Appendices

APPENDIX A Practice Problems

Chapter 2

Section 2-1

1. The density of a substance is 4.8 g/mL. What is the volume of a sample that is 19.2 g?

2. A 2.00-mL sample of substance A has a density of 18.4 g/mL and a 5.00-mL sample of substance B has a density of 35.5 g/mL. Do you have an equal mass of substances A and B?

Section 2-2

3. Express the following quantities in scientific notation.
- **a.** 5 453 000 m
- **b.** 300.8 kg
- **c.** 0.005 36 ng
- **d.** 0.012 032 5 km
- **e.** 34 800 s
- **f.** 332 080 000 cm
- **g.** 0.000 238 3 ms
- **h.** 0.3048 mL

4. Solve the following problems. Express your answers in scientific notation.
- **a.** 3×10^{2} m + 5×10^{2} m
- **b.** 8×10^{-5} m + 4×10^{-5} m
- **c.** 6.0×10^{5} m + 2.38×10^{6} m
- **d.** 2.3×10^{-3} L + 5.78×10^{-2} L
- **e.** 2.56×10^{2} g − 1.48×10^{2} g
- **f.** 5.34×10^{-3} L − 3.98×10^{-3} L
- **g.** 7.623×10^{5} nm − 8.32×10^{4} nm
- **h.** 9.052×10^{-2} s − 3.61×10^{-3} s

5. Solve the following problems. Express your answers in scientific notation.
- **a.** $(8 \times 10^{3}\ \text{m}) \times (1 \times 10^{5}\ \text{m})$
- **b.** $(4 \times 10^{2}\ \text{m}) \times (2 \times 10^{4}\ \text{m})$
- **c.** $(5 \times 10^{-3}\ \text{m}) \times (3 \times 10^{4}\ \text{m})$
- **d.** $(3 \times 10^{-4}\ \text{m}) \times (3 \times 10^{-2}\ \text{m})$
- **e.** $(8 \times 10^{4}\ \text{g}) \div (4 \times 10^{3}\ \text{mL})$
- **f.** $(6 \times 10^{-3}\ \text{g}) \div (2 \times 10^{-1}\ \text{mL})$
- **g.** $(1.8 \times 10^{-2}\ \text{g}) \div (9 \times 10^{-5}\ \text{mL})$
- **h.** $(4 \times 10^{-4}\ \text{g}) \div (1 \times 10^{3}\ \text{mL})$

6. Convert the following as indicated.
- **a.** 96 kg to g
- **b.** 155 mg to g
- **c.** 15 cg to kg
- **d.** 584 μs to s
- **e.** 188 dL to L
- **f.** 3600 m to km
- **g.** 24 g to pg
- **h.** 85 cm to nm

7. How many minutes are there in 5 days?

8. A car is traveling at 118 km/h. What is its speed in Mm/h?

Section 2-3

9. Three measurements of 34.5 m, 38.4 m, and 35.3 m are taken. If the accepted value of the measurement is 36.7 m, what is the percent error for each measurement?

10. Three measurements of 12.3 mL, 12.5 mL, and 13.1 mL are taken. The accepted value for each measurement is 12.8 mL. Calculate the percent error for each measurement.

CONTENTS

11. Determine the number of significant figures in each measurement.
  - **a.** 340 438 g
  - **b.** 87 000 ms
  - **c.** 4080 kg
  - **d.** 961 083 110 m
  - **e.** 1.040 s
  - **f.** 0.0483 m
  - **g.** 0.2080 mL
  - **h.** 0.000 048 1 g

12. Write the following in three significant figures.
  - **a.** 0.003 085 0 km
  - **b.** 3.0823 g
  - **c.** 5808 mL
  - **d.** 34.654 mg

13. Write the answers in scientific notation.
  - **a.** 0.005 832g
  - **b.** 386 808 ns
  - **c.** 0.000 580 0 km
  - **d.** 2086 L

14. Use rounding rules when you complete the following.
  - **a.** 34.3 m + 35.8 m + 33.7 m
  - **b.** 0.056 kg + 0.0783 kg + 0.0323 kg
  - **c.** 309.1 mL + 158.02 mL + 238.1 mL
  - **d.** 1.03 mg + 2.58 mg + 4.385 mg
  - **e.** 8.376 km − 6.153 km
  - **f.** 34.24 s −12.4 s
  - **g.** 804.9 dm − 342.0 dm
  - **h.** 6.38×10^2 m − 1.57×10^2 m

15. Complete the following calculations. Round off the answers to the correct number of significant figures.
  - **a.** 34.3 cm × 12 cm
  - **b.** 0.054 mm × 0.3804 mm
  - **c.** 45.1 km × 13.4 km
  - **d.** 45.5g ÷ 15.5 mL
  - **e.** 35.43 g ÷ 24.84 mL
  - **f.** 0.0482 g ÷ 0.003 146 mL

Chapter 3

Section 3-2

1. A 3.5-kg iron shovel is left outside through the winter. The shovel, now orange with rust, is rediscovered in the spring. Its mass is 3.7 kg. How much oxygen combined with the iron?

2. When 5.0 g of tin reacts with hydrochloric acid, the mass of the products, tin chloride and hydrogen, totals 8.1 g. How many grams of hydrochloric acid were used?

Section 3-3

3. A compound is analyzed and found to be 50.0% sulfur and 50.0% oxygen. If the total amount of the sulfur oxide compound is 12.5 g, how many grams of sulfur are there?

4. Two unknown compounds are analyzed. Compound I contain 5.63 g of tin and 3.37 g of chlorine, while compound II contains 2.5 g of tin and 2.98 g of chlorine. Are the compounds the same?

Chapter 4

Section 4-3

1. How many protons and electrons are in each of the following atoms?
  - **a.** gallium
  - **b.** silicon
  - **c.** cesium
  - **d.** calcium
  - **e.** molybdenum
  - **f.** titanium

2. What is the atomic number of each of the following elements?
  - **a.** an atom that contains 37 electrons
  - **b.** an atom that contains 72 protons

CONTENTS

c. an atom that contains 1 electron
d. an atom that contains 85 protons

3. Use the periodic table to write the name and the symbol for each element identified in question 2.

4. An isotope of copper contains 29 electrons, 29 protons, and 36 neutrons. What is the mass number of this isotope?

5. An isotope of uranium contains 92 electrons and 144 neutrons. What is the mass number of this isotope?

6. Use the periodic table to write the symbols for each of the following elements. Then, determine the number of electrons, protons, and neutrons each contains.
a. yttrium-88
b. arsenic-75
c. xenon-129
d. bromine-79
e. gold-197
f. helium-4

7. An element has two naturally occurring isotopes: ^{14}X and ^{15}X. ^{14}X has a mass of 14.003 07 amu and a relative abundance of 99.63%. ^{15}X has a mass of 15.000 11 amu and a relative abundance of 0.37%. Identify the unknown element.

8. Silver has two naturally occurring isotopes. Ag-107 has an abundance of 51.82% and a mass of 106.9 amu. Ag-109 has a relative abundance of 48.18% and a mass of 108.9 amu. Calculate the atomic mass of silver.

Chapter 5

Section 5-1

1. What is the frequency of an electromagnetic wave that has a wavelength of 4.55×10^{-3} m? 1.00×10^{-12} m?

2. Calculate the wavelength of an electromagnetic wave with a frequency of 8.68×10^{16} Hz; 5.0×10^{14} Hz; 1.00×10^{6} Hz.

3. What is the energy of a quantum of visible light having a frequency of 5.45×10^{14} s^{-1}?

4. An X ray has a frequency of 1.28×10^{18} s^{-1}. What is the energy of a quantum of the X ray?

Section 5-3

5. Write the ground-state electron configuration for the following.
a. nickel
b. cesium
c. boron
d. krypton

6. What element has the following ground-state electron configuration $[He]2s^2$? $[Xe]6s^24f^{14}5d^{10}6p^1$?

7. Which element in period 4 has four electrons in its electron-dot structure?

8. Which element in period 2 has six electrons in its electron-dot structure?

9. Draw the electron-dot structure for each element in question 5.

Chapter 6

Section 6-2

1. Identify the group, period, and block of an atom with the following electron configuration.
a. $[He]2s^2 2p^1$ **b.** $[Kr]5s^2 4d^5$ **c.** $[Xe]6s^2 5f^{14} 6d^5$

2. Write the electron configuration for the element fitting each of the following descriptions.
a. The noble gas in the first period.
b. The group 4B element in the fifth period.
c. The group 4A element in the sixth period.
d. The group 1A element in the seventh period.

Section 6-3

3. Using the periodic table and not **Figure 6-11,** rank each main group element in order of increasing size.
a. calcium, magnesium, and strontium
b. oxygen, lithium, and fluorine
c. fluorine, cesium, and calcium
d. selenium, chlorine, tellurium
e. iodine, krypton, and beryllium

Chapter 8

Section 8-2

1. Explain the formation of an ionic compound from zinc and chlorine.

2. Explain the formation of an ionic compound from barium and nitrogen.

Section 8-3

3. Write the chemical formula of an ionic compound composed of the following ions.
a. calcium and arsenide
b. iron(III) and chloride
c. magnesium and sulfide
d. barium and iodide
e. gallium and phosphide

4. Determine the formula for ionic compounds composed of the following ions.
a. copper(II) and acetate
b. ammonium and phosphate
c. calcium and hydroxide
d. gold(III) and cyanide

5. Name the following compounds.
a. $Co(OH)_2$
b. $Ca(ClO_3)_2$
c. Na_3PO_4
d. $K_2Cr_2O_7$
e. SrI_2
f. HgF_2

Chapter 9

Section 9-1

1. Draw the Lewis structure for the following molecules.
a. CCl_2H_2
b. HF
c. PCl_3
d. CH_4

Section 9-2

2. Name the following binary compounds.
a. S_4N_2
b. OCl_2
c. SF_6
d. NO
e. SiO_2
f. IF_7

3. Name the following acids: H_3PO_4, HBr, HNO_3.

Section 9-3

4. Draw the Lewis structure for each of the following.
- **a.** CO
- **b.** CH_2O
- **c.** N_2O
- **d.** OCl_2
- **e.** SiO_2
- **f.** $AlBr_3$

5. Draw the Lewis resonance structure for CO_3^{2-}.

6. Draw the Lewis resonance structure for $CH_3CO_2^-$.

7. Draw the Lewis structure for NO and IF_4^-.

Section 9-4

8. Determine the molecular geometry, bond angles, and hybrid of each molecule in question 4.

Section 9-5

9. Determine whether each of the following molecules is polar or nonpolar.
- **a.** CH_2O
- **b.** BF_3
- **c.** SiH_4
- **d.** H_2S

Chapter 10

Section 10-1 **Write skeleton equations for the following reactions.**

1. Solid barium and oxygen gas react to produce solid barium oxide.

2. Solid iron and aqueous hydrogen sulfate react to produce aqueous iron(III) sulfate and gaseous hydrogen.

Write balanced chemical equations for the following reactions.

3. Liquid bromine reacts with solid phosphorus (P_4) to produce solid diphosphorus pentabromide.

4. Aqueous lead(II) nitrate reacts with aqueous potassium iodide to produce solid lead(II) iodide and aqueous potassium nitrate.

5. Solid carbon reacts with gaseous fluorine to produce gaseous carbon tetrafluoride.

6. Aqueous carbonic acid reacts to produce liquid water and gaseous carbon dioxide.

7. Gaseous hydrogen chloride reacts with gaseous ammonia to produce solid ammonium chloride.

8. Solid copper(II) sulfide reacts with aqueous nitric acid to produce aqueous copper(II) sulfate, liquid water, and nitrogen dioxide gas.

Section 10-2 **Classify each of the following reactions in as many classes as possible.**

9. $2Mo(s) + 3O_2(g) \rightarrow 2MoO_3(s)$

10. $N_2H_4(l) + 3O_2(g) \rightarrow 2NO_2(g) + 2H_2O(l)$

Write balanced chemical equations for the following decomposition reactions.

11. Aqueous hydrogen chlorite decomposes to produce water and gaseous chlorine(III) oxide.

12. Calcium carbonate(s) decomposes to produce calcium oxide(s) and carbon dioxide(g).

Use the activity series to predict whether each of the following single-replacement reactions will occur:

13. $Al(s) + FeCl_3(aq) \rightarrow AlCl_3(aq) + Fe(s)$

14. $Br_2(l) + 2LiI(aq) \rightarrow 2LiBr(aq) + I_2(aq)$

15. $Cu(s) + MgSO_4(aq) \rightarrow Mg(s) + CuSO_4(aq)$

Write chemical equations for the following chemical reactions:

16. Bismuth(III) nitrate(aq) reacts with sodium sulfide(aq) yielding bismuth(III) sulfide(s) plus sodium nitrate(aq).

17. Magnesium chloride(aq) reacts with potassium carbonate(aq) yielding magnesium carbonate(s) plus potassium chloride(aq).

Section 10-3 **Write net ionic equations for the following reactions.**

18. Aqueous solutions of barium chloride and sodium fluoride are mixed to form a precipitate of barium fluoride.

19. Aqueous solutions of copper(I) nitrate and potassium sulfide are mixed to form insoluble copper(I) sulfide.

20. Hydrobromic acid reacts with aqueous lithium hydroxide

21. Perchloric acid reacts with aqueous rubidium hydroxide

22. Nitric acid reacts with aqueous sodium carbonate.

23. Hydrochloric acid reacts with aqueous lithium cyanide.

Chapter 11

Section 11-1

1. Determine the number of atoms in 3.75 mol Fe.

2. Calculate the number of formula units in 12.5 mol $CaCO_3$.

3. How many moles of $CaCl_2$ contains 1.26×10^{24} formula units $CaCl_2$?

4. How many moles of Ag contains 4.59×10^{25} atoms Ag?

Section 11-2

5. Determine the mass in grams of 0.0458 moles of sulfur.

6. Calculate the mass in grams of 2.56×10^{-3} moles of iron.

7. Determine the mass in grams of 125 mol of neon.

8. How many moles of titanium are contained in 71.4 g?

9. How many moles of lead are equivalent to 9.51×10^3 g Pb?

10. Determine the number of moles of arsenic in 1.90 g As.

11. Determine the number of atoms in 4.56×10^{-2} g of sodium.

12. How many atoms of gallium are in 2.85×10^3 g of gallium?

13. Determine the mass in grams of 5.65×10^{24} atoms Se.

14. What is the mass in grams of 3.75×10^{21} atoms Li?

Section 11-3

15. How many moles of each element is in 0.0250 mol K_2CrO_4.

16. How many moles of ammonium ions are in 4.50 mol $(NH_4)_2CO_3$?

17. Determine the molar mass of silver nitrate.

18. Calculate the molar mass of acetic acid (CH_3COOH).

19. Determine the mass of 8.57 mol of sodium dichromate ($Na_2Cr_2O_7$).

20. Calculate the mass of 42.5 mol of potassium cyanide.

21. Determine the number of moles present in 456 g $Cu(NO_3)_2$.

22. Calculate the number of moles in 5.67 g potassium hydroxide.

23. Calculate the number of each atom in 40.0 g of methanol (CH_3OH).

CONTENTS

24. What mass of sodium hydroxide contains 4.58×10^{23} formula units?

Section 11-4

25. What is the percent by mass of each element in sucrose ($C_{12}H_{22}O_{11}$)?

26. Which of the following compounds has a greater percent by mass of chromium, K_2CrO_4 or $K_2Cr_2O_7$?

27. Analysis of a compound indicates the percent composition 42.07% Na, 18.89% P, and 39.04% O. Determine its empirical formula.

28. A colorless liquid was found to contain 39.12% C, 8.76% H, and 52.12% O. Determine the empirical formula of the substance.

29. Analysis of a compound used in cosmetics reveals the compound contains 26.76% C, 2.21% H, 71.17% O and has a molar mass of 90.04 g/mol. Determine the molecular formula for this substance.

30. Eucalyptus leaves are the food source for panda bears. Eucalyptol is an oil found in these leaves. Analysis of eucalyptol indicates it has a molar mass of 154 g/mol and contains 77.87% C, 11.76% H, and 10.37% O. Determine the molecular formula of eucalyptol.

31. Beryl is a hard mineral which occurs in a variety of colors. A 50.0-g sample of beryl contains 2.52 g Be, 5.01 g Al, 15.68 g Si, and 26.79g O. Determine its empirical formula.

32. Analysis of a 15.0-g sample of a compound used to leach gold from low grade ores is 7.03 g Na, 3.68 g C, and 4.29 g N. Determine the empirical formula for this substance.

Section 11-5

33. Analysis of a hydrate of iron(III) chloride revealed that in a 10.00-g sample of the hydrate, 6.00 g is anhydrous iron(III) chloride and 4.00 g is water. Determine the formula and name of the hydrate.

34. When 25.00 g of a hydrate of nickel(II) chloride was heated, 11.37 g of water were released. Determine the name and formula of the hydrate.

Chapter 12

Section 12-1

Interpret the following balanced chemical equation in terms of particles, moles, and mass.

1. $Mg + 2HCl \rightarrow MgCl_2 + H_2$
2. $2Al + 3CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu$

3. Write and balance the equation for the decomposition of aluminum carbonate. Determine the possible mole ratios.

4. Write and balance the equation for the formation of magnesium hydroxide and hydrogen from magnesium and water. Determine the possible mole ratios.

Section 12-2

5. Some antacid tablets contain aluminum hydroxide. The aluminum hydroxide reacts with stomach acid according to the equation: $Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$. Determine the moles of acid neutralized if a tablet contains 0.200 mol $Al(OH)_3$.

