H_2O(\ell) \rightarrow 2KOH(aq) + H_2(g)$

9. $2HCl(aq) + Cd(s) \rightarrow CdCl_2(aq) + H_2(g)$

10. $3Pb(ClO_3)_4(aq) + 4Al(s) \rightarrow 4Al(ClO_3)_3 + 3Pb(s)$

(Student textbook page 175)

11. $K_2SO_4(aq) + CaCl_2(aq) \rightarrow 2KCl(aq) + CaSO_4(s)$

12. $Ba(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow 2NaNO_3(aq) + BaCO_3(s)$

13. $FeCl_3(aq) + 3NaOH(aq) \rightarrow 3NaCl(aq) + Fe(OH)_3(s)$

14. $Rb_2S(aq) + CuI_2(aq) \rightarrow 2RbI(aq) + CuS(s)$

15. $ZnBr_2(aq) + 2CuCH_3COO(aq) \rightarrow Zn(CH_3COO)_2(aq) + 2CuBr(s)$

16. $2LiOH(aq) + MgCl_2(aq) \rightarrow 2LiCl(aq) + Mg(OH)_2(s)$

17. $Al_2(SO_4)_3(aq) + 3Pb(NO_3)_2(aq) \rightarrow 2Al(NO_3)_3(aq) + 3PbSO_4(s)$

18. $2Li_3PO_4(aq) + 3MgCl_2(aq) \rightarrow 6LiCl(aq) + Mg_3(PO_4)_2(s)$

19. $Ca(NO_3)_2(aq) + MgSO_4(aq) \rightarrow Mg(NO_3)_2(aq) + CaSO_4(s)$

(Student textbook page 179)

20. $2AgNO_3(aq) + MgCl_2(aq) \rightarrow Mg(NO_3)_2(aq) + 2AgCl(s)$

21. $K_2CO_3(aq) + 2HCl(aq) \rightarrow 2KCl(aq) + H_2O(\ell) + CO_2(g)$

22. $H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + H_2O(\ell) + CO_2(g)$

23. $NH_4Cl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(\ell) + NH_3(g)$

24. $RbOH(aq) + HCl(aq) \rightarrow RbCl(aq) + H_2O(\ell)$

25. $CaCO_3(s) + 2CH_3COOH(aq) \rightarrow Ca(CH_3COO)_2(aq) + H_2O(\ell) + CO_2(g)$

26. $LiOH(aq) + NH_4Br(aq) \rightarrow LiBr(aq) + H_2O(\ell) + NH_3(g)$

27. $H_2SO_4(aq) + 2LiOH(aq) \rightarrow Li_2SO_4(aq) + 2H_2O(\ell)$

28. $LiHCO_3(aq) + CH_3COOH(aq) \rightarrow LiCH_3COO(aq) + H_2O(\ell) + CO_2(g)$

29. $Ca(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + 2H_2O(\ell)$

30. $2NH_4Cl(aq) + Mg(OH)_2(aq) \rightarrow MgCl_2(aq) + 2H_2O(\ell) + 2NH_3(g)$

Chapter 4 Review Questions

(Student textbook pages 201–3)

1. c

2. a

3. b

4. d

5. c

6. d

7. d

8. b

9. alkali metals

10. sodium

11. If ammonium hydroxide or carbonic acid (hydrogen carbonate) form as a result of reactants switching ions, a decomposition reaction happens in which the compound breaks down and forms a gas.

12. Bromine is less reactive than fluorine and chlorine but is more reactive than iodine.

13. A neutralization reaction can be used to clean up a chemical spill involving an acid or a base.

14. a. The production of copper is most dependent on oxygen.

b. Oxygen reacts with sulfide in ore to form a gas, SO_2, which separates the sulfur from the copper and iron metals. Oxygen also reacts with the iron found in the ore, and the resulting Fe_3O_4 is separated from the copper.

15. $A + BX \rightarrow BA + X$

16. metal

17. I would expect to see bubbles form. Potassium is less reactive than lithium, so it cannot displace lithium from the solution. However, the potassium can displace hydrogen from the water in the solution. Hydrogen gas would form as a result.