6. Chromium reacts with oxygen according to the equation: $4Cr + 3O\ _2 \rightarrow 2Cr_2O_3$. Determine the moles of chromium(III) oxide produced when 4.58 moles of chromium is allowed to react.

7. Space vehicles use solid lithium hydroxide to remove exhaled carbon dioxide according to the equation: $2LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O$. Determine the mass of carbon dioxide removed if the space vehicle carries 42.0 mol LiOH.

8. Some of the sulfur dioxide released into the atmosphere is converted to sulfuric acid according to the equation $2SO_2 + 2H_2O + O_2 \rightarrow 2H_2SO_4$. Determine the mass of sulfuric acid formed from 3.20 moles of sulfur dioxide.

9. How many grams of carbon dioxide are produced when 2.50 g of sodium hydrogen carbonate react with excess citric acid according to the equation: $3NaHCO_3 + H_3C_6H_5O_7 \rightarrow Na_3C_6H_5O_7 + 3CO_2 + 3H_2O$.

10. Aspirin ($C_9H_8O_4$) is produced when salicylic acid ($C_7H_6O_3$) reacts with acetic anhydride ($C_4H_6O_3$) according to the equation: $C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + HC_2H_3O_2$. Determine the mass of aspirin produced when 150.0 g of salicylic acid reacts with an excess of acetic anhydride.

Section 12-3

11. Chlorine reacts with benzene to produce chlorobenzene and hydrogen chloride, $Cl_2 + C_6H_6 \rightarrow C_6H_5Cl + HCl$. Determine the limiting reactant if 45.0 g of benzene reacts with 45.0 g of chlorine, the mass of the excess reactant after the reaction is complete, and the mass of chlorobenzene produced.

12. Nickel reacts with hydrochloric acid to produce nickel(II) chloride and hydrogen according to the equation $Ni + 2HCl \rightarrow NiCl_2 + H_2$. If 5.00 g Ni and 2.50 g HCl react, determine the limiting reactant, the mass of the excess reactant after the reaction is complete, and the mass of nickel(II) chloride produced.

Section 12-4

13. Tin(IV) iodide is prepared by reacting tin with iodine. Write the balanced chemical equation for the reaction. Determine the theoretical yield if a 5.00-g sample of tin reacts in an excess of iodine. Determine the percent yield, if 25.0 g SnI_4 was actually recovered.

14. Gold is extracted from gold bearing rock by adding sodium cyanide in the presence of oxygen and water, according to the reaction, $4\ Au\ (s) + 8\ NaCN\ (aq) + O_2\ (g) + 2H_2O(l) \rightarrow 4\ NaAu(CN)_2\ (aq) + NaOH\ (aq)$. Determine the theoretical yield of $NaAu(CN)_2$ if 1000.0 g of gold bearing rock is used which contains 3.00% gold by mass. Determine the percent yield of $NaAu(CN)_2$ if 38.790 g $NaAu(CN)_2$ is recovered.

Chapter 13

Section 13-1

1. Calculate the ratio of effusion rates for methane (CH_4) and nitrogen.

2. Calculate the molar mass of butane. Butane's rate of diffusion is 3.8 times slower than that of helium.

Section 13-2

3. What is the total pressure in a canister that contains oxygen gas at a partial pressure of 804 mm Hg, nitrogen at a partial pressure of 220 mm Hg, and hydrogen at a partial pressure of 445 mm Hg?

4. Calculate the partial pressure of neon in a flask that has a total pressure of 1.87 atm. The flask contains krypton at a partial pressure of 0.77 atm and helium at a partial pressure of 0.62 atm.

Chapter 14

Section 14-1

1. The pressure of air in a 2.25-L container is 1.20 atm. What is the new pressure if the sample is transferred to a 6.50-L container? Temperature is constant.

2. The volume of a sample of hydrogen gas at 0.997 atm is 5.00 L. What will be the new volume if the pressure is decreased to 0.977 atm? Temperature is constant.

3. A gas at 55.0°C occupies a volume of 3.60 L. What volume will it occupy at 30.0°C? Pressure is constant.

4. The volume of a gas is 0.668 L at 66.8°C. At what Celsius temperature will the gas have a volume of 0.942 L, assuming the pressure remains constant?

5. The pressure in a bicycle tire is 1.34 atm at 33.0°C. At what temperature will the pressure inside the tire be 1.60 atm? Volume is constant.

6. If a sample of oxygen gas has a pressure of 810 torr at 298 K, what will be its pressure if its temperature is raised to 330 K?

7. Air in a tightly sealed bottle has a pressure of 0.978 atm at 25.5°C. What will its pressure be if the temperature is raised to 46.0°C?

Section 14-2

8. Hydrogen gas at a temperature of 22.0°C that is confined in a 5.00-L cylinder exerts a pressure of 4.20 atm. If the gas is released into a 10.0-L reaction vessel at a temperature of 33.6°C, what will be the pressure inside the reaction vessel?

9. A sample of neon gas at a pressure of 1.08 atm fills a flask with a volume of 250 mL at a temperature of 24.0°C. If the gas is transferred to another flask at 37.2°C at a pressure of 2.25 atm, what is the volume of the new flask?

10. What volume of beaker contains exactly 2.23×10^{-2} mol of nitrogen gas at STP?

11. How many moles of air are in a 6.06-L tire at STP?

12. How many moles of oxygen are in a 5.5-L canister at STP?

13. What mass of helium is in a 2.00-L balloon at STP?

14. What volume will 2.3 kg of nitrogen gas occupy at STP?

Section 14-3

15. Calculate the number of moles of gas that occupy a 3.45-L container at a pressure of 150 kPa and a temperature of 45.6°C.

16. What is the pressure in torr that a 0.44-g sample of carbon dioxide gas will exert at a temperature of 46.2°C when it occupies a volume of 5.00 L?

17. What is the molar mass of a gas that has a density of 1.02 g/L at 0.990 atm pressure and 37°C?

18. Calculate the grams of oxygen gas present in a 2.50-L sample kept at 1.66 atm pressure and a temperature of 10.0°C.

19. What volume of oxygen gas is needed to completely combust 0.202 L of butane (C_4H_{10}) gas?

20. Determine the volume of methane (CH_4) gas needed to react completely with 0.660 L of O_2 gas to form methanol (CH_3OH).

Section 14-4 **21.** Calculate the mass of hydrogen peroxide needed to obtain 0.460 L of oxygen gas at STP. $2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$

22. When potassium chlorate is heated in the presence of a catalyst such as manganese dioxide, it decomposes to form solid potassium chloride and oxygen gas: $2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$. How many liters of oxygen will be produced at STP if 1.25 kg of potassium chlorate decomposes completely?

Chapter 15

Section 15-1 **1.** Calculate the mass of gas dissolved at 150.0 kPa, if 0.35 g of the gas dissolves in 2.0 L of water at 30.0 kPa.

2. At which depth, 33 ft. or 133 ft, will a scuba diver have more nitrogen dissolved in the bloodstream?

Section 15-2 **3.** What is the percent by mass of a sample of ocean water that is found to contain 1.36 grams of magnesium ions per 1000 g?

4. What is the percent by mass of iced tea containing 0.75 g of aspartame in 250 g of water?

5. A bottle of hydrogen peroxide is labeled 3%. If you pour out 50 mL of hydrogen peroxide solution, what volume is actually hydrogen peroxide?

6. If 50 mL of pure acetone is mixed with 450 mL of water, what is the percent volume?

7. Calculate the molarity of 1270 g K_3PO_4 in 4.0 L aqueous solution.

8. What is the molarity of 90.0 g NH_4Cl in 2.25 L aqueous solution?

9. Which is more concentrated, 25 g NaCl dissolved in 500 mL of water or a 10% solution of NaCl (percent by mass)?

10. Calculate the mass of NaOH required to prepare a 0.343*M* solution dissolved in 2500 mL of water?

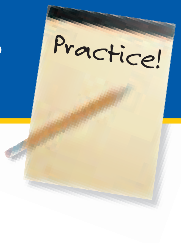
11. Calculate the volume required to dissolve 11.2 g $CuSO_4$ to prepare a 0.140*M* solution.

12. How would you prepare 500 mL of a solution that has a new concentration of 4.5*M* if the stock solution is 11.6*M*?

13. Caustic soda is 19.1*M* NaOH and is diluted for household use. What is the household concentration if 10 mL of the concentrated solution is diluted to 400 mL?

14. What is the molality of a solution containing 63.0 g HNO_3 in 0.500 kg of water?

CONTENTS



15. What is the molality of an acetic acid solution containing 0.500 mole of $HC_2H_3O_2$ in 0.800 kg of water?

16. What mass of ethanol (C_2H_5OH) will be required to prepare a 2.00*m* solution in 8.00 kg of water?

17. Determine the mole fraction of nitrogen in a gas mixture containing 0.215 mol N_2, 0.345 mol O_2, 0.023 mol CO_2, and 0.014 mol SO_2. What is the mole fraction of N_2?

18. A necklace contains 4.85 g of gold, 1.25 g of silver, and 2.40 g of copper. What is the mole fraction of each metal?

Section 15-3

19. Calculate the freezing point and boiling point of a solution containing 6.42 g of sucrose ($C_{12}H_{22}O_{11}$) in 100.0 g of water.

20. Calculate the freezing point and boiling point of a solution containing 23.7 g copper(II) sulfate in 250.0 g of water.

21. Calculate the freezing point and boiling point of a solution containing 0.15 mol of the molecular compound naphthalene in 175 g of benzene (C_6H_6).

Chapter 16

Section 16-1

1. What is the equivalent in joules of 126 Calories?

2. Convert 455 kilojoules to kilocalories.

3. How much heat is required to warm 122 g of water by 23.0°C?

4. The temperature of 55.6 grams of a material decreases by 14.8°C when it loses 3080 J of heat. What is its specific heat?

5. What is the specific heat of a metal if the temperature of a 12.5-g sample increases from 19.5°C to 33.6°C when it absorbs 37.7 J of heat?

Section 16-2

6. A 75.0-g sample of a metal is placed in boiling water until its temperature is 100.0°C. A calorimeter contains 100.00 g of water at a temperature of 24.4°C. The metal sample is removed from the boiling water and immediately placed in water in the calorimeter. The final temperature of the metal and water in the calorimeter is 34.9°C. Assuming that the calorimeter provides perfect insulation, what is the specific heat of the metal?

Section 16-3

7. Use **Table 16-6** to determine how much heat is released when 1.00 mole of gaseous methanol condenses to a liquid.

8. Use **Table 16-6** to determine how much heat must be supplied to melt 4.60 grams of ethanol.

Section 16-4

9. Calculate ΔH_{rxn} for the reaction $2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$ given the following thermochemical equations:

$2CO_2(g) + 2H_2O(l) \rightarrow C_2H_4(g) + 3O_2(g)\ \Delta H = 1411\ kJ$

$C(s) + O_2(g) \rightarrow CO_2(g)\ \Delta H = -393.5\ kJ$

$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)\ \Delta H = -572\ kJ$

10. Calculate ΔH_{rxn} for the reaction $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$ given the following thermochemical equations:
$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)\ \Delta H = -184$ kJ
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)\ \Delta H = -92$ kJ
$N_2(g) + 4H_2(g) + Cl_2(g) \rightarrow 2NH_4Cl(s)\ \Delta H = -628$ kJ

Use standard enthalpies of formation from Table 16-7 and Appendix C to calculate $\Delta H°_{rxn}$ for each of the following reactions.

11. $2HF(g) \rightarrow H_2(g) + F_2(g)$
12. $2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(l) + 2SO_2(g)$

Section 16-5 **Predict the sign of ΔS_{system} for each reaction or process.**

13. $FeS(s) \rightarrow Fe^{2+}(aq) + S^{2-}(aq)$
14. $SO_2(g) + H_2O(l) \rightarrow H_2SO_3(aq)$

Determine if each of the following processes or reactions is spontaneous or nonspontaneous.

15. $\Delta H_{system} = 15.6$ kJ, $T = 415$ K, $\Delta S_{system} = 45$ J/K
16. $\Delta H_{system} = 35.6$ kJ, $T = 415$ K, $\Delta S_{system} = 45$ J/K

Chapter 17

Section 17-1

1. In the reaction $A \rightarrow 2B$, suppose that [A] changes from 1.20 mol/L at time = 0 to 0.60 mol/L at time = 3.00 min and that [B] = 0.00 mol/L at time = 0.

a. What is the average rate at which A is consumed in mol/(L·min)?
b. What is the average rate at which B is produced in mol/(L·min)?

Section 17-3

2. What are the overall reaction orders in practice problems 16-18 on page 545?

3. If halving [A] in the reaction $A \rightarrow B$ causes the initial rate to decrease to one fourth its original value, what is the probable rate law for the reaction?

4. Use the data below and the method of initial rates to determine the rate law for the reaction $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

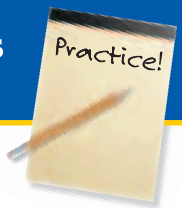
Formation of NO_2 Data

Trial	Initial [NO] (*M*)	Initial [O_2] (*M*)	Initial rate (mol/(L s))
1	0.030	0.020	0.0041
2	0.060	0.020	0.0164
3	0.030	0.040	0.0082

Section 17-4

5. The rate law for the reaction in which one mole of cyclobutane (C_4H_8) decomposes to two moles of ethylene (C_2H_4) at 1273 K is Rate = $(87\ s^{-1})[C_4H_8]$. What is the instantaneous rate of this reaction when

a. $[C_4H_8] = 0.0100$ mol/L?
b. $[C_4H_8] = 0.200$ mol/L?



Chapter 18

Section 18-1

Write equilibrium constant expressions for the following equilibria.

1. $N_2(g) + O_2(g) \rightleftharpoons 2NO$
2. $3O_2(g) \rightleftharpoons 2O_3(g)$
3. $P_4(g) + 6H_2(g) \rightleftharpoons 4PH_3(g)$
4. $CCl_4(g) + HF(g) \rightleftharpoons CFCl_2(g) + HCl(g)$

Write equilibrium constant expressions for the following equilibria.

5. $NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$
6. $SO_3(g) + H_2O(l) \rightleftharpoons H_2SO_4(l)$

Calculate K_{eq} for the following equilibria.

7. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
   $[H_2] = 0.0109$, $[I_2] = 0.00290$, $[HI] = 0.0460$
8. $I_2(s) \rightleftharpoons I_2(g)$
   $[I_2(g)] = 0.0665$

Section 18-3

9. At a certain temperature, $K_{eq} = 0.0211$ for the equilibrium $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$.
   - **a.** What is $[Cl_2]$ in an equilibrium mixture containing 0.865 mol/L PCl_5 and 0.135 mol/L PCl_3?
   - **b.** What is $[PCl_5]$ in an equilibrium mixture containing 0.100 mol/L PCl_3 and 0.200 mol/L Cl_2?
10. Use the K_{sp} value for zinc carbonate given in **Table 18-3** to calculate its molar solubility at 298 K.
11. Use the K_{sp} value for iron(II) hydroxide given in **Table 18-3** to calculate its molar solubility at 298 K.
12. Use the K_{sp} value for silver carbonate given in **Table 18-3** to calculate $[Ag^+]$ in a saturated solution at 298 K.
13. Use the K_{sp} value for calcium phosphate given in **Table 18-3** to calculate $[Ca^{2+}]$ in a saturated solution at 298 K.
14. Does a precipitate form when equal volumes of $0.0040M$ $MgCl_2$ and $0.0020M$ K_2CO_3 are mixed? If so, identify the precipitate.
15. Does a precipitate form when equal volumes of $1.2 \times 10^{-4}M$ $AlCl_3$ and $2.0 \times 10^{-3}M$ NaOH are mixed? If so, identify the precipitate.

Chapter 19

Section 19-1

1. Write the balanced formula equation for the reaction between zinc and nitric acid.
2. Write the balanced formula equation for the reaction between magnesium carbonate and sulfuric acid.
3. Identify the base in the reaction
   $H_2O(l) + CH_3NH_2(aq) \rightarrow OH^-(aq) + CH_3NH_3^+(aq)$
4. Identify the conjugate base described in the reaction in practice problems 1 and 2.
5. Write the steps in the complete ionization of hydrosulfuric acid.
6. Write the steps in the complete ionization of carbonic acid.

CONTENTS

Section 19-2

7. Write the acid ionization equation and ionization constant expression for formic acid (HCOOH).

8. Write the acid ionization equation and ionization constant expression for the hydrogen carbonate ion (HCO^{3-}).

9. Write the base ionization constant expression for ammonia.

10. Write the base ionization expression for aniline ($C_6H_5NH_2$).

Section 19-3

11. Is a solution in which $[H^+] = 1.0 \times 10^{-5}M$ acidic, basic, or neutral?

12. Is a solution in which $[OH^-] = 1.0 \times 10^{-11}M$ acidic, basic, or neutral?

13. What is the pH of a solution in which $[H^+] = 4.5 \times 10^{-4}M$?

14. Calculate the pH and pOH of a solution in which $[OH^-] = 8.8 \times 10^{-3}M$.

15. Calculate the pH and pOH of a solution in which $[H^+] = 2.7 \times 10^{-6}M$.

16. What is $[H^+]$ in a solution having a pH of 2.92?

17. What is $[OH^-]$ in a solution having a pH of 13.56?

18. What is the pH of a 0.000 67*M* H_2SO_4 solution?

19. What is the pH of a 0.000 034*M* NaOH solution?

20. The pH of a 0.200*M* HBrO solution is 4.67. What is the acid's K_a?

21. The pH of a 0.030*M* C_2H_5COOH solution is 3.20. What is the acid's K_a?

Section 19-4

22. Write the formula equation for the reaction between hydroiodic acid and beryllium hydroxide.

23. Write the formula equation for the reaction between perchloric acid and lithium hydroxide.

24. In a titration, 15.73 mL of 0.2346*M* HI solution neutralizes 20.00 mL of a LiOH solution. What is the molarity of the LiOH?