18. a. precipitate

b. double displacement reaction

19. a. double displacement reaction

b. single displacement reaction

c. single displacement reaction

d. double displacement reaction

20. a. $3Mg(s) + 2Co(NO_3)_3(aq) \rightarrow 3Mg(NO_3)_2(aq) + 2Co(s)$

b. $Cl_2(g) + 2LiBr(aq) \rightarrow Br_2(g) + 2LiCl(aq)$

c. $Zn(s) + 2HClO_4(aq) \rightarrow Zn(ClO_4)_2(aq) + H_2(g)$

d. NR

e. $2Al(s) + 3NiCl_2(aq) \rightarrow 2AlCl_3(aq) + 3Ni(s)$

f. $2K(s) + H_2O(\ell) \rightarrow 2KOH(aq) + H_2(g)$

g. NR

21. Sample answer: I would need samples of each metal and a solution of each metal. I would test for reactivity by placing each metal sample into the solutions of the other three metals and record the results. I would then list the metals in order starting with the most reactive metal—the one that reacted with solutions of the other three metals.

22. a. Oxygen is more reactive than sulfur.

b. Oxygen displaces sulfur from iron and copper sulfides.

23. a. potassium bromide and barium sulfate; $K_2SO_4(aq) + BaBr_2(aq) \rightarrow 2KBr(aq) + BaSO_4(s)$

b. lithium nitrate, water, and carbon dioxide; $2HNO_3(aq) + Li_2CO_3(aq) \rightarrow 2LiNO_3(aq) + H_2O(\ell) + CO_2(g)$

c. copper(II) hydroxide and sodium bromide; $CuBr_2(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + 2NaBr(aq)$

d. rubidium nitrate and lead(II) sulfide; $Rb_2S(aq) + Pb(NO_3)_2(aq) \rightarrow 2RbNO_3(aq) + PbS(s)$

e. potassium sulfate, water, and ammonia; $(NH_4)_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell) + 2NH_3(g)$

f. iron(II) nitrate and silver bromide; $FeBr_2(aq) + 2AgNO_3(aq) \rightarrow Fe(NO_3)_2(aq) + 2AgBr(s)$

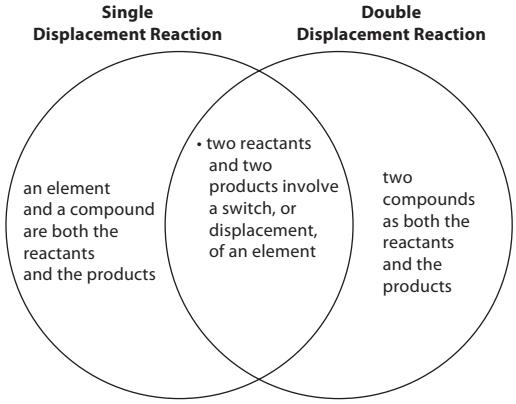
g. lithium sulfate and water; $2LiOH(aq) + H_2SO_4(aq) \rightarrow Li_2SO_4(aq) + 2H_2O(\ell)$

24. The unknown metal is more reactive than nickel but is less reactive than aluminum or calcium.

25. $Al(s) + 3H_2SO_4(aq) \rightarrow 3H_2(g) + Al_2(SO_4)_3(aq)$; $2Al(OH)_3(aq) + 3H_2SO_4(aq) \rightarrow 3H_2O(\ell) + Al_2(SO_4)_3(aq)$

26. Ammonia gas can form from a double displacement reaction if an ammonium compound and a hydroxide react together. Ammonia is produced when ammonium hydroxide formed in the double displacement reaction decomposes. $NH_4Cl(aq) + NaOH(aq) \rightarrow NaCl(aq) + NH_4OH(aq)$
$NH_4OH(aq) \rightarrow H_2O(\ell) + NH_3(g)$

27. Sample answer:



28. If the products of a potential double displacement reaction are two compounds that are both soluble ionic compounds, then no real change has happened, because the ions do not change form between the reactants and the products.

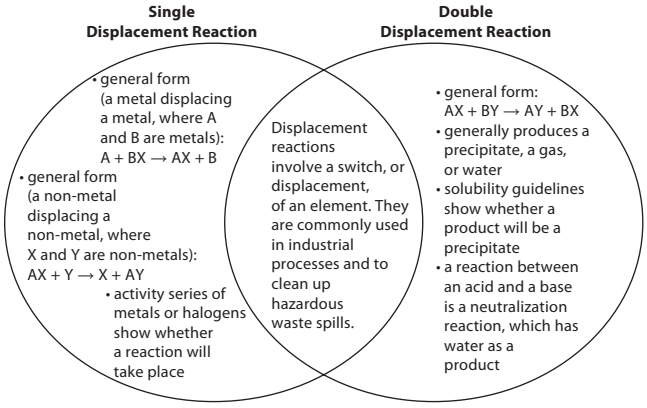
29. Points in favour: more jobs, more income to the town. Points in opposition: health risks, the possibility of a spill and the poisoning of local water supplies, destruction of local habitats

30. Scripts should convey that as the solid grey metal enters the colourless solution, the surface of the metal erupts with bubbles. As the bubbles rise to the surface of the liquid and pop, the metal seems to be wearing away.

31. Answers should include an understanding that lead can be leached from the pipes by displacement reactions and can then be ingested, which can lead to lead poisoning.

32. A likely mistake is not understanding that the uncombined element must be higher on the activity series than the element in a compound that it might replace.

33. Sample answer:



34. Sample answer: By adding a metal that is more active than copper (such as zinc) to a solution that contains copper ions, I could produce a sample of the element copper using a single displacement reaction.

35. The chlorine can be changed into hydrochloric acid (hydrogen chloride) and used in the neutralization of the magnesium hydroxide.

36. If too little iron(II) sulfate is used, the cyanide will form the soluble compound iron(II) cyanide and will not form complex iron(II) cyanide ions. Enough iron(II) sulfate must be added to completely react with the cyanide to form precipitates.

37. a. Lead, nickel, and cadmium are more reactive than hydrogen is in acids. If these metals were present in the tailings pile, the acid formed from the sulfides could have reacted with the metals and leached them from the tailings into the water. Thus, when the water was released, it could have been carrying the ions of these metals dissolved in it.

b. Sample answer: An engineer would need to have training in chemistry to understand the possible reactions taking place in a tailings pile that can result in acid mine drainage. This person would also need training in geology and geotechnical engineering to assess local hydrology conditions and the stability of retaining walls.

38. a. React magnesium metal with hydrochloric acid. Add sodium phosphate solution to the magnesium chloride solution formed. Filter the resulting products to collect the magnesium phosphate precipitate.

b. $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
$3MgCl_2(aq) + 2Na_3PO_4(aq) \rightarrow Mg_3(PO_4)_2(s) + 6NaCl(aq)$

39. a. The reaction of the acidic ingredient with the sodium hydrogen carbonate is a double displacement reaction followed by a decomposition that results in the formation of carbon dioxide gas.

b. Baking soda is used to provide bubbles of gas in the batter to make it rise.

40. $HCl(aq) + NaHCO_3(aq) \rightarrow NaCl(aq) + H_2O(\ell) + CO_2(g)$

Chapter 4 Self-Assessment Questions

(Student textbook pages 204–5)

1. e

2. b

3. e

4. d

5. b

6. d

7. b

8. a

9. c

10. d

11. a. double displacement

b. single displacement

c. single displacement

d. double displacement

12. a. silver chloride and lithium nitrate; $LiCl(aq) + AgNO_3(aq) \rightarrow AgCl(s) + LiNO_3(aq)$

b. NR

c. potassium chloride and iodine; $Cl_2(g) + 2KI(aq) \rightarrow 2KCl(aq) + I_2(s)$

d. lead(II) sulfate and sodium nitrate; $Pb(NO_3)_2(aq) + Na_2SO_4(aq) \rightarrow PbSO_4(s) + 2NaNO_3(aq)$

13. The halogens are listed from top to bottom in Group 17 of the periodic table in order from most reactive to least reactive. When examining a single displacement reaction that involves halogens, the reaction will only occur if the halogen that is uncombined is closer to the top of the group than the halogen it is trying to replace.