25. What is the molarity of a caustic soda (NaOH) solution if 35.00 mL of solution is neutralized by 68.30 mL of 1.250*M* HCl?

26. Write the chemical equation for the hydrolysis reaction that occurs when sodium hydrogen carbonate is dissolved in water. Is the resulting solution acidic, basic, or neutral?

27. Write the chemical equation for any hydrolysis reaction that occurs when cesium chloride is dissolved in water. Is the resulting solution acidic, basic, or neutral?

Chapter 20

Section 20-1 **Identify the following information for each problem. What element is oxidized? Reduced? What is the oxidizing agent? Reducing agent?**

1. $2P + 3Cl_2 \rightarrow 2PCl_3$
2. $C + H_2O \rightarrow CO + H_2$

3. Determine the oxidation number for each element in the following compounds.
- **a.** Na_2SeO_3
- **b.** $HAuCl_4$
- **c.** H_3BO_3

4. Determine the oxidation number for the following compounds or ions.
- **a.** P_4O_8
- **b.** Na_2O_2 (hint: this is like H_2O_2)
- **c.** AsO_4^{-3}

Section 20-2 **5.** How many electrons will be lost or gained in each of the following half-reactions? Identify whether it is an oxidation or reduction.
- **a.** $Cr \rightarrow Cr^{3+}$
- **b.** $O_2 \rightarrow O^{2-}$
- **c.** $Fe^{+2} \rightarrow Fe^{3+}$

6. Balance the following reaction by the oxidation number method: $MnO_4^- + CH_3OH \rightarrow MnO_2 + HCHO$ (acidic). (Hint: assign the oxidation of hydrogen and oxygen as usual and solve for the oxidation number of carbon.)

7. Balance the following reaction by the oxidation number method: $Zn + HNO_3 \rightarrow ZnO + NO_2 + NH_3$

8. Use the oxidation number method to balance these net ionic equations:
- **a.** $SeO_3^{2-} + I^- \rightarrow Se + I_2$ (acidic solution)
- **b.** $NiO_2 + S_2O_3^{2-} \rightarrow Ni(OH)_2 + SO_3^{2-}$ (acidic solution)

Section 20-3 **Use the half-reaction method to balance the following redox equations.**

9. $Zn(s) + HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$

10. $MnO_4^-(aq) + H_2SO_3(aq) \longrightarrow Mn^{2+}(aq) + HSO_4^-(aq) + H_2O(l)$ (acidic solution)

11. $NO_2(aq) + OH^-(aq) \longrightarrow NO_2^-(aq) + NO_3^-(aq) + H_2O(l)$ (basic solution)

12. $HS^-(aq) + IO_3^-(aq) \longrightarrow I^-(aq) + S(s) + H_2O(l)$ (acidic solution)

Chapter 21

Section 21-1 **1.** Calculate the cell potential for each of the following.
- **a.** $Co^{2+}(aq) + Al(s) \rightarrow Co(s) + Al^{3+}(aq)$
- **b.** $Hg^{2+}(aq) + Cu(s) \rightarrow Cu^{2+}(aq) + Hg(s)$
- **c.** $Zn(s) + Br_2(l) \rightarrow Br^{1-}(aq) + Zn^{2+}(aq)$

2. Calculate the cell potential to determine whether the reaction will occur spontaneously or not spontaneously. For each reaction that is not spontaneous, correct the reactants or products so that a reaction would occur spontaneously.
- **a.** $Ni^{2+}(aq) + Al(s) \rightarrow Ni(s) + Al^{3+}(aq)$
- **b.** $Ag^+(aq) + H_2(g) \rightarrow Ag(s) + H^+(aq)$
- **c.** $Fe^{2+}(aq) + Cu(s) \rightarrow Fe(s) + Cu^{2+}(aq)$

Chapter 22

Section 22-1 **1.** Draw the structure of the following branched alkanes.

- **a.** 2,2,4-trimethylheptane
- **b.** 4-isopropyl-2-methylnonane

Section 22-2 **2.** Draw the structure of each of the following cycloalkanes.

- **a.** 1-ethyl-2-methylcyclobutane
- **b.** 1,3-dibutylcyclohexane

Section 22-3 **3.** Draw the structure of each of the following alkenes.

- **a.** 1,4-hexadiene
- **b.** 2,3-dimethyl-2-butene
- **c.** 4-propyl-1-octene
- **d.** 2,3-diethylcyclohexene

Chapter 23

Section 23-1 **1.** Draw the structures of the following alkyl halides.

- **a.** chloroethane
- **b.** chloromethane
- **c.** 1-fluoropentane
- **d.** 1,3-dibromocyclohexane
- **e.** 1,2-dibromo-3-chloropropane

Chapter 25

Section 25-2 **1.** Write balanced equations for each of the following decay processes.

- **a.** Alpha emission of $^{244}_{96}\mathrm{Cm}$
- **b.** Positron emission of $^{70}_{33}\mathrm{As}$
- **c.** Beta emission of $^{210}_{83}\mathrm{Bi}$
- **d.** Electron capture by $^{116}_{51}\mathrm{Sb}$

2. $^{47}_{20}\mathrm{Ca} \rightarrow {}^{0}_{-1}\beta + ?$

3. $^{240}_{95}\mathrm{Am} + ? \rightarrow {}^{243}_{97}\mathrm{Bk} + {}^{1}_{0}\mathrm{n}$

Section 25-3 **4.** How much time has passed if 1/8 of an original sample of radon-222 is left? Use **Table 25-5** for half-life information.

5. If a basement air sample contains 3.64 μg of radon-222, how much radon will remain after 19 days?

6. Cobalt-60, with a half-life of 5 years, is used in cancer radiation treatments. If a hospital purchases a supply of 30.0 g, how much would be left after 15 years?

APPENDIX B Math Handbook

Mathematics is a language used in science to express and solve problems. Use this handbook to review basic math skills and to reinforce some math skills presented in the chapters in more depth.

Arithmetic Operations

Calculations you perform during your study of chemistry require arithmetic operations, such as addition, subtraction, multiplication, and division, using numbers. Numbers can be positive or negative, as you can see in **Figure 1.** Examine the number line below. Numbers that are positive are greater than zero. A plus sign (+) or no sign at all indicates a positive number. Numbers that are less than zero are negative. A minus sign (−) indicates a negative number. Zero (the origin) is neither positive nor negative.

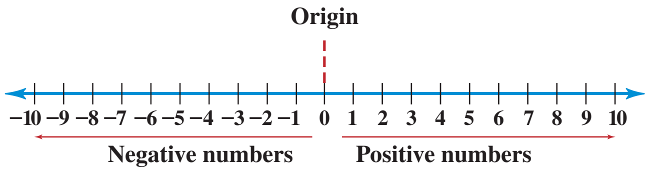


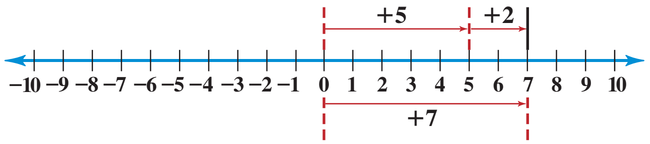
Figure 1

Water freezes at 32°F and 0°C. What temperature scale do you think was used on this sign? Explain.

1. Addition and subtraction

Addition is an arithmetic operation. As you can see in **Table 1,** the result of addition is called a sum. When the signs of the numbers you are adding are alike, add the numbers and keep the same sign. Use the number line below to solve for the sum 5 + 2 in which both numbers are positive. To represent the first number, draw an arrow that starts at the origin. The arrow that represents the second number starts at the arrowhead of the first arrow. The sum is at the head of the second arrow. In this case, the sum equals the positive number seven.

$$5 + 2 = 7$$



The process of adding two negative numbers is similar to adding two positive numbers. The negative sign indicates that you must move in the direction opposite to the direction that you moved to add two positive numbers. Use the number line below to verify that the sum below equals −7. Notice that the sign of the resulting number when you add two negative numbers is always negative.

$$-2 - 5 = -7$$
$$-2 +(-5) = -7$$

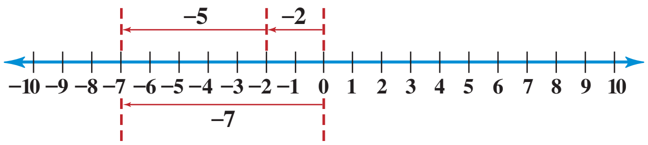


Table 1

Arithmetic Operations

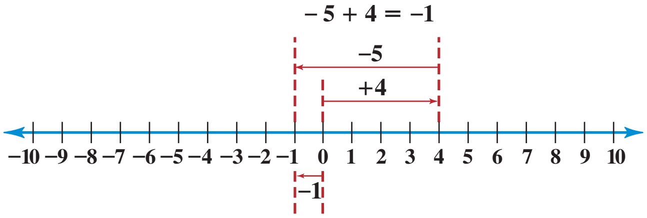
Operation	Sign	Result
Addition	+	Sum
Subtraction	−	Difference
Multiplication	×	Product
Division	÷	Quotient

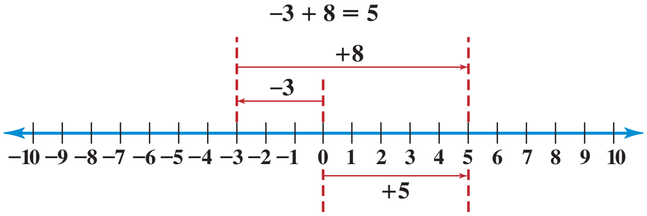
CONTENTS

Figure 2

The total mass of the eggs and the bowl is the sum of their individual masses. How would you determine the total mass of the eggs?

When adding a negative number to a positive number, the sign of the resulting number will be the same as the larger number.



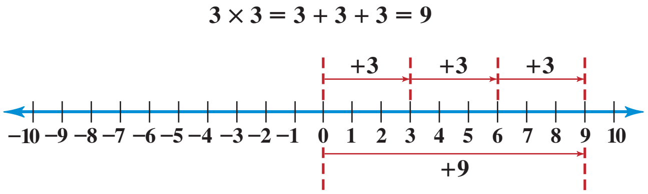


Suppose you must find the mass of the dozen eggs in **Figure 2.** You would measure the mass of the bowl alone. Then, subtract it from the mass of the eggs and the bowl. The result of this subtraction is called the difference. To find the difference between numbers, change the sign of the number being subtracted and follow the rules for addition. Use a number line to verify that the sign of the resulting number always will be the same as the larger number.

$$4 - 5 = 4 + (-5) = -1$$
$$4 - (-5) = 4 + 5 = 9$$
$$-4 - (-5) = -4 + 5 = 1$$
$$-4 - (+5) = -4 - 5 = -9$$

2. Multiplication

The result of multiplication is called a product. The operation "three times three" can be expressed by 3×3, (3)(3), or $3 \cdot 3$. Multiplication is simply repeated addition. For example, $3 \times 3 = 3 + 3 + 3 = 9$.



Use a number line to show that a negative number multiplied by a positive number yields a negative number.

$$(3)(-3) = -9$$
$$(-3) + (-3) + (-3) = -9$$

What happens when a negative number is multiplied by a negative number? The product is always positive.

$$(-4)(-5) = 20$$

3. Division

Division is an arithmetic operation whose result is called a quotient. A quotient is expressed by ÷ or as a ratio.The quotient of numbers that have the same sign is always positive.

$$\frac{32}{8} = 4 \text{ and } \frac{-32}{-4} = 8$$

A negative number divided by a positive number, or a positive number divided by a negative number always yields a negative number.

$$\frac{35}{-7} = -5 \text{ and } \frac{-48}{8} = -6$$

PRACTICE PROBLEMS

1. **Perform the following operations.**

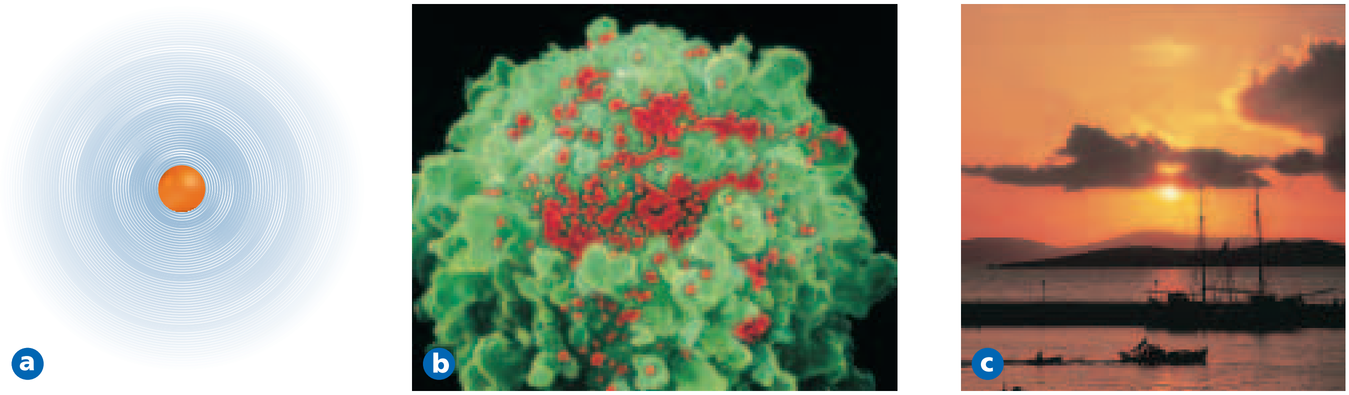
- **a.** $8 + 5 - 6$
- **b.** $-4 - 9$
- **c.** 6×8
- **d.** $56 \div 7$
- **e.** $0 - 12$
- **f.** -6×5
- **g.** $-14 + 9$
- **h.** $-44 \div 2$
- **i.** $(-16)(-4)$
- **j.** $(-32) \div (-8)$

Scientific Notation

Scientists must use extremely small and extremely large numbers to describe the objects in **Figure 3**. The mass of the proton at the center of a hydrogen atom is 0.000 000 000 000 000 000 000 000 001 673 kg. The length of the AIDS virus is about 0.000 000 11 m. The temperature at the center of the Sun reaches 15 000 000 K. Such small and large numbers are difficult to read and hard to work with in calculations. Scientists have adopted a method of writing exponential numbers called scientific notation. It is easier than writing numerous zeros when numbers are very large or small. It also is easier to compare the relative size of numbers when they are written in scientific notation.

Figure 3

Scientific notation provides a convenient way to express data with extremely large or small numbers. Express the mass of a proton ⓐ, the length of the AIDS virus ⓑ, and the temperature of the Sun ⓒ in scientific notation.



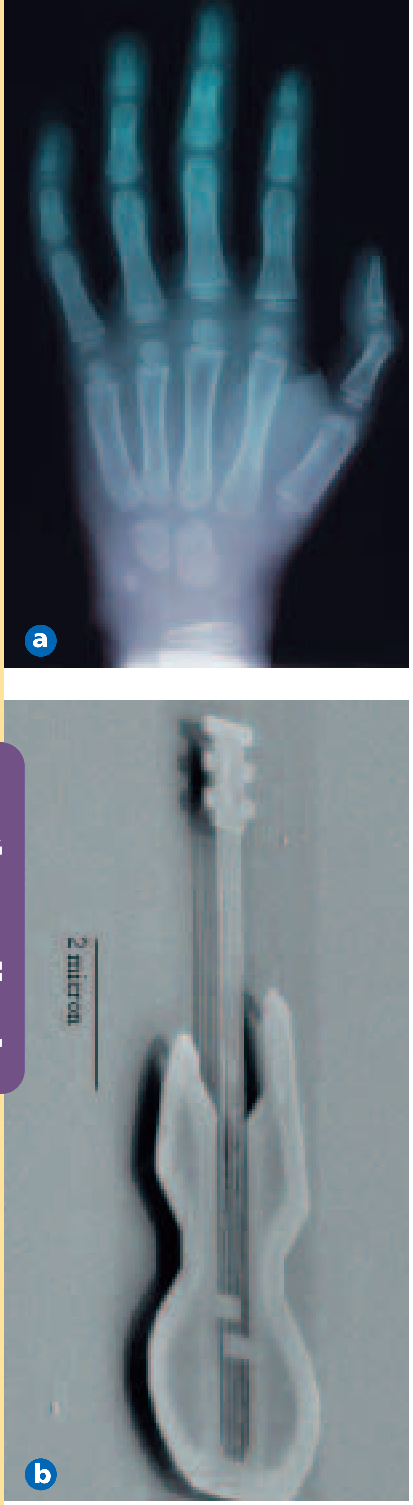


Figure 4

ⓐ Because of their short wavelengths (10^{-8} m to 10^{-13} m), X rays can pass through some objects. ⓑ A micron is 10^{-6} meter. Estimate the length of this nanoguitar in microns.

A number written in scientific notation has two parts.

$$N \times 10^n$$

The first part (N) is a number in which only one digit is placed to the left of the decimal point and all remaining digits to the right of the decimal point. The second part is an exponent of ten (10^n) by which the decimal portion is multiplied. For example, the number 2.53×10^6 is written in scientific notation.

$$\underbrace{2.53}_{\substack{\text{Number between}\\\text{one and ten}}} \times \underbrace{10^6}_{\substack{\text{Exponent}\\\text{of ten}}}$$

The decimal portion is 2.53 and the exponent is 10^6.