14. a. A precipitate will form if calcium chloride or lead(II) acetate is present.

b. $CaCl_2(aq) + Na_2SO_4(aq) \rightarrow CaSO_4(s) + 2NaCl(aq)$; $Pb(CH_3COO)_2(aq) + Na_2SO_4(aq) \rightarrow PbSO_4(s) + 2NaCH_3COO(aq)$

15. a. Water should be a liquid. The product should be potassium hydroxide rather than potassium oxide. $2K(s) + 2H_2O(\ell) \rightarrow 2KOH(aq) + H_2(g)$

b. Lithium nitrate is soluble, so it should be marked aqueous rather than solid, and lead(II) chloride is not soluble, so it should be marked solid rather than aqueous. A coefficient is needed in front of lithium nitrate to balance the equation. $2LiCl(aq) + Pb(NO_3)_2(aq) \rightarrow 2LiNO_3(aq) + PbCl_2(s)$

16. The statement is a correct description of a double displacement reaction. The exchange of ions can be described as either the positive ions or the negative ions switching places.

17. Many metals are found as sulfide ores. These sulfur-containing compounds react during refining and form sulfur dioxide gas.

18. A single displacement reaction occurs when a more reactive element displaces a less reactive one from a compound. In the reverse direction, the uncombined element is less reactive than the element it would replace, so no reaction can occur.

19. B, C, A

20. a. precipitate

b. double displacement reaction

21. A neutralization reaction is a double displacement reaction that occurs between an acidic solution and a basic solution. The reaction forms a salt and water.

22. During leaching, a metal is extracted by dissolving it in an aqueous solution. Leaching is helpful when it is done to extract a desirable metal from its ore. It is harmful when dangerous metals, such as lead or mercury, are dissolved and enter the environment.

23. a. $H_2CO_3(aq) + 2NaOH(aq) \rightarrow Na_2CO_3(aq) + 2H_2O(\ell)$

b. double displacement reaction and neutralization reaction

c. $Na_2CO_3(aq) + Ca(OH)_2(aq) \rightarrow CaCO_3(s) + 2NaOH(aq)$

24. Precipitation is the process by which a solid precipitate forms during a double displacement reaction when an insoluble solid forms. Acid precipitation describes rain, snow, and fog that is acidic as a result of chemical reactions between non-metal oxides and water in the air.

25. fluorine

Unit 2 Review Questions

(Student textbook pages 209–13)

1. d

2. d

3. c

4. c

5. b

6. e

7. b

8. c

9. e

10. b

11. $3NaOH(aq) + AlCl_3(aq) \rightarrow 3NaCl(aq) + Al(OH)_3(aq)$

12. a. In a synthesis reaction, the metal atoms give up electrons and the non-metal atoms accept the electrons.

b. Ionic bonds form as a result of the total electron transfer between bonding atoms.

13. Decomposition Products

Type of Compound	Products
metal carbonate	metal oxide and carbon dioxide
binary compound	two elements
metal nitrate	metal nitrite and oxygen

14. decomposition reaction

15. synthesis reaction

16. a. $Ca_3N_2(s) \rightarrow 3Ca(s) + N_2(g)$

b. $4Cr(s) + 3O_2(g) \rightarrow 2Cr_2O_3(s)$

c. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

d. $2BaO(s) \rightarrow 2Ba(s) + O_2(g)$

17. a. decomposition reaction

b. synthesis reaction

c. combustion reaction

d. decomposition reaction

18. a. single displacement reaction; an uncombined element displaces an element in a compound

b. synthesis reaction; two reactants produce a single product

c. decomposition reaction; a single reactant produces multiple products

d. synthesis reaction; two reactants produce a single product

e. double displacement reaction; the positive ions switch places

f. decomposition reaction; a single reactant produces multiple products

19. decomposition reaction and double displacement reaction

20. a. base **b.** acid **c.** acid **d.** base

21. a non-metal oxide

22. a. single displacement reaction

b. decomposition reaction

23. It is a synthesis reaction when it proceeds to right, and it is a decomposition reaction when it proceeds to the left.

24. The bright yellow flame represents incomplete combustion. A in the yellow flame of a candle, the unburned carbon glows and causes the bright yellow colour. The blue flame represents complete combustion.

25. a. Oxygen is formed. Oxygen supports combustion and causes a glowing splint to reignite.

b. decomposition reaction

c. The mass of the container will decrease as the container is heated because the gas produced leaves the container.

26. a. The gas is carbon dioxide because it extinguishes a burning splint.

b. The solution is acidic and will turn blue litmus paper red. $CO_2(g) \rightarrow H_2O(\ell) \rightarrow H_2CO_3(aq)$

27. c

28. a. $2C_6H_6(\ell) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(\ell)$

b. $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

c. $Cl_2(g) + 2NaBr(aq) \rightarrow 2NaCl(s) + Br_2(g)$

d. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

29. a. combustion reaction

b. synthesis or combustion reaction

c. single displacement reaction

d. decomposition reaction

30. a. $Cu(NO_3)_2(aq)$; copper(II) nitrate

b. $Cu(s) + 2AgNO_3(aq) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$

c. 187.5 g

31. a. Beaker A contained sodium nitrate, and Beaker B contained silver nitrate.

b. silver chloride, AgCl(s)

c. double displacement

d. $HCl(aq) + AgNO_3(aq) \rightarrow HNO_3(aq) + AgCl(s)$

e. No reaction is evident in Beaker A because both sodium nitrate and sodium chloride are soluble.

32. a. No reaction will occur because both sodium sulfate and ammonium hydroxide are soluble.

b. $Nb_2(SO_4)_5(aq) + 5Ba(NO_3)_2(aq) \rightarrow 2Nb(NO_3)_5(aq) + 5BaSO_4(s)$

c. $SrBr_2(aq) + 2AgNO_3(aq) \rightarrow Sr(NO_3)_2(aq) + 2AgBr(s)$

33. a. an acid and a base

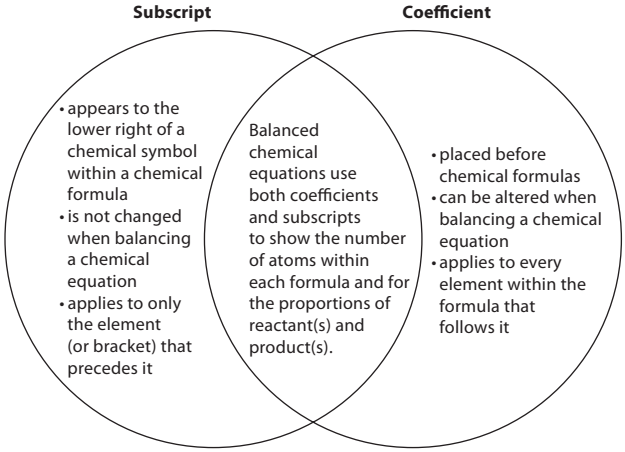
b. The resulting mixture would contain a salt and water and would be neutral.

c. I could evaporate the water to show the crystals of the salt that are left behind.

34. Add sodium sulfate. A precipitate indicates the presence of lead(II) ions. Separate the solid from the remaining solution. Add sodium chloride to the remaining solution. A precipitate indicates the presence of silver ions.

35. Diagrams or models should correctly show the atoms and molecules involved in the reaction and reflect the changes signified by the addition of coefficients.

36. Sample answer:



37. Add a coefficient of 2 in front of propene, and double the coefficient of each product. Then, the number of oxygen atoms in the products is 18, which can be balanced by adding a coefficient of 9 in front of oxygen in the reactants.

38. The process of balancing a chemical equation involves representing equal numbers of atoms of each element in both the reactants and the products. But it is not just the number of atoms, but the actual atoms themselves that are represented on each side of the equation. Because the same atoms appear in the products as appear in the reactants, matter is neither created nor destroyed.

39. Graphic organizers should illustrate that a single reactant is decomposition, two elements is synthesis, a substance with oxygen is combustion, an element and a compound is generally single displacement, and two ionic compounds is double displacement.