Positive exponents

A positive exponent of ten (n) tells how many times a number must be multiplied by ten to give the long form of the number.

$$2.53 \times 10^6 = 2.53 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 2\ 530\ 000$$

You also can think of the positive exponent of ten as the number of places you move the decimal to the left until only one nonzero digit is to the left of the decimal point.

$$2\ 530\ 000.$$

The decimal point moves six places to the left.

To convert the number 567.98 to scientific notation, first write the number as an exponential number by multiplying by 10^0.

$$567.98 \times 10^0$$

(Remember that multiplying any number by 10^0 is the same as multiplying the number by 1.) Move the decimal point to the left until there is only one digit to the left of the decimal. At the same time, increase the exponent by the same number as the number of places the decimal is moved.

$$5\ 67.98 \times 10^{0+2}$$

The decimal point moves two places to the left.

Thus, 567.98 written in scientific notation is 5.6798×10^2.

Negative exponents

Measurements also can have negative exponents. See **Figure 4.** A negative exponent of ten tells how many times a number must be divided by ten to give the long form of the number.

$$6.43 \times 10^{-4} = \frac{6.43}{10 \times 10 \times 10 \times 10} = 0.000643$$

A negative exponent of ten is the number of places you move the decimal to the right until it is just past the first nonzero digit.

When converting a number that requires the decimal to be moved to the right, the exponent is decreased by the appropriate number. For example, the expression of 0.0098 in scientific notation is as follows:

$$\begin{aligned} 0.\,0098 &\times 10^{0} \\ 0\ \overset{\curvearrowright}{009}8 &\times 10^{0-3} \\ 9.8 &\times 10^{-3} \end{aligned}$$

The decimal point
moves
three places
to the right.

Thus, 0.0098 written in scientific notation is 9.8×10^{-3}.

Figure 5

As blood passes through the body's tissues, red blood cells deliver oxygen and remove wastes. There are approximately 270 million hemoglobin molecules in one red blood cell.

Operations with scientific notation

The arithmetic operations performed with ordinary numbers can be done with numbers written in scientific notation. But, the exponential portion of the numbers also must be considered.

1. Addition and subtraction

Before numbers in scientific notation can be added or subtracted, the exponents must be equal. Remember that the decimal is moved to the left to increase the exponent and to the right to decrease the exponent.

$$\begin{aligned} (3.4 \times 10^{2}) + (4.57 \times 10^{3}) &= (0.34 \times 10^{3}) + (4.57 \times 10^{3}) \\ &= (0.34 + 4.57) \times 10^{3} \\ &= 4.91 \times 10^{3} \end{aligned}$$

2. Multiplication

When numbers in scientific notation are multiplied, only the decimal portion is multiplied. The exponents are added.

$$\begin{aligned} (2.00 \times 10^{3})(4.00 \times 10^{4}) &= (2.00)(4.00) \times 10^{3+4} \\ &= 8.00 \times 10^{7} \end{aligned}$$

3. Division

When numbers in scientific notation are divided, again, only the decimal portion is divided, while the exponents are subtracted as follows:

$$\frac{9.60 \times 10^{7}}{1.60 \times 10^{4}} = \frac{9.60}{1.60} \times 10^{7-4} = 6.00 \times 10^{3}$$

PRACTICE PROBLEMS

2. Express the following numbers in scientific notation.

a. 5800
b. 453 000
c. 67 929
d. 0.000 587 7
e. 0.0036
f. 0.000 087 5

Continued on next page

CONTENTS

3. Perform the following operations.

a. $(5.0 \times 10^{6}) + (3.0 \times 10^{7})$
b. $(1.8 \times 10^{9}) + (2.5 \times 10^{8})$
c. $(3.8 \times 10^{12}) - (1.9 \times 10^{11})$
d. $(6.0 \times 10^{-8}) - (4.0 \times 10^{-9})$

4. Perform the following operations.

a. $(6.0 \times 10^{-4}) \times (4.0 \times 10^{-6})$
b. $(4.5 \times 10^{9}) \times (7.0 \times 10^{-10})$
c. $\dfrac{4.5\times10^{-8}}{1.5\times10^{-4}}$
d. $\dfrac{9.6\times10^{8}}{1.6\times10^{-6}}$
e. $\dfrac{(2.5\times10^{6})(7.0\times10^{4})}{1.8\times10^{-5}}$
f. $\dfrac{(6.2\times10^{12})(5.8\times10^{-7})}{1.2\times10^{6}}$

5. See **Figure 5.** If you contain an average of 25 billion red blood cells, how many hemoglobin molecules are in your body?

Square and Cube Roots

A square root is one of two identical factors of a number. As you can see in **Figure 6a,** the number four is the product of two identical factors—two. Thus, the square root of four is two. The symbol $\sqrt{\ }$, called a radical sign, is used to indicate a square root. Most scientific calculators have a square root key labeled $\boxed{\sqrt{\ }}$.

$$\sqrt{4} = \sqrt{2 \times 2} = 2$$

This equation is read "the square root of four equals two." What is the square root of 9, shown in **Figure 6b?**

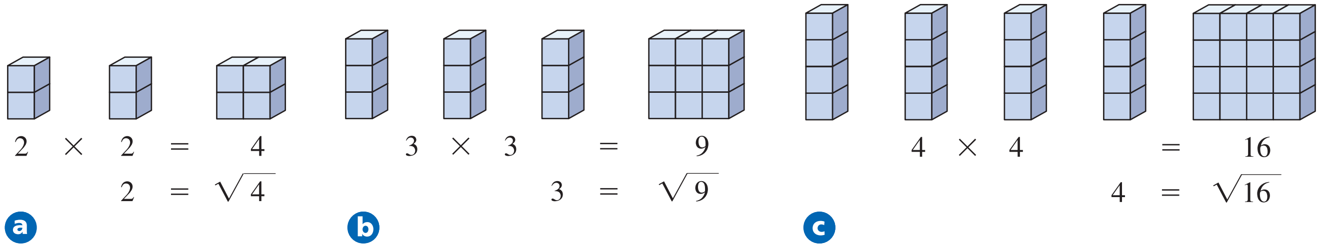
There may be more than two identical factors of a number. You know that $2 \times 4 = 8$. Are there any other factors of the number 8? It is the product of $2 \times 2 \times 2$. A cube root is one of three identical factors of a number. Thus, what is the cube root of 8? It is 2. A cube root also is indicated by a radical.

$$\sqrt[3]{8} = \sqrt[3]{2 \times 2 \times 2} = 2$$

Check your calculator handbook for more information on finding roots.

Figure 6

ⓐ The number four can be expressed as two groups of two. The identical factors are two. ⓑ The number nine can be expressed as three groups of three. Thus, three is the square root of nine. ⓒ Four is the square root of 16. Use your calculator to determine the cube root of 16.



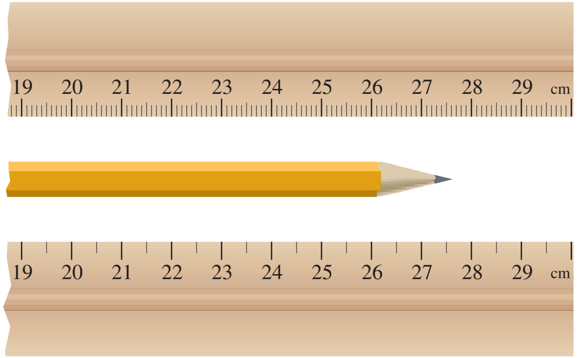


Figure 7

The estimated digit must be read between the millimeter markings on the top ruler. Why is the bottom ruler less precise?

Significant Figures

Much work in science involves taking measurements. Measurements that you take in the laboratory should show both accuracy and precision. Accuracy reflects how close your measurement comes to the real value. Precision describes the degree of exactness of your measurement. Which ruler in **Figure 7** would give you the most precise length? The top ruler with the millimeter markings would allow your measurements to come closer to the actual length of the pencil. The measurement would be more precise.

Measuring tools are never perfect, nor are the people doing the measuring. Therefore, whenever you measure a physical quantity, there will always be uncertainty in the measurement. The number of significant figures in the measurement indicates the uncertainty of the measuring tool.

The number of significant figures in a measured quantity is all of the certain digits plus the first uncertain digit. For example, the pencil in **Figure 8** has a length that falls between 27.6 and 27.7 cm. You can read the ruler to the nearest millimeter (27.6 cm), but after that you must estimate the next digit in the measurement. If you estimate that the next digit is 5, you would report the measured length of the pencil as 27.65 cm. Your measurement has four significant figures. The first three are certain and the last is uncertain. The ruler used to measure the pencil has precision to the nearest tenth of a millimeter.

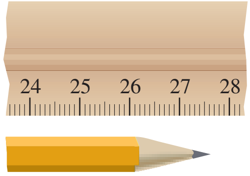


Figure 8

If you determine that the length of this pencil is 27.65 cm, that measurement has four significant figures.

How many significant figures?

When a measurement is provided, the following series of rules will help you to determine how many significant figures there are in that measurement.

1. *All nonzero figures are significant.*
2. *When a zero falls between nonzero digits, the zero is also significant.*
3. *When a zero falls after the decimal point and after a significant figure, that zero is significant.*
4. *When a zero is used merely to indicate the position of the decimal, it is not significant.*
5. *All counting numbers and exact numbers are treated as if they have an infinite number of significant figures.*

CONTENTS

Examine each of the following measurements. Use the rules on the previous page to check that all of them have three significant figures.

245 K 18.0 L 308 km 0.006 23 g 186 000 m

Suppose you must do a calculation using the measurement 200 L. You cannot be certain which zero was estimated. To indicate the significance of digits, especially zeros, write measurements in scientific notation. In scientific notation, all digits in the decimal portion are significant. Which of the following measurements is most precise?

200 L has unknown significant figures.
2×10^2 L has one significant figure.
2.0×10^2 L has two significant figures.
2.00×10^2 L has three significant figures.

The greater the number of digits in a measurement expressed in scientific notation, the more precise the measurement is. In this example, 2.00×10^2 L is the most precise data.

EXAMPLE PROBLEM 1

How many significant digits are in the measurement 0.00302 g? 5.620 m? 9.80×10^2 m/s^2?

$\underline{0.003}\ \underline{02}$ g

Not significant (Rule 4) — Significant (Rules 1 and 2)

The measurement 0.00302 g has three significant figures.

$\underline{60}$ min

Unlimited significant figures
(Rule 5)

$\underline{5.620}$ m

Significant
(Rules 1 and 3)

The measurement 5.620 m has four significant figures.

$\underline{9.80} \times 10^2$ m/s^2

Significant
(Rules 1 and 3)

The measurement 9.80×10^2 m/s^2 has three significant figures.

CONTENTS

PRACTICE PROBLEMS

6. Determine the number of significant figures in each measurement:

a. 35 g
b. 3.57 m
c. 3.507 km
d. 0.035 kg
e. 0.246 L
f. 0.004 m^3
g. 24.068 kPa
h. 268 K
i. 20.040 80 g
j. 20 dozen
k. 730 000 kg
l. 6.751 g
m. 0.157 kg
n. 28.0 mL
o. 2500 m
p. 0.070 mol
q. 30.07 nm
r. 0.106 cm
s. 0.0076 g
t. 0.0230 cm^3
u. 26.509 cm
v. 54.52 cm^3
w. 2.40×10^6 kg
x. 4.07×10^{16} m

Rounding

Arithmetic operations that involve measurements are done the same way as operations involving any other numbers. But, the results must correctly indicate the uncertainty in the calculated quantities. Perform all of the calculations and then round the result to the least number of significant figures. To round a number, use the following rules.

1. *When the leftmost digit to be dropped is less than 5, that digit and any digits that follow are dropped. Then the last digit in the rounded number remains unchanged.* For example, when rounding the number 8.7645 to 3 significant figures, the leftmost digit to be dropped is 4. Therefore, the rounded number is 8.76.
2. *When the leftmost digit to be dropped is greater than 5, that digit and any digits that follow are dropped, and the last digit in the rounded number is increased by one.* For example, when rounding the number 8.7676 to 3 significant figures, the leftmost digit to be dropped is 7. Therefore, the rounded number is 8.77.
3. *When the leftmost digit to be dropped is 5 followed by a nonzero number, that digit and any digits that follow are dropped. The last digit in the rounded number increases by one.* For example, 8.7519 rounded to 2 significant figures equals 8.8.
4. *If the digit to the right of the last significant figure is equal to 5 and 5 is not followed by a nonzero digit, look at the last significant figure. If it is odd, increase it by one; if even, do not round up.* For example, 92.350 rounded to 3 significant figures equals 92.4 and 92.25 equals 92.2.

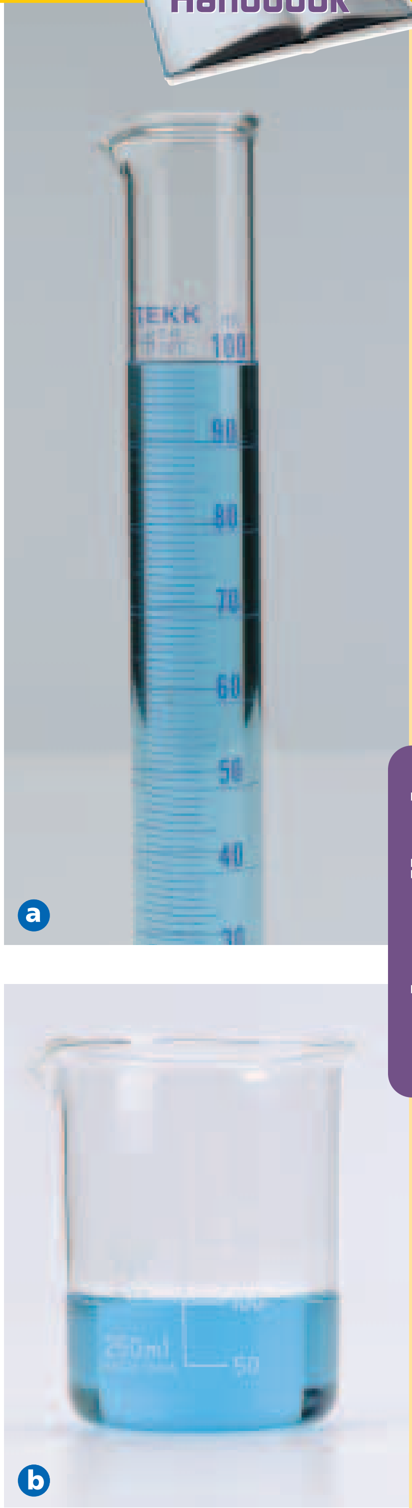


Figure 9

Compare the markings on the graduated cylinder ⓐ to the markings on the beaker ⓑ. Which piece of glassware will yield more precise measurements?

Calculations with significant figures

Look at the glassware in **Figure 9.** Would you expect to measure a more precise volume with the beaker or the graduated cylinder? When you perform any calculation using measured quantities such as volume, it is important to

Math Handbook

CONTENTS

remember that the result never can be more precise than the least precise measurement. That is, your answer cannot have more significant figures than the least precise measurement. Be sure to perform all calculations before dropping any insignificant digits.

The following rules determine how to use significant figures in calculations that involve measurements.

1. *To add or subtract measurements, first perform the mathematical operation, then round off the result to the least precise value.* There should be the same number of digits to the right of the decimal as the measurement with the least number of decimal digits.
2. *To multiply or divide measurements, first perform the calculation, then round the answer to the same number of significant figures as the measurement with the least number of significant figures.* The answer should contain no more significant figures than the fewest number of significant figures in any of the measurements in the calculation.

Table 2

Gas Pressures in Air

	Pressure (kPa)
Nitrogen gas	79.10
Carbon dioxide gas	0.040
Trace gases	0.94
Total gases	101.3

EXAMPLE PROBLEM 2

Air contains oxygen (O_2), nitrogen (N_2), carbon dioxide (CO_2), and trace amounts of other gases. Use the known pressures in **Table 2** to calculate the partial pressure of oxygen.

To add or subtract measurements, first perform the operation, then round off the result to correspond to the least precise value involved.

$$P_{O_2} = P_{total} - (P_{N_2} + P_{CO_2} + P_{trace})$$
$$P_{O_2} = 101.3 \text{ kPa} - (79.10 \text{ kPa} + 0.040 \text{ kPa} + 0.94 \text{ kPa})$$
$$P_{O_2} = 101.3 \text{ kPa} - 80.080 \text{ kPa}$$
$$P_{O_2} = 21.220 \text{ kPa}$$

The total pressure (P_{total}) was measured to the tenths place. It is the least precise measurement. Therefore, the result should be rounded to the nearest tenth of a kilopascal. The leftmost dropped digit (1) is less than five, so the last two digits can be dropped.

The pressure of oxygen is $P_{O_2} = 21.2$ kPa.

A small, hand-held pressure gauge can be used to monitor tire pressure.

EXAMPLE PROBLEM 3

The reading on a tire-pressure gauge is 35 psi. What is the equivalent pressure in kilopascals?

$$P = 35 \cancel{\text{psi}} \times \frac{101.3 \text{ kPa}}{14.7 \cancel{\text{psi}}}$$
$$P = 241.1904762 \text{ kPa}$$

There are two significant figures in the measurement, 35 psi. Thus, the answer can have only two significant figures. Do not round up the last digit to be kept because the leftmost dropped digit (1) is less than five.

The equivalent pressure is $P = 240 \text{ kPa} = 2.4 \times 10^2$ kPa.

PRACTICE PROBLEMS

7. Round off the following measurements to the number of significant figures indicated in parentheses.

a. 2.7518 g (3)

b. 8.6439 m (2)

c. 13.841 g (2)

d. 186.499 m (5)

e. 634 892.34 g (4)

f. 355 500 g (2)

8. Perform the following operations.

a. $(2.475\text{ m}) + (3.5\text{ m}) + (4.65\text{ m})$

b. $(3.45\text{ m}) + (3.658\text{ m}) + (47\text{ m})$

c. $(5.36 \times 10^{-4}\text{ g}) - (6.381 \times 10^{-5}\text{ g})$

d. $(6.46 \times 10^{12}\text{ m}) - (6.32 \times 10^{11}\text{ m})$

e. $(6.6 \times 10^{12}\text{ m}) \times (5.34 \times 10^{18}\text{ m})$

f. $\dfrac{5.634 \times 10^{11}\text{ m}}{3.0 \times 10^{12}\text{ m}}$

g. $\dfrac{(4.765 \times 10^{11}\text{ m})(5.3 \times 10^{-4}\text{ m})}{7.0 \times 10^{-5}\text{ m}}$

Solving Algebraic Equations

When you are given a problem to solve, it often can be written as an algebraic equation. You can use letters to represent measurements or unspecified numbers in the problem. The laws of chemistry are often written in the form of algebraic equations. For example, the ideal gas law relates pressure, volume, amount, and temperature of the gases the pilot in **Figure 10** breathes. The ideal gas law is written

$$PV = nRT$$

where the variables are pressure (P), volume (V), number of moles (n), and temperature (T). R is a constant. This is a typical algebraic equation that can be manipulated to solve for any of the individual variables.

Figure 10

Pilots must rely on additional oxygen supplies at high altitudes to prevent hypoxia–a condition in which the tissues of the body become oxygen deprived.

When you solve algebraic equations, any operation that you perform on one side of the equal sign must be performed on the other side of the equation. Suppose you are asked to use the ideal gas law to find the pressure of the gas (P) in the bottle in **Figure 11.** To solve for, or isolate, P requires you to divide the left-hand side of the equation by V. This operation must be performed on the right-hand side of the equation as well.

$$PV = nRT$$

$$\frac{PV}{V} = \frac{nRT}{V}$$

The V's on the left-hand side of the equation cancel each other out.

$$\frac{PV}{V} = \frac{nRT}{V}$$

$$P \times \frac{V}{V} = \frac{nRT}{V}$$

$$P \times 1 = \frac{nRT}{V}$$

$$P = \frac{nRT}{V}$$

The ideal gas law equation is now written in terms of pressure. That is, P has been isolated.

Order of operations

When isolating a variable in an equation, it is important to remember that arithmetic operations have an order of operations that must be followed. See **Figure 12.** Operations in parentheses (or brackets) take precedence over multiplication and division, which in turn take precedence over addition and subtraction. For example, in the equation

$$a + b \times c$$

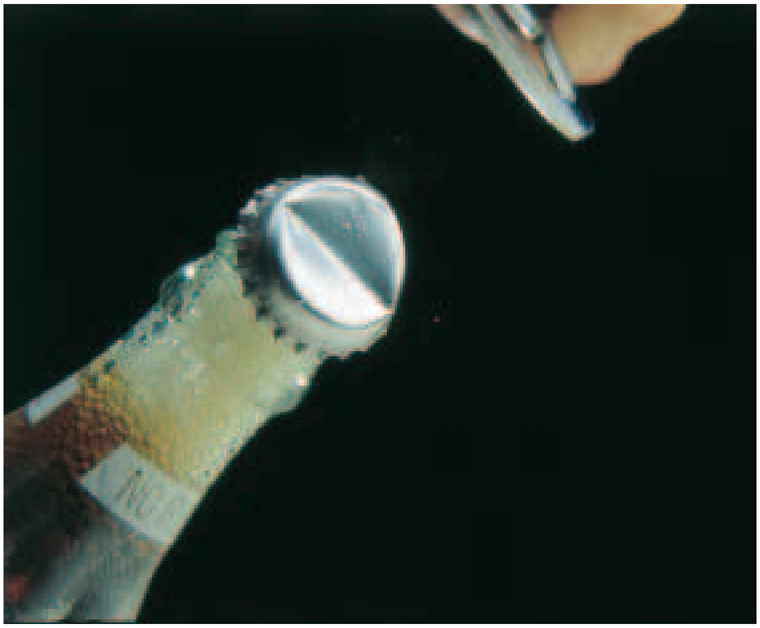
variable b must be multiplied first by variable c. Then, the resulting product is added to variable a. If the equation is written

$$(a + b) \times c$$

the operation in parentheses or brackets must be done first. In the equation above, variable a is added to variable b before the sum is multiplied by variable c.

Figure 11

This beverage is bottled under pressure in order to keep carbon dioxide gas in the beverage solution.



To see the difference order of operations makes, try replacing a with 2, b with 3, and c with 4.

$$a + (b \times c) = 2 + (3 \times 4) = 14$$
$$(a + b) \times c = (2 + 3) \times 4 = 20$$

To solve algebraic equations, you also must remember the distributive property. To remove parentheses to solve a problem, any number outside the parentheses is "distributed" across the parentheses as follows:

$$6(x + 2y) = 6x + 12y$$

EXAMPLE PROBLEM 4

The temperature on a cold day was 25°F. What was the temperature on the Celsius scale?

Begin with the equation for the conversion from the Celsius to Fahrenheit temperature. Celsius temperature is the unknown variable.

$$°\text{F} = \frac{9}{5}°\text{C} + 32$$

Rearrange the equation to isolate °C. Begin by subtracting 32 from both sides.

$$°\text{F} - 32 = \frac{9}{5}°\text{C} + 32 - 32$$

$$°\text{F} - 32 = \frac{9}{5}°\text{C}$$

Then, multiply both sides by 5.

$$5 \times (°\text{F} - 32) = 5 \times \frac{9}{5}°\text{C}$$

$$5 \times (°\text{F} - 32) = 9°\text{C}$$

Finally, divide both sides by 9.

$$\frac{5 \times (°\text{F} - 32)}{9} = \frac{9°\text{C}}{9}$$

$$°\text{C} = \frac{5}{9}(°\text{F} - 32)$$

Substitute in the known Fahrenheit temperature.

$$°\text{C} = \frac{5}{9}(°\text{F} - 32)$$

$$= \frac{5}{9}(25 - 32)$$

$$= -3.9°\text{C}$$

The Celsius temperature is −3.9°C.

PRACTICE PROBLEMS

Isolate the indicated variable in each equation.

9. $PV = nRT$ for R

10. $3 = 4(x + y)$ for y

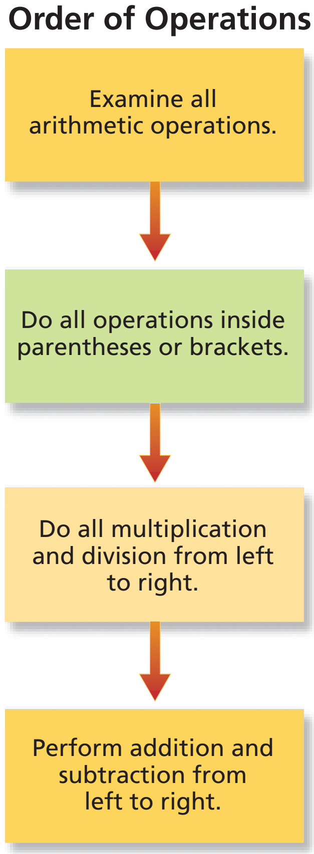
11. $z = x(4 + 2y)$ for y

12. $\frac{2}{x} = 3 + y$ for x

13. $\frac{2x + 1}{3} = 6$ for x

Figure 12

When faced with an equation that contains more than one operation, use this flow chart to determine the order in which to perform your calculations.



Order of Operations

Dimensional Analysis

The dimensions of a measurement refer to the type of units attached to a quantity. For example, length is a dimensional quantity that can be measured in meters, centimeters, and kilometers. Dimensional analysis is the process of solving algebraic equations for units as well as numbers. It is a way of checking to ensure that you have used the correct equation, and that you have correctly applied the rules of algebra when solving the equation. It also can help you to choose and set up the correct equation, as you will see on the next page when you learn how to do unit conversions. It is good practice to make dimensional analysis a habit by always stating the units as well as the numerical values whenever substituting values into an equation.

Aluminum is a metal that is useful from the kitchen to the sculpture garden.

EXAMPLE PROBLEM 5

The density (D) of aluminum is 2700 kg/m^3. Determine the mass (m) of a piece of aluminum of volume (V) 0.20 m^3.

The equation for density is

$$D = \frac{m}{V}$$

Multiply both sides of the equation by V and isolate m.

$$DV = \frac{mV}{V}$$

$$DV = \frac{V}{V} \times m$$

$$m = DV$$

Substitute the known values for D and V.

$$m = DV = (2700\ \text{kg}/\cancel{\text{m}^3})(0.20\ \cancel{\text{m}^3}) = 540\ \text{kg}$$

Notice that the unit m^3 cancels out, leaving mass in kg, a unit of mass.

PRACTICE PROBLEMS

Determine whether the following equations are dimensionally correct. Explain.

14. $v = s \times t$ where v = 24 m/s, s = 12 m and t = 2 s.

15. $R = \frac{nT}{PV}$ where R is in L·atm/mol·K, n is in mol, T is in K, P is in atm, and V is in L.

16. $t = \frac{v}{s}$ where t is in seconds, v is in m/s and s is in m.

17. $s = \frac{at^2}{2}$ where s is in m, a is in m/s^2, and t is in s.

CONTENTS

Unit Conversion

Recall from Chapter 2 that the universal unit system used by scientists is called Le Système Internationale d'Unités or SI. It is a metric system based on seven base units—meter, second, kilogram, kelvin, mole, ampere, and candela—from which all other units are derived. The size of a unit in a metric system is indicated by a prefix related to the difference between that unit and the base unit. For example, the base unit for length in the metric system is the meter. One tenth of a meter is a decimeter where the prefix *deci-* means one tenth. And, one thousand meters is a kilometer. The prefix *kilo-* means one thousand.

You can use the information in **Table 3** to express a measured quantity in different units. For example, how is 65 meters expressed in centimeters? **Table 3** indicates one centimeter and one-hundredth meter are equivalent, that is, 1 cm = 10^{-2} m. This information can be used to form a conversion factor. A conversion factor is a ratio equal to one that relates two units. You can make the following conversion factors from the relationship between meters and centimeters. Be sure when you set up a conversion factor that the measurement in the numerator (the top of the ratio) is equivalent to the denominator (the bottom of the ratio).

$$1 = \frac{1\text{ cm}}{10^{-2}\text{ m}} \text{ and } 1 = \frac{10^{-2}\text{ m}}{1\text{ cm}}$$

Recall that the value of a quantity does not change when it is multiplied by one. To convert 65 m to centimeters, multiply by a conversion factor.

$$65\ \cancel{\text{m}} \times \frac{1\text{ cm}}{10^{-2}\ \cancel{\text{m}}} = 65 \times 10^{2}\text{ cm} = 6.5 \times 10^{3}\text{ cm}$$

Note the conversion factor is set up so that the unit meters cancels and the answer is in centimeters as required. When setting up a unit conversion, use dimensional analysis to check that the units cancel to give an answer in the desired units. And, always check your answer to be certain the units make sense.

Table 3

Common SI Prefixes

Prefix	Symbol	Exponential notation	Prefix	Symbol	Exponential notation
Peta	P	10^{15}	Deci	d	10^{-1}
Tera	T	10^{12}	Centi	c	10^{-2}
Giga	G	10^{9}	Milli	m	10^{-3}
Mega	M	10^{6}	Micro	µ	10^{-6}
Kilo	k	10^{3}	Nano	n	10^{-9}
Hecto	h	10^{2}	Pico	p	10^{-12}
Deka	da	10^{1}	Femto	f	10^{-15}

CONTENTS

You make unit conversions everyday when you determine how many quarters are needed to make a dollar or how many feet are in a yard. One unit that is often used in calculations in chemistry is the mole. Chapter 11 shows you equivalent relationships among mole, grams, and the number of representative particles (atoms, molecules, formula units, or ions). For example, one mole of a substance contains 6.02×10^{23} representative particles. Try the next example to see how this information can be used in a conversion factor to determine the number of atoms in a sample of manganese.

EXAMPLE PROBLEM 6

One mole of manganese (Mn) in the photo has a mass of 54.94 g. How many atoms are in two moles of manganese?

You are given the mass of one mole of manganese. In order to convert to the number of atoms, you must set up a conversion factor relating the number of moles and the number of atoms.

$$\frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ atoms}} \quad \text{and} \quad \frac{6.02 \times 10^{23} \text{ atoms}}{1 \text{ mole}}$$

Choose the conversion factor that cancels units of moles and gives an answer in number of atoms.

$$2.0 \cancel{\text{mole}} \times \frac{6.02 \times 10^{23} \text{ atoms}}{1 \cancel{\text{mole}}} = 12.04 \times 10^{23} \text{ atoms}$$

$$= 1.2 \times 10^{24} \text{ atoms}$$

The answer is expressed in the desired units (number of atoms). It is expressed in two significant figures because the number of moles (2.0) has the least number of significant figures.

How many significant figures are in this measurement?

PRACTICE PROBLEMS

18. Convert the following measurements as indicated.

a. 4 m = ______cm

b. 50.0 cm = ______m

c. 15 cm = ______mm

d. 567 mg = _____g

e. 4.6×10^3 m = _____mm

f. 8.3×10^4 g = ______kg

g. 7.3×10^5 mL = _____L

h. 8.4×10^{10} m = _____km

i. 3.8×10^4 m^2 = _____mm^2

j. 6.9×10^{12} cm^2 = _____m^2

k. 6.3×10^{21} mm^3 = _____cm^3

l. 9.4×10^{12} cm^3 = _____m^3

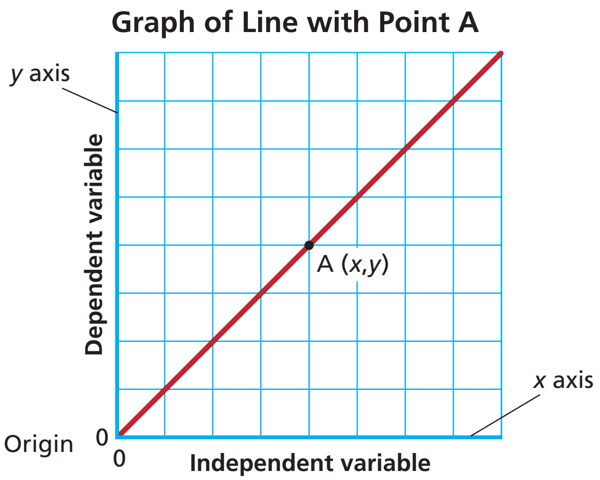


Figure 13

a Once experimental data has been collected, it must be analyzed to determine the relationships between the measured variables.
b Any graph of your data should include labeled *x*- and *y*-axes, a suitable scale, and a title.

Drawing Line Graphs

Scientists, such as the one in **Figure 13a,** as well as you and your classmates, use graphing to analyze data gathered in experiments. Graphs provide a way to visualize data in order to determine the mathematical relationship between the variables in your experiment. Most often you use line graphs.

Line graphs are drawn by plotting variables along two axes. See **Figure 13b.** Plot the independent variable on the *x*-axis (horizontal axis), also called the abscissa. The independent variable is the quantity controlled by the person doing the experiment. Plot the dependent variable on the *y*-axis (vertical axis), also called the ordinate. The dependent variable is the variable that depends on the independent variable. Label the axes with the variables being plotted and the units attached to those variables.

Determining a scale

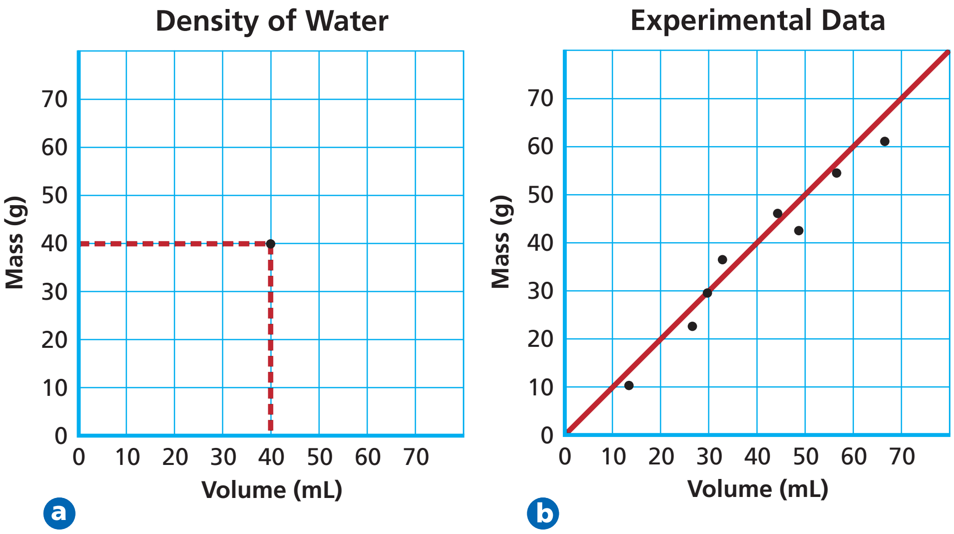
An important part of graphing is the selection of a scale. Scales should be easy to plot and easy to read. First, examine the data to determine the highest and lowest values. Assign each division on the axis (the square on the graph paper) with an equal value so that all data can be plotted along the axis. Scales divided into multiples of 1, 2, 5, or 10, or decimal values, often are the most convenient. It is not necessary to start at zero on a scale, nor is it necessary to plot both variables to the same scale. Scales must, however, be labeled clearly with the appropriate numbers and units.