40. Procedures should call for using indicators such as litmus paper to test the solutions. Safety eyewear, an apron, and gloves are safety gear should be indicated. Expected results should describe what result will happen for an acidic and for a basic solution.

41. Diagrams should show non-metal oxides being emitted from the sources and combining with water to form acidic solutions (depending on the sources chosen).

42. i. a. decomposition; b. The reactant is a compound, and the products are elements or smaller compounds.
ii. a. synthesis; b. The reactants are elements or small compounds, and the product is a compound.
iii. a. displacement; b. The reactants are an element and a compound, and the products are a different compound and one of the elements.
iv. a. double displacement; b. The reactants are a compounds, and the products are two different compounds.

43. In a double displacement reaction, you must often tell whether a product of the reaction forms an insoluble precipitate in order to know whether the reaction happens. A single displacement reaction is not determined by whether a precipitate forms, but by whether one element is more reactive than another.

44. Start by looking at the cation. If the cation is an alkali metal, hydrogen, or ammonium ion, mark the compound as being in aqueous solution. If the cation is something else, then look at the anion in the table. Read across to find the cation in the compound. If the combination of anion and cation is listed as having low solubility, mark the compound as a solid precipitate.

45. Sample answer: The reactivity of sodium is too great for this process. You are counting on the reaction $Na(s) + AgNO_3(aq) \rightarrow NaNO_3(aq) + Ag(s)$.

However, sodium is reactive enough to displace hydrogen from water by the reaction $2Na(s) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + H_2(g)$.

In addition to the dangerous nature of the sodium itself, the sodium hydroxide is caustic, and the hydrogen is flammable.

46. These chemicals should not be identified as solids. If the reaction occurred while they were in a solid state, the tablet would react without placing it in water. The need for water to begin the reaction indicates that the chemicals should be identified as being in aqueous solution in the balanced equation.

47. Sample answer: Incomplete combustion produces carbon monoxide, which is a poisonous gas. Complete combustion produces carbon dioxide, which is a greenhouse gas and is thought to contribute to a global rise in temperatures. Carbon dioxide can also displace oxygen, especially in low-lying areas.

48. a. magnesium carbonate decomposing into a metal oxide and carbon dioxide; magnesium hydroxide decomposing into a metal oxide and water

b. $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$; $Mg(OH)_2 \rightarrow MgO(s) + H_2O(g)$

49. a. A double displacement reaction could be used to remove the ions as solid precipitates.

b. Whatever reactant is used to provide the ions needed to form the precipitate will also provide a metal ion, which could cause additional problems.

50. a. $H_2SO_4(aq) + CaCO_3(s) \rightarrow H_2O(\ell) + CO_2(g) + CaSO_4(aq)$

b. The limestone could change the chemical balance in the water by increasing calcium levels, to which some species are sensitive.

51. Sample answer: Catalytic converters break down nitrogen oxides into the elements nitrogen and oxygen through decomposition reactions. They also change carbon monoxide into carbon dioxide through a synthesis/combustion reaction.

52. a. $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

b. synthesis/combustion reaction; iron combines with oxygen to form a compound

53. formula for DTBP: $C_8H_{18}O_2(g)$ or $(CH_3)_3COOC(CH_3)_3(g)$
complete combustion: $2(CH_3)_3COOC(CH_3)_3(g) + 23O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$
decomposition: $(CH_3)_3COOC(CH_3)_3(g) \rightarrow C_2H_6(g) + 2(CH_3)_2CO(g)$
A fuel that could power an engine in the absence of oxygen could be used in low-oxygen environments, such as to power a chainsaw for use by a firefighter within a burning building.

54. a. $Ni(s) + 4CO(g) \rightarrow Ni(CO)_4(g)$

b. The incomplete combustion of carbon monoxide could produce carbon monoxide gas.

c. Carbon monoxide is a toxic gas. Trapping the carbon monoxide produced during the decomposition of $Ni(CO)_4$ and reusing it as a reactant reduces the cost of materials and helps to prevent the release of the toxic gas into the atmosphere.