Plotting data

The values of the independent and dependent variables form ordered pairs of numbers, called the *x*-coordinate and the *y*-coordinate (x,y), that correspond to points on the graph. The first number in an ordered pair always corresponds to the *x*-axis; the second number always corresponds to the *y*-axis. The ordered pair (0,0) always is the origin. Sometimes the points are named by using a letter. In **Figure 13b,** point A corresponds to the point (x,y).

Figure 14

a To plot a point on a graph, place a dot at the location for each ordered pair (*x*,*y*) determined by your data. In this example, the dot marks the ordered pair (40 mL, 40 g).
b Generally, the line or curve that you draw will not include all of your experimental data points.



After the scales are chosen, plot the data. To graph or plot an ordered pair means to place a dot at the point that corresponds to the values in the ordered pair. The *x*-coordinate indicates how many units to move right (if the number is positive) or left (if the number is negative). The *y*-coordinate indicates how many units to move up or down. Which direction is positive on the *y*-axis? Negative? Locate each pair of *x*- and *y*-coordinates by placing a dot as shown in **Figure 14a.** Sometimes, a pair of rulers, one extending from the *x*-axis and the other from the *y*-axis, can ensure that data is plotted correctly.

Drawing a curve

Once the data is plotted, a straight line or a curve is drawn. It is not necessary to make it go through every point plotted, or even any of the points, as shown in **Figure 14b.** Graphing of experimental data is an averaging process. If the points do not fall along a line, the best-fit line or most probable smooth curve through the points should be drawn. When drawing the curve, do not assume it will go through the origin (0,0).

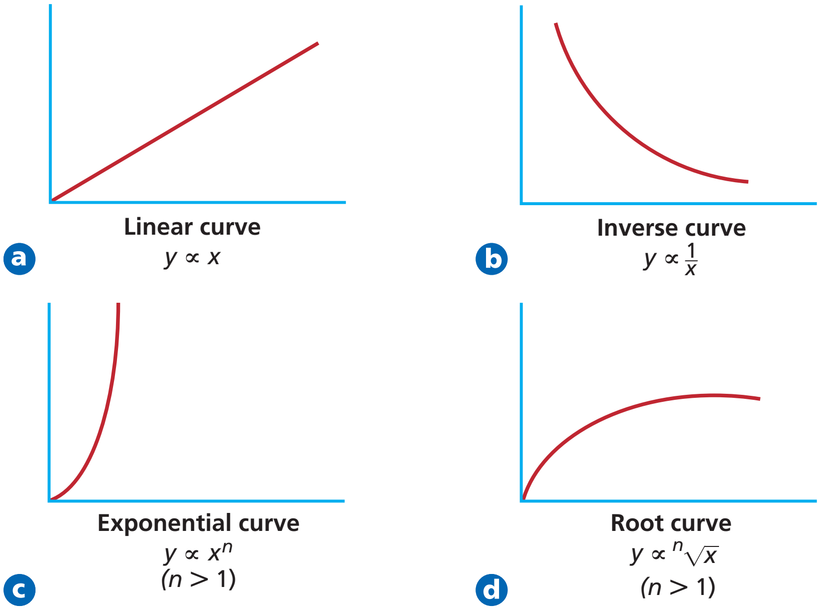
Naming a graph

Last but not least, give each graph a title that describes what is being graphed. The title should be placed at the top of the page, or in a box on a clear area of the graph. It should not cross the data curve.

Once the data from an experiment has been collected and plotted, the graph must be interpreted. Much can be learned about the relationship between the independent and dependent variables by examining the shape and slope of the curve.

Using Line Graphs

The curve on a graph gives a great deal of information about the relationship between the variables. Four common types of curves are shown in **Figure 15.** Each type of curve corresponds to a mathematical relationship between the independent and dependent variables.



Linear curve $y \propto x$

Inverse curve $y \propto \frac{1}{x}$

Exponential curve $y \propto x^n$ $(n > 1)$

Root curve $y \propto \sqrt[n]{x}$ $(n > 1)$

Figure 15

The shape of the curve formed by a plot of experimental data indicates how the variables are related.

Direct and inverse relationships

In your study of chemistry, the most common curves are the linear, representing the direct relationship ($y \propto x$), and the inverse, representing the inverse relationship ($y \propto 1/x$), where x represents the independent variable and y represents the dependent variable. In a direct relationship, y increases in value as x increases in value or y decreases when x decreases. In an inverse relationship, y decreases in value as x increases in value.

An example of a typical direct relationship is the increase in volume of a gas with increasing temperature. When the gases inside a hot air balloon are heated, the balloon gets larger. As the balloon cools, its size decreases. However, a plot of the decrease in pressure as the volume of a gas increases yields a typical inverse curve.

You also may encounter exponential and root curves in your study of chemistry. See **Figure 15c** and **d.** What types of relationships between the independent and dependent variables do the curves describe? How do the curves differ from **a** and **b?** An exponential curve describes a relationship in which one variable is expressed by an exponent. And, a root curve describes a relationship in which one variable is expressed by a root. What type of relationship is described by the curve in **Figure 16?**

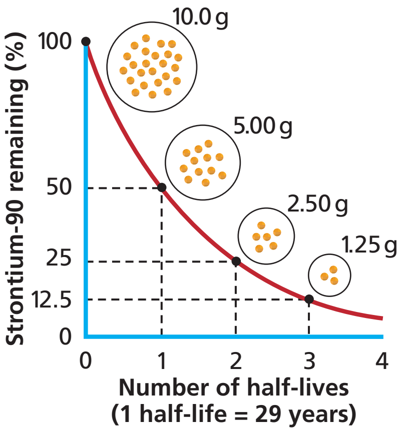


Figure 16

Half-life is the amount of time it takes for half of a sample of a radioactive isotope to decay (Chapters 4 and 25). Notice that as the number of half-lives increases, the amount of sample decreases.

The linear graph

The linear graph is useful in analyzing data because a linear relationship can be translated easily into equation form using the equation for a straight line

$$y = mx + b$$

where y stands for the dependent variable, m is the slope of the line, x stands for the independent variable, and b is the y-intercept, the point where the curve crosses the y-axis.

CONTENTS

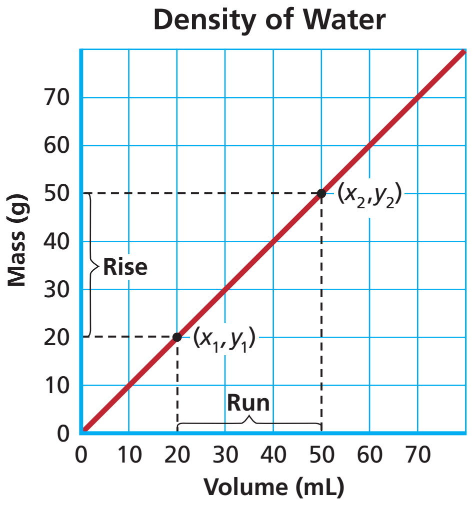


Figure 17

A steep slope indicates that the dependent variable changes rapidly with a change in the independent variable. What would an almost flat line indicate?

The slope of a linear graph is the steepness of the line. Slope is defined as the ratio of the vertical change (the rise) to the horizontal change (the run) as you move from one point to the next along the line. See **Figure 17.** To calculate slope, choose any two points on the line, (x_1,y_1) and (x_2,y_2). The two points need not be actual data points, but both must fall somewhere on the straight line. Once two points have been selected, calculate slope m using the equation

$$m = \frac{\text{rise}}{\text{run}} = \frac{\triangle y}{\triangle x} = \frac{y_2 - y_1}{x_2 - x_1}, \text{ where } x_1 \neq x_2$$

where the symbol $\triangle$ stands for change, x_1 and y_1 are the coordinates or values of the first point, and x_2 and y_2 are the coordinates of the second point.

Choose any two points along the graph of mass vs. volume in **Figure 18** and calculate its slope.

$$m = \frac{135\text{ g} - 54\text{ g}}{50.0\text{ cm}^3 - 20.0\text{ cm}^3} = 2.7\text{ g/cm}^3$$

Note that the units for the slope are the units for density. Plotting a graph of mass versus volume is one way of determining the density of a substance.

Apply the general equation for a straight line to the graph in **Figure 18.**

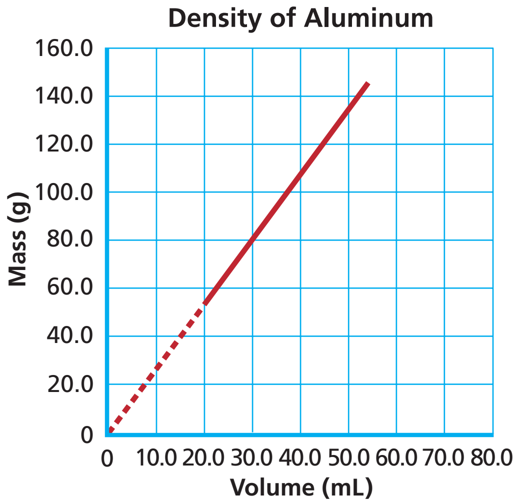
$$y = mx + b$$
$$mass = (2.7\text{ g/cm}^3)(volume) + 0$$
$$mass = (2.7\text{ g/cm}^3)(volume)$$

This equation verifies the direct relationship between mass and volume. For any increase in volume, the mass also increases.

Interpolation and extrapolation

Graphs also serve functions other than determining the relationship between variables. They permit interpolation, the prediction of values of the independent and dependent variables. For example, you can see in the table in **Figure 18** that the mass of 40.0 cm^3 of aluminum was not measured. But, you can interpolate from the graph that the mass would be 108 g.

Graphs also permit extrapolation, which is the determination of points beyond the measured points. To extrapolate, draw a broken line to extend the



Data

Volume (mL)	Mass (g)
20.0	54.0
30.0	81.0
50.0	135.0

Figure 18

Interpolation and extrapolation will help you determine the values of points you did not plot.

curve to the desired point. In **Figure 18,** you can determine that the mass at 10.0 cm^3 equals 27 g. One caution regarding extrapolation—some straight-line curves do not remain straight indefinitely. So, extrapolation should only be done where there is a reasonable likelihood that the curve doesn't change.

PRACTICE PROBLEMS

19. Plot the data in each table. Explain whether the graphs represent direct or inverse relationships.

Table 4

Effect of Pressure on Gas

Pressure (mm Hg)	Volume (mL)
3040	5.0
1520	10.0
1013	15.0
760	20.0

Table 5

Effect of Pressure on Gas

Pressure (mm Hg)	Temperature (K)
3040	1092
1520	546
1013	410
760	273

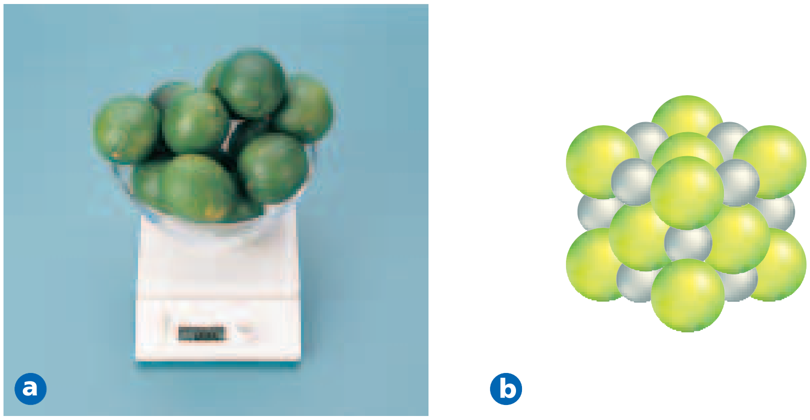
Ratios, Fractions, and Percents

When you analyze data, you may be asked to compare measured quantities. Or, you may be asked to determine the relative amounts of elements in a compound. Suppose, for example, you are asked to compare the molar masses of the diatomic gases, hydrogen (H_2) and oxygen (O_2). The molar mass of hydrogen gas equals 2.00 g/mol; the molar mass of oxygen equals 32.00 g/mol. The relationship between molar masses can be expressed in three ways: a ratio, a fraction, or a percent.

CONTENTS

Figure 19

ⓐ The mass of one lime would be one-twelfth the mass of one dozen limes. ⓑ In a crystal of table salt (sodium chloride), each sodium ion is surrounded by chloride ions, yet the ratio of sodium ions to chloride ions is one:one. The formula for sodium chloride is NaCl.



Ratios

You make comparisons using ratios in your daily life. For example, if the mass of a dozen limes is shown in **Figure 19a,** how does it compare to the mass of one lime? The mass of one dozen limes is twelve times larger than the mass of one lime. In chemistry, the chemical formula for a compound compares the elements that make up that compound. See **Figure 19b.** A ratio is a comparison of two numbers by division. One way it can be expressed is with a colon (:). The comparison between the molar masses of oxygen and hydrogen can be expressed as follows.

$$\begin{gathered}\text{molar mass } (H_2)\text{:molar mass } (O_2)\\ 2.00 \text{ g/mol:}32.00 \text{ g/mol}\\ 2.00\text{:}32.00\\ 1\text{:}16\end{gathered}$$

Notice that the ratio 1:16 is the smallest integer (whole number) ratio. It is obtained by dividing both numbers in the ratio by the smaller number, and then rounding the larger number to remove the digits after the decimal. The ratio of the molar masses is one to sixteen. In other words, the ratio indicates that the molar mass of diatomic hydrogen gas is sixteen times smaller than the molar mass of diatomic oxygen gas.

Fractions

Ratios are often expressed as fractions in simplest form. A fraction is a quotient of two numbers. To express the comparison of the molar masses as a fraction, place the molar mass of hydrogen over the molar mass of oxygen as follows:

$$\frac{\text{molar mass } H_2}{\text{molar mass } O_2} = \frac{2.00 \cancel{\text{g/mol}}}{32.00 \cancel{\text{g/mol}}} = \frac{2.00}{32.00} = \frac{1}{16}$$

In this case, the simplified fraction is calculated by dividing both the numerator (top of the fraction) and the denominator (bottom of the fraction) by 2.00. This fraction yields the same information as the ratio. That is, diatomic hydrogen gas has one-sixteenth the mass of diatomic oxygen gas.

Percents

A percent is a ratio that compares a number to 100. The symbol for percent is %. You also are used to working with percents in your daily life. The number of correct answers on an exam may be expressed as a percent. If you answered 90 out of 100 questions correctly, you would receive a grade of 90%. Signs like the one in **Figure 20** indicate a reduction in price. If the item's regular price is $100, how many dollars would you save? Sixty-five percent means 65 of every 100, so you would save $65. How much would you save if the sign said 75% off?

Figure 20

Would the savings be large at this sale? How would you determine the sale price?

The comparison between molar mass of hydrogen gas and the molar mass of oxygen gas described on the previous page also can be expressed as a percent by taking the fraction, converting it to decimal form, and multiplying by 100 as follows:

$$\frac{\text{molar mass } H_2}{\text{molar mass } O_2} \times 100 = \frac{2.00 \cancel{\text{g/mol}}}{32.00 \cancel{\text{g/mol}}} \times 100 = 0.0625 \times 100 = 6.25\%$$

Thus, diatomic hydrogen gas has 6.25% of the mass of diatomic oxygen gas.

Operations Involving Fractions

Fractions are subject to the same type of operations as other numbers. Remember that the number on the top of a fraction is the numerator and the number on the bottom is the denominator. See **Figure 21.**

$$\text{Quotient} = \frac{9 \times 10^{8}}{3 \times 10^{-4}}$$

Dividend (numerator)

Divisor (denominator)

Figure 21

When two numbers are divided, the one on top is the numerator and the one on the bottom is the denominator. The result is called the quotient. When you perform calculations with fractions, the quotient may be expressed as a fraction or a decimal.

1. Addition and subtraction

Before two fractions can be added or subtracted, they must have a common denominator. Common denominators are found by finding the least common multiple of the two denominators. Finding the least common multiple often is as easy as multiplying the two denominators together. For example, the least common multiple of the denominators of the fractions 1/2 and 1/3 is 2 × 3 or 6.

$$\frac{1}{2} + \frac{1}{3} = \left(\frac{3}{3} \times \frac{1}{2}\right) + \left(\frac{2}{2} \times \frac{1}{3}\right) = \frac{3}{6} + \frac{2}{6} = \frac{5}{6}$$

Sometimes, one of the denominators will divide into the other, which makes the larger of the two denominators the least common multiple. For example, the fractions 1/2 and 1/6 have 6 as the least common multiple denominator.

$$\frac{1}{2} + \frac{1}{6} = \left(\frac{3}{3} \times \frac{1}{2}\right) + \frac{1}{6} = \frac{3}{6} + \frac{1}{6} = \frac{4}{6}$$

In still other situations, both denominators will divide into a number that is not the product of the two. For example, the fractions 1/4 and 1/6 have the number 12 as their least common multiple denominator, rather than 24, the product of the two denominators. This can be deduced as follows:

$$\frac{1}{6} + \frac{1}{4} = \left(\frac{4}{4} \times \frac{1}{6}\right) + \left(\frac{6}{6} \times \frac{1}{4}\right) = \frac{4}{24} + \frac{6}{24} = \frac{2}{12} + \frac{3}{12} = \frac{5}{12}$$

Because both fractions can be simplified by dividing numerator and denominator by 2, the least common multiple must be 12.