55. a. Copper is less reactive than most metals, so copper can be displaced by other metals, such as iron, and it exists in its elemental form in nature.

b. $CuCO_3(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(\ell) + CO_2(g)$
$CuSO_4(aq) + Fe(s) \rightarrow FeSO_4(aq) + Cu(s)$

56. a. Answers should show an understanding of the chemical reactions that occurred and the processes that allowed the chemicals to react.

b. Answers should include a list of economic and social costs.

c. Answers should list the immediate and long-term effects of the explosion.

Unit 2 Self-Assessment Questions

(Student textbook pages 214–5)

1. d

2. b

3. e

4. b

5. In a synthesis reaction, a compound is formed, but in a decomposition reaction, a compound is broken down.

6. c

7. b

8. c

9. a

10. a

11. A coefficient is a full-sized number in front of a chemical formula that can be changed while writing a balanced chemical equation. A subscript is a small number to the lower right of a chemical symbol that should not be changed while balancing a chemical equation.

12. a. $Br_2(\ell) + 2NaI(aq) \rightarrow 2NaBr(aq) + I_2(s)$

b. $2Al(s) + 3Cu(NO_3)_2(aq) \rightarrow 3Cu(s) + 2Al(NO_3)_3(aq)$

c. $2Fe_2O_3(s) \rightarrow 4Fe(s) + 3O_2(g)$

d. $Cl_2(g) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(\ell)$

e. $6Li(s) + N_2(g) \rightarrow 2Li_3N(s)$

f. $2AgNO_3(aq) + CaCl_2(aq) \rightarrow 2AgCl(s) + Ca(NO_3)_2(aq)$

13. A synthesis reaction that produces only the desired compound would result in less waste products and greater efficiency than a reaction that also formed additional products.

14. An acidic solution and a basic solution react and neutralize each another.

15. a. carbon dioxide and water; $C_4H_8(g) + 6O_2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$

b. aluminum tribromide; $2Al(s) + 3Br_2(\ell) \rightarrow 2AlBr_3(s)$

c. rubidium nitrite; $RbNO_3(s) \rightarrow RbNO_2(s) + O_2(g)$

16. a. $2LiCl(\ell) \rightarrow 2Li(\ell) + Cl_2(g)$

b. If water enters the reaction chamber, the lithium that forms might react with the water and produce flammable hydrogen gas, which could ignite and cause injury to the scientist. $2Li(\ell) + 2H_2O(\ell) \rightarrow 2LiOH(aq) + H_2(g)$

17. a. The reactant is a compound, and the products are two or more elements or compounds.

b. The reactants are two compounds, and the products are two other compounds.

18. a. $SiO_2(s) + C(s) \rightarrow CO_2(g) + Si(\ell)$

b. This reaction appears to be a single displacement reaction. Carbon replaces silicon from silicon dioxide, and the element silicon forms.

c. The release of carbon dioxide gas is potentially damaging to the environment because of carbon dioxide's role as a greenhouse gas. If silicon could be made through decomposition of silicon dioxide, the other product would be oxygen, so the process would not contribute greenhouse gases, nor would expensive scrubbing technology be needed.

19. a metal carbonate and a metal hydroxide

20. a. Liming an acidified lake is done to help neutralize acids in the lake water.

b. $H_2SO_4(aq) + CaCO_3(s) \rightarrow H_2O(\ell) + CO_2(g) + CaSO_4(aq)$

21. Sample answer: Heat each compound and test the gas that is produced. If a glowing splint reignites, the compound is a metal nitrate because it decomposes to produce oxygen gas. If a burning splint is extinguished, the compound is a metal carbonate because it decomposes to produce carbon dioxide gas.

22. Non-metal oxides react with water to produce the acids that make precipitation acidic.

23. a. $MgS(aq) + Cu(NO_3)_2(aq) \rightarrow CuS(s) + Mg(NO_3)_2(aq)$

b. No reaction

c. $Br_2(g) + 2KI(aq) \rightarrow 2KBr(aq) + I_2(s)$

d. No reaction

24. Acids produce positively charged hydrogen ions, and bases produce negatively charged hydroxide ions.

25. The products would both be soluble, so no reaction would occur.