CONTENTS

Figure 22

Carbon-dating of this skull is based on the radioactive decay of carbon-14 atoms which is measured in half-lives.

2. Multiplication and division

When multiplying fractions, the numerators and denominators are multiplied together as follows:

$$\frac{1}{2} \times \frac{2}{3} = \frac{1 \times 2}{2 \times 3} = \frac{2}{6} = \frac{1}{3}$$

Note the final answer is simplified by dividing the numerator and denominator by two.

When dividing fractions, the divisor is inverted and multiplied by the dividend as follows:

$$\frac{2}{3} \div \frac{1}{2} = \frac{2}{3} \times \frac{2}{1} = \frac{2 \times 2}{3 \times 1} = \frac{4}{3}$$

PRACTICE PROBLEMS

20. Perform the indicated operation:

a. $\frac{2}{3} + \frac{3}{4}$

b. $\frac{4}{5} + \frac{3}{10}$

c. $\frac{1}{4} - \frac{1}{6}$

d. $\frac{7}{8} - \frac{5}{6}$

e. $\frac{1}{3} \times \frac{3}{4}$

f. $\frac{3}{5} \times \frac{2}{7}$

g. $\frac{5}{8} \div \frac{1}{4}$

h. $\frac{4}{9} \div \frac{3}{8}$

Logarithms and Antilogarithms

When you perform calculations, such as using half-life of carbon to determine the age of the skull in **Figure 22** or the pH of the products in **Figure 23,** you may need to use the log or antilog function on your calculator. A logarithm (log) is the power or exponent to which a number, called a base, must be raised in order to obtain a given positive number. This textbook uses common logarithms based on a base of 10. Therefore, the common log of any number is the power to which ten is raised to equal that number. Examine **Table 4.** Note the log of each number is the power of ten for the exponent of that number. For example, the common log of 100 is two and the common log of 0.01 is −2.

$$\log 10^2 = 2$$
$$\log 10^{-2} = -2$$

A common log can be written in the following general form.

$$\text{If } 10^n = y, \text{ then } \log y = n.$$

In each example in **Table 4,** the log can be determined by inspection. How do you express the common log of 5.34×10^5? Because logarithms are exponents, they have the same properties as exponents. See **Table 5.**

$$\log 5.34 \times 10^5 = \log 5.34 + \log 10^5$$

Table 4

Comparison Between Exponents and Logs

Exponent	Logarithm
$10^0 = 1$	$\log 1 = 0$
$10^1 = 10$	$\log 10 = 1$
$10^2 = 100$	$\log 100 = 2$
$10^{-1} = 0.1$	$\log 0.1 = -1$
$10^{-2} = 0.01$	$\log 0.01 = -2$

Most scientific calculators have a button labeled $\boxed{\log}$ and, in most cases, the number is simply entered and the log button is pushed to display the log of the number. Note that there is the same number of digits after the decimal in the log as there are significant figures in the original number entered.

$$\log 5.34 \times 10^5 = \log 5.34 + \log 10^5 = 0.728 + 5 = 5.728$$

Suppose the pH of the aqueous ammonia in **Figure 23** is 9.54 and you are asked to find the concentration of the hydrogen ions in that solution. By definition, pH $= -\log [H^+]$. Compare this to the general equation for the common log.

$$\begin{array}{ll} \text{Equation for pH:} & \text{pH} = -\log [H^+] \\ \text{General equation:} & y = \log 10^n \end{array}$$

To solve the equation for $[H^+]$, you must follow the reverse process and calculate the antilogarithm (antilog) of -9.54 to find $[H^+]$.

Antilogs are the reverse of logs. To find the antilog, use a scientific calculator to input the value of the log. Then, use the inverse function and press the log button.

$$\text{If } n = \text{antilog } y, \text{ then } y = 10^n.$$

$$\begin{aligned} \text{Thus, } [H^+] = \text{antilog}(-9.54) &= 10^{-9.54} = 10^{0.46\ +(-10)} \\ &= 10^{0.46} \times 10^{-10} \\ &= 2.9 \times 10^{-10} M \end{aligned}$$

Check the instruction manual for your calculator. The exact procedure to calculate logs and antilogs may vary.

Figure 23

Ammonia is a base. That means, its hydrogen ion concentration is less than $10^{-7}M$.

Table 5

Properties of Exponents

Exponential Notation	Logarithm
$10^A \times 10^B = 10^{A+B}$	$\log (A \times B) = \log A + \log B$
$10^A \div 10^B = 10^{A-B}$	$\log (A \div B) = \log A - \log B$
A^B	$(\log A) \times B$

PRACTICE PROBLEMS

21. Find the log of each of the following numbers:

a. 367

b. 4078

c. X^n

d. $\left(\frac{1}{2}\right)^{t/T}$

22. Find the antilog of each of the following logs:

a. 4.663

b. 2.367

c. 0.371

d. -1.588

APPENDIX C Tables

Table C-1

Color Key

●	**Carbon**	●	**Bromine**	●	**Sodium/ Other metals**
●	**Hydrogen**	●	**Iodine**	●	**Gold**
●	**Oxygen**	●	**Sulfur**	●	**Copper**
●	**Nitrogen**	●	**Phosphorus**	●	**Electron**
●	**Chlorine**	●	**Silicon**	●	**Proton**
●	**Fluorine**	●	**Helium**	●	**Neutron**

Table C-2

Symbols and Abbreviations

α = rays from radioactive materials, helium nuclei
β = rays from radioactive materials, electrons
γ = rays from radioactive materials, high-energy quanta
Δ = change in
λ = wavelength
ν = frequency
A = ampere (*electric current*)
amu = atomic mass unit
Bq = becquerel (*nuclear disintegration*)
°C = Celsius degree (*temperature*)
C = coulomb (*quantity of electricity*)
c = speed of light
cd = candela (*luminous intensity*)
c = specific heat
D = density
E = energy, electromotive force
F = force
G = free energy
g = gram (*mass*)
Gy = gray (*radiation*)
H = enthalpy
Hz = hertz (*frequency*)
h = Planck's constant
h = hour (*time*)
J = joule (*energy*)
K = kelvin (*temperature*)
K_a = ionization constant (*acid*)
K_b = ionization constant (*base*)
K_eq = equilibrium constant
K_sp = solubility product constant
kg = kilogram (*mass*)
M = molarity
m = mass, molality
m = meter (*length*)
mol = mole (*amount*)
min = minute (*time*)
N = newton (*force*)
N_A = Avogadro's number
n = number of moles
P = pressure, power
Pa = pascal (*pressure*)
q = heat
R = ideal gas constant
S = entropy
s = second (*time*)
Sv = sievert (*absorbed radiation*)
T = temperature
V = volume
V = volt (*electric potential*)
v = velocity
W = watt (*power*)
w = work
X = mole fraction

◀ CONTENTS ▶

Table C-3

SI Prefixes

Prefix	Symbol	Scientific notation
femto	f	10^{-15}
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ	10^{-6}
milli	m	10^{-3}
centi	c	10^{-2}
deci	d	10^{-1}
deka	da	10^{1}
hecto	h	10^{2}
kilo	k	10^{3}
mega	M	10^{6}
giga	G	10^{9}
tera	T	10^{12}
peta	P	10^{15}

Table C-4

The Greek Alphabet

Alpha	A	α	Nu	N	ν
Beta	B	β	Xi	Ξ	ξ
Gamma	Γ	γ	Omicron	O	o
Delta	Δ	δ	Pi	Π	π
Epsilon	E	ϵ	Rho	P	ρ
Zeta	Z	ζ	Sigma	Σ	σ
Eta	H	η	Tau	T	τ
Theta	Θ	θ	Upsilon	Υ	υ
Iota	I	ι	Phi	Φ	ϕ
Kappa	K	κ	Chi	X	χ
Lambda	Λ	λ	Psi	Ψ	ψ
Mu	M	μ	Omega	Ω	ω

Table C-5

Physical Constants

Quantity	Symbol	Value
Atomic mass unit	amu	1.6605×10^{-27} kg
Avogadro's number	N	6.022×10^{23} particles/mole
Ideal gas constant	R	8.31 L·kPa/mol·K 0.0821 L·atm/mol·K 62.4 mm Hg·L/mol·K 62.4 torr·L/mol·K
Mass of an electron	m_e	9.109×10^{-31} kg 5.48586×10^{-4} amu
Mass of a neutron	m_n	1.67492×10^{-27} kg 1.008 665 amu
Mass of a proton	m_p	1.6726×10^{-27} kg 1.007 276 amu
Molar volume of ideal gas at STP	V	22.414 L/mol
Normal boiling point of water	T_b	373.15 K 100.0°C
Normal freezing point of water	T_f	273.15 K 0.00°C
Planck's constant	h	$6.626\,076 \times 10^{-34}$ J·s
Speed of light in a vacuum	c	$2.997\,925 \times 10^{8}$ m/s

Table C-6

Properties of Elements

Element	Symbol	Atomic Number	Atomic Mass* (amu)	Melting Point (°C)	Boiling Point (°C)	Density (g/cm^3) (gases measured at STP)	Atomic Radius (pm)	First Ionization Energy (kJ/mol)	Standard Reduction Potential (V) (for elements from or to oxidation state indicated)	Enthalpy of Fusion (kJ/mol)	Specific Heat (J/g • C°)	Enthalpy of Vaporization (kJ/mol)	Abundance in Earth's Crust (%)	Major Oxidation States
Actinium	Ac	89	[227]	1050	3300	10.07	203	499	(3+)−2.13	14.3	0.120	293	trace	3+
Aluminum	Al	13	26.981539	660.37	2517.6	2.699	143	577.5	(3+)−1.67	10.71	0.9025	290.8	8.1	3+
Americium	Am	95	[243]	1176	2607	13.67	183	579	(3+)−2.07	10	—	238.5	—	2+, 3+, 4+
Antimony	Sb	51	121.760	630.7	1587	6.697	161	834	(3+)+0.15	19.5	0.2072	193	2×10^{-5}	3+, 5+
Argon	Ar	18	39.948	−189.37	−185.86	0.001784	98	1521	—	1.18	0.52033	6.52	4×10^{-6}	
Arsenic	As	33	74.92159	816 (2840 kPa)	615 (sublimes)	5.778	121	947	(3+)+0.24	27.7	0.3289	— (sublimes)	1.9×10^{-4}	3+, 5+
Astatine	At	85	[210]	300	350	—	—	916	(1−)+0.2	23.8	—	90.3	trace	1−, 5+
Barium	Ba	56	137.327	726.9	1845	3.62	222	502.9	(2+)−2.92	8.012	0.2044	140	0.039	2+
Berkelium	Bk	97	[247]	986	—	14.78	170	601	(3+)−2.01	—	—	—	—	3+, 4+
Beryllium	Be	4	9.012182	1287	2468	1.848	112	899.5	(2+)−1.97	7.895	1.824	297.6	2×10^{-4}	2+
Bismuth	Bi	83	208.98037	271.4	1564	9.78	151	703	(3+)+0.317	10.9	0.1221	179	8×10^{-7}	3+, 5+
Bohrium	Bh	107	[264]	—	—	—	—	—	—	—	—	—	—	
Boron	B	5	10.811	2080	3927	2.46	85	800.6	(3+)−0.89	50.2	1.026	504.5	9×10^{-4}	3+
Bromine	Br	35	79.904	−7.25	59.35	3.1028	119	1139.9	(1−)+1.065	10.571	0.47362	29.56	2.5×10^{-4}	1−, 1+, 3+, 5+
Cadmium	Cd	48	112.411	320.8	770	8.65	151	867.7	(2+)−0.4025	6.19	0.2311	100	1.6×10^{-5}	2+
Calcium	Ca	20	40.078	841.5	1484	1.55	197	589.8	(2+)−2.84	8.54	0.6315	155	4.66	2+
Californium	Cf	98	[251]	900	—	—	186	608	(3+)−2	—	—	—	—	3+, 4+
Carbon	C	6	12.011	3620	4200	2.266	77	1086.5	(4−)+0.132	104.6	0.7099	711	0.018	4−, 2+, 4+
Cerium	Ce	58	140.115	804	3470	6.773	181.8	541	(3+)−2.34	5.2	0.1923	313	0.007	3+, 4+
Cesium	Cs	55	132.90543	28.4	674.8	1.9	262	375.7	(1+)−2.923	2.087	0.2421	67	2.6×10^{-4}	1+
Chlorine	Cl	17	35.4527	−101	−34	0.003214	91	1255.5	(1−)+1.3583	6.41	0.47820	20.41	0.013	1−, 1+, 3+, 5+
Chromium	Cr	24	51.9961	1907	2679	7.2	128	652.8	(3+)−0.74	20.5	0.4491	339	0.01	2+, 3+, 6+
Cobalt	Co	27	58.9332	1495	2912	8.9	125	758.8	(2+)−0.277	16.192	0.4210	382	0.0028	2+, 3+
Copper	Cu	29	63.546	1085	2570	8.92	128	745.5	(2+)+0.34	13.38	0.38452	304	0.0058	1+, 2+
Curium	Cm	96	[247]	1340	3540	13.51	174	581	(3+)−2.06	—	—	—	—	3+, 4+
Darmstadtium	Ds	110	[281]	—	—	—	—	—	—	—	—	—	—	—
Dubnium	Db	105	[262]	—	—	—	—	—	—	—	—	—	—	—
Dysprosium	Dy	66	162.5	1407	2600	8.536	178.1	572	(3+)−2.29	10.4	0.1733	250	6×10^{-4}	2+, 3+
Einsteinium	Es	99	[252]	860	—	—	186	619	(3+)−2	—	—	—	—	3+
Erbium	Er	68	167.26	1497	2900	9.045	176.1	589	(3+)−2.32	17.2	0.1681	293	3.5×10^{-4}	3+
Europium	Eu	63	151.965	826	1596	5.245	208.4	547	(3+)−1.99	10.5	0.1820	176	2.1×10^{-3}	2+, 3+
Fermium	Fm	100	[257]	—	—	—	—	627	(3+)−1.96	—	—	—	—	2+, 3+
Fluorine	F	9	18.9984032	−219.7	−188.2	0.001696	69	1681	(1−)+2.87	0.51	0.8238	6.54	0.0544	1−
Francium	Fr	87	[223]	27	650	—	280	393	—	2	—	63.6	trace	1+
Gadolinium	Gd	64	157.25	1312	3000	7.886	180.4	592	(3+)−2.29	15.5	0.2355	311.7	6.3×10^{-4}	3+
Gallium	Ga	31	69.723	29.77	2203	5.904	134	578.8	(3+)−0.529	5.59	0.3709	256	0.0018	1+, 3+
Germanium	Ge	32	72.64	945	2850	5.323	123	761.2	(4+)+0.124	31.8	0.3215	334.3	1.5×10^{-4}	2+, 4+

* [ ] indicates mass of longest-lived isotope.

CONTENTS

Table C-6

Properties of Elements (continued)

Element	Symbol	Atomic Number	Atomic Mass* (amu)	Melting Point (°C)	Boiling Point (°C)	Density (g/cm³) (gases measured at STP)	Atomic Radius (pm)	First Ionization Energy (kJ/mol)	Standard Reduction Potential (V) (for elements from or to oxidation state indicated)	Enthalpy of Fusion (kJ/mol)	Specific Heat (J/g • C°)	Enthalpy of Vaporization (kJ/mol)	Abundance in Earth's Crust (%)	Major Oxidation States
Gold	Au	79	196.96654	1064	2856	19.32	144	889.9	(3+)+1.52	12.4	0.12905	324.4	3×10^{-7}	1+, 3+
Hafnium	Hf	72	178.49	2227	4603	13.28	159	654.4	(4+)−1.56	29.288	0.1442	661	3×10^{-4}	4+
Hassium	Hs	108	[277]	—	—	—	—	—	—	—	—	—	—	—
Helium	He	2	4.002602	−269.7 (2536 kPa)	−268.93	0.00017847	31	2372	—	0.02	5.1931	0.084	—	
Holmium	Ho	67	164.9032	1461	2600	8.78	176.2	581	(3+)−2.33	17.1	0.1646	251	1.5×10^{-4}	3+
Hydrogen	H	1	1.00794	−259.19	−252.76	0.0000899	37	1312	(1+) 0.0000	0.117	14.298	0.904	—	1 −, 1+
Indium	In	49	114.818	156.61	2080	7.29	167	558.2	(3+)−0.3382	3.26	0.2407	231.8	2×10^{-5}	1+, 3+
Iodine	I	53	126.90447	113.6	184.5	4.93	138	1008.4	(1−)+0.5355	15.517	0.21448	41.95	4.6×10^{-5}	1 −, 1+, 5+, 7+
Iridium	Ir	77	192.22	2447	4550	22.65	135.5	880	(4+)+0.926	26.4	0.1306	563.6	1×10^{-7}	3+, 4+, 5+
Iron	Fe	26	55.845	1536	2860	7.874	126	759.4	(3+)−0.4	13.807	0.4494	350	5.8	2+, 3+
Krypton	Kr	36	83.80	−157.2	−153.35	0.0037493	112	1351	—	1.64	0.2480	9.03	—	
Lanthanum	La	57	138.9055	920	3420	6.17	187	538	(3+)−2.37	8.5	0.1952	402	0.0035	3+
Lawrencium	Lr	103	[262]	—	—	—	—	—	(3+)−2.06	—	—	—	—	3+
Lead	Pb	82	207.2	327	1746	11.342	146	715.6	(2+)−0.1251	4.77	0.1276	178	0.0013	2+, 4+
Lithium	Li	3	6.941	180.5	1347	0.534	156	520.2	(1+)−3.045	3	3.569	148	0.002	1+
Lutetium	Lu	71	174.967	1652	3327	9.84	173.8	524	(3+)−2.3	11.9	0.1535	414	8×10^{-5}	3+
Magnesium	Mg	12	24.305	650	1105	1.738	160	737.8	(2+)−2.356	8.477	1.024	127.4	2.76	2+
Manganese	Mn	25	54.93805	1246	2061	7.43	127	717.5	(2+)−1.18	12.058	0.4791	219.7	0.1	2+, 3+, 4+, 6+, 7+
Meitnerium	Mt	109	[268]	—	—	—	—	—	—	—	—	—	—	—
Mendelevium	Md	101	[258]	—	—	—	—	635	—	—	—	—	—	2+, 3+
Mercury	Hg	80	200.59	−38.9	357	13.534	151	1007	(2+)+0.8535	2.2953	0.13950	59.1	2×10^{-6}	1+, 2+
Molybdenum	Mo	42	95.94	2623	4679	10.28	139	685	(6+) 0.114	36	0.2508	590	1.2×10^{-4}	4+, 5+, 6+
Neodymium	Nd	60	144.24	1024	3111	7.003	181.4	530	(3+)−2.32	7.13	0.1903	283.7	0.004	2+, 3+
Neon	Ne	10	20.1797	−248.61	−246.05	0.0008999	71	2081	—	0.34	1.0301	1.77	—	
Neptunium	Np	93	[237]	640	3900	20.45	155	597	(5+)−0.91	9.46	—	336	—	2+, 3+, 4+, 5+, 6+
Nickel	Ni	28	58.6934	1455	2883	8.908	124	736.7	(2+)−0.257	17.15	0.4442	375	0.0075	2+, 3+, 4+
Niobium	Nb	41	92.90638	2477	4858	8.57	146	664.1	(5+)−0.65	26.9	0.2648	690	0.002	4+, 5+
Nitrogen	N	7	14.0067	−210	−195.8	0.0012409	75	1402	(3−)−0.092	0.72	1.0397	5.58	0.002	3−, 2−, 1−, 1+, 2+, 3+, 4+, 5+
Nobelium	No	102	[259]	—	—	—	—	642	(2+)−2.5	—	—	—	—	2+, 3+
Osmium	Os	76	190.23	3045	5025	22.57	135	840	(4+)+0.687	31.7	0.130	627.6	2×10^{-7}	4+, 6+, 8+
Oxygen	O	8	15.9994	−218.8	−183	0.001429	60	1313.9	(2−) 1.229	0.44	0.91738	6.82	45.5	2−, 1−
Palladium	Pd	46	106.42	1552	2940	11.99	137	805	(2+) 0.915	17.6	0.2441	362	3×10^{-7}	2+, 4+
Phosphorus	P	15	30.973762	44.2	280.5	1.823	109	1012	(3−)−0.063	0.659	0.76968	49.8	0.11	3−, 3+, 5+
Platinum	Pt	78	195.078	1769	3824	21.41	138.5	868	(4+)+1.15	19.7	0.1326	510.4	1×10^{-6}	2+, 4+
Plutonium	Pu	94	[244]	640	3230	19.86	162	585	(4+)−1.25	2.8	0.138	343.5	—	3+, 4+, 5+, 6+
Polonium	Po	84	[209]	254	962	9.4	164	813	(4+)+0.73	3.81	0.125	103	—	2−, 2+, 4+, 6+
Potassium	K	19	39.0983	63.2	766.4	0.862	231	418.8	(1+)−2.925	2.334	0.7566	76.9	1.84	1+
Praseodymium	Pr	59	140.90765	935	3520	6.782	182.4	522	(3+)−2.35	11.3	0.1930	332.6	9.1×10^{-4}	3+, 4+
Promethium	Pm	61	[145]	1042	3000	7.2	183.4	536	(3+)−2.29	8.17	—	293	—	3+

* [ ] indicates mass of longest-lived isotope.

CONTENTS

Table C-6

Properties of Elements (continued)

Element	Symbol	Atomic Number	Atomic Mass* (amu)	Melting Point (°C)	Boiling Point (°C)	Density (g/cm^3) (gases measured at STP)	Atomic Radius (pm)	First Ionization Energy (kJ/mol)	Standard Reduction Potential (V) (for elements from or to oxidation state indicated)	Enthalpy of Fusion (kJ/mol)	Specific Heat (J/g • C°)	Enthalpy of Vaporization (kJ/mol)	Abundance in Earth's Crust (%)	Major Oxidation States
Protactinium	Pa	91	231.03588	1552	4227	15.37	163	568	(5+)−1.19	14.6	—	481	trace	3+, 4+, 5+
Radium	Ra	88	[226]	700	1630	5	228	509.1	(2+)−2.916	8.36	—	136.8	—	2+
Radon	Rn	86	[222]	−71	−62	0.00973	140	1037	—	16.4	—	16.4	—	
Rhenium	Re	75	186.207	3180	5650	21.232	137	760	(7+)+0.34	33.4	0.1368	707	1×10^{-7}	3+, 4+, 6+, 7+
Rhodium	Rh	45	102.9055	1960	3727	12.39	134	720	(3+)+0.76	21.6	0.2427	494	1×10^{-7}	3+, 4+, 5+
Rubidium	Rb	37	85.4678	39.5	697	1.532	248	403	(1+)−2.925	2.19	0.36344	69.2	0.0078	1+
Ruthenium	Ru	44	101.07	2310	4119	12.41	134	711	(4+)+0.68	25.5	0.2381	567.8	—	2+, 3+, 4+, 5+
Rutherfordium	Rf	104	[261]	—	—	—	—	—	—	—	—	—	—	—
Samarium	Sm	62	150.36	1072	1800	7.536	180.4	542	(3+)−2.3	8.9	0.1965	191	7×10^{-4}	2+, 3+
Scandium	Sc	21	44.95591	1539	2831	3	162	631	(3+)−2.03	15.77	0.5677	304.8	0.0022	3+
Seaborgium	Sg	106	[266]	—	—	—	—	—	—	—	—	—	—	—
Selenium	Se	34	78.96	221	685	4.79	117	940.7	(2−)− 0.924	5.43	0.3212	26.3	5×10^{-6}	2−, 2+, 4+, 6+
Silicon	Si	14	28.0855	1411	3231	2.336	118	786.5	(4−)−0.143	50.2	0.7121	359	27.2	2+, 4+
Silver	Ag	47	107.8682	961	2195	10.49	144	730.8	(1+)+0.7991	11.65	0.23502	255	8×10^{-6}	1+
Sodium	Na	11	22.989768	97.83	897.4	0.968	186	495.9	(1+)−2.714	2.602	1.228	97.4	2.27	1+
Strontium	Sr	38	87.62	776.9	1382	2.6	215	549.5	(2+)−2.89	7.4308	0.301	137	0.0384	2+
Sulfur	S	16	32.065	115.2	444.7	2.08	103	999.6	(2−)−0.45	1.7272	0.7060	9.62	0.03	2−, 4+, 6+
Tantalum	Ta	73	180.9479	3017	5458	16.65	146	760.8	(5+)−0.81	36.57	0.1402	737	2×10^{-4}	4+, 5+
Technetium	Tc	43	[98]	2157	4265	11.5	136	702	(6+)+0.83	23.0	—	577	—	2+, 4+, 6+, 7+
Tellurium	Te	52	127.60	450	990	6.25	138	869	(2−)−1.14	17.4	0.2016	50.6	2×10^{-7}	2−, 2+, 4+, 6+
Terbium	Tb	65	158.92534	1356	3230	8.272	177.3	564	(3+)−2.31	10.3	0.1819	293	1×10^{-4}	3+, 4+
Thallium	Tl	81	204.3833	303.5	1457	11.85	170	589.1	(1+)−0.3363	4.27	0.1288	162	7×10^{-5}	1+, 3+
Thorium	Th	90	232.0381	1750	4787	11.78	179	587	(4+)−1.83	16.11	0.1177	543.9	8.1×10^{-4}	4+
Thulium	Tm	69	168.93421	1545	1950	9.318	175.9	596	(3+)−2.32	18.4	0.1600	213	5×10^{-5}	
Tin	Sn	50	118.710	232	2623	7.265	141	708.4	(4+)+0.151	7.07	0.2274	296	2.1×10^{-4}	2+, 4+
Titanium	Ti	22	47.867	1666	3358	4.5	147	658.1	(4+)−0.86	14.146	0.5226	425	0.63	2+, 3+, 4+
Tungsten	W	74	183.84	3422	5555	19.3	139	770.4	(6+)−0.09	35.4	0.1320	806	1.2×10^{-4}	4+, 5+, 6+
Ununbium	Uub	112	[285]											
Ununquadium	Uuq	114	[289]											
Unununium	Uuu	111	[272]											
Uranium	U	92	238.0289	1130	4131	19.05	156	597	(6+)−0.83	12.6	0.11618	423	2.3×10^{-4}	3+, 4+, 5+, 6+
Vanadium	V	23	50.9415	1917	3417	6.11	134	650.3	(4+)−0.54	22.84	0.4886	459.7	0.0136	2+, 3+, 4+, 5+
Xenon	Xe	54	131.293	−111.8	−108.09	0.0058971	218	1170	—	2.29	0.15832	12.64	—	
Ytterbium	Yb	70	173.04	824	1196	6.973	193.3	603	(3+)−2.22	7.66	0.1545	155	3.4×10^{-4}	2+, 3+
Yttrium	Y	39	88.90585	1530	3264	4.5	180	600	(3+)−2.37	17.15	0.2984	393	0.0035	3+
Zinc	Zn	30	65.39	419.6	907	7.14	134	906.4	(2+)−0.7626	7.322	0.3884	115	0.0076	2+
Zirconium	Zr	40	91.224	1852	4400	6.51	160	640	(4+)−1.7	20.92	0.2780	590.5	0.0162	4+

* [ ] indicates mass of longest-lived isotope.

CONTENTS

Table C-7

Electron Configurations of Elements

		Sublevels																		
	Elements	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	6d	6f	7s
1	Hydrogen	1																		
2	Helium	2																		
3	Lithium	2	1																	
4	Beryllium	2	2																	
5	Boron	2	2	1																
6	Carbon	2	2	2																
7	Nitrogen	2	2	3																
8	Oxygen	2	2	4																
9	Fluorine	2	2	5																
10	Neon	2	2	6																
11	Sodium	2	2	6	1															
12	Magnesium	2	2	6	2															
13	Aluminum	2	2	6	2	1														
14	Silicon	2	2	6	2	2														
15	Phosphorus	2	2	6	2	3														
16	Sulfur	2	2	6	2	4														
17	Chlorine	2	2	6	2	5														
18	Argon	2	2	6	2	6														
19	Potassium	2	2	6	2	6		1												
20	Calcium	2	2	6	2	6		2												
21	Scandium	2	2	6	2	6	1	2												
22	Titanium	2	2	6	2	6	2	2												
23	Vanadium	2	2	6	2	6	3	2												
24	Chromium	2	2	6	2	6	5	1												
25	Manganese	2	2	6	2	6	5	2												
26	Iron	2	2	6	2	6	6	2												
27	Cobalt	2	2	6	2	6	7	2												
28	Nickel	2	2	6	2	6	8	2												
29	Copper	2	2	6	2	6	10	1												
30	Zinc	2	2	6	2	6	10	2												
31	Gallium	2	2	6	2	6	10	2	1											
32	Germanium	2	2	6	2	6	10	2	2											
33	Arsenic	2	2	6	2	6	10	2	3											
34	Selenium	2	2	6	2	6	10	2	4											
35	Bromine	2	2	6	2	6	10	2	5											
36	Krypton	2	2	6	2	6	10	2	6											
37	Rubidium	2	2	6	2	6	10	2	6			1								
38	Strontium	2	2	6	2	6	10	2	6			2								
39	Yttrium	2	2	6	2	6	10	2	6	1		2								
40	Zirconium	2	2	6	2	6	10	2	6	2		2								
41	Niobium	2	2	6	2	6	10	2	6	4		1								
42	Molybdenum	2	2	6	2	6	10	2	6	5		1								
43	Technetium	2	2	6	2	6	10	2	6	5		2								
44	Ruthenium	2	2	6	2	6	10	2	6	7		1								
45	Rhodium	2	2	6	2	6	10	2	6	8		1								
46	Palladium	2	2	6	2	6	10	2	6	10										
47	Silver	2	2	6	2	6	10	2	6	10		1								
48	Cadmium	2	2	6	2	6	10	2	6	10		2								
49	Indium	2	2	6	2	6	10	2	6	10		2	1							
50	Tin	2	2	6	2	6	10	2	6	10		2	2							
51	Antimony	2	2	6	2	6	10	2	6	10		2	3							
52	Tellurium	2	2	6	2	6	10	2	6	10		2	4							
53	Iodine	2	2	6	2	6	10	2	6	10		2	5							
54	Xenon	2	2	6	2	6	10	2	6	10		2	6							

Table C-7

Electron Configurations of Elements (continued)

	Sublevels																			
Elements	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p	5d	5f	6s	6p	6d	6f	7s	7p
55 Cesium	2	2	6	2	6	10	2	6	10		2	6			1					
56 Barium	2	2	6	2	6	10	2	6	10		2	6			2					
57 Lanthanum	2	2	6	2	6	10	2	6	10		2	6	1		2					
58 Cerium	2	2	6	2	6	10	2	6	10	2	2	6			2					
59 Praseodymium	2	2	6	2	6	10	2	6	10	3	2	6			2					
60 Neodymium	2	2	6	2	6	10	2	6	10	4	2	6			2					
61 Promethium	2	2	6	2	6	10	2	6	10	5	2	6			2					
62 Samarium	2	2	6	2	6	10	2	6	10	6	2	6			2					
63 Europium	2	2	6	2	6	10	2	6	10	7	2	6			2					
64 Gadolinium	2	2	6	2	6	10	2	6	10	7	2	6	1		2					
65 Terbium	2	2	6	2	6	10	2	6	10	9	2	6			2					
66 Dysprosium	2	2	6	2	6	10	2	6	10	10	2	6			2					
67 Holmium	2	2	6	2	6	10	2	6	10	11	2	6			2					
68 Erbium	2	2	6	2	6	10	2	6	10	12	2	6			2					
69 Thulium	2	2	6	2	6	10	2	6	10	13	2	6			2					
70 Ytterbium	2	2	6	2	6	10	2	6	10	14	2	6			2					
71 Lutetium	2	2	6	2	6	10	2	6	10	14	2	6	1		2					
72 Hafnium	2	2	6	2	6	10	2	6	10	14	2	6	2		2					
73 Tantalum	2	2	6	2	6	10	2	6	10	14	2	6	3		2					
74 Tungsten	2	2	6	2	6	10	2	6	10	14	2	6	4		2					
75 Rhenium	2	2	6	2	6	10	2	6	10	14	2	6	5		2					
76 Osmium	2	2	6	2	6	10	2	6	10	14	2	6	6		2					
77 Iridium	2	2	6	2	6	10	2	6	10	14	2	6	7		2					
78 Platinum	2	2	6	2	6	10	2	6	10	14	2	6	9		1					
79 Gold	2	2	6	2	6	10	2	6	10	14	2	6	10		1					
80 Mercury	2	2	6	2	6	10	2	6	10	14	2	6	10		2					
81 Thallium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	1				
82 Lead	2	2	6	2	6	10	2	6	10	14	2	6	10		2	2				
83 Bismuth	2	2	6	2	6	10	2	6	10	14	2	6	10		2	3				
84 Polonium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	4				
85 Astatine	2	2	6	2	6	10	2	6	10	14	2	6	10		2	5				
86 Radon	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6				
87 Francium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6			1	
88 Radium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6			2	
89 Actinium	2	2	8	2	6	10	2	6	10	14	2	6	10		2	6	1		2	
90 Thorium	2	2	6	2	6	10	2	6	10	14	2	6	10		2	6	2		2	
91 Protactinium	2	2	6	2	6	10	2	6	10	14	2	6	10	2	2	6	1		2	
92 Uranium	2	2	6	2	6	10	2	6	10	14	2	6	10	3	2	6	1		2	
93 Neptunium	2	2	6	2	6	10	2	6	10	14	2	6	10	4	2	6	1		2	
94 Plutonium	2	2	6	2	6	10	2	6	10	14	2	6	10	6	2	6			2	
95 Americium	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6			2	
96 Curium	2	2	6	2	6	10	2	6	10	14	2	6	10	7	2	6	1		2	
97 Berkelium	2	2	6	2	6	10	2	6	10	14	2	6	10	9	2	6			2	
98 Californium	2	2	6	2	6	10	2	6	10	14	2	6	10	10	2	6			2	
99 Einsteinium	2	2	6	2	6	10	2	6	10	14	2	6	10	11	2	6			2	
100 Fermium	2	2	6	2	6	10	2	6	10	14	2	6	10	12	2	6			2	
101 Mendelevium	2	2	6	2	6	10	2	6	10	14	2	6	10	13	2	6			2	
102 Nobelium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6			2	
103 Lawrencium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	1		2	
104 Rutherfordium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	2		2?	
105 Dubnium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	3		2?	
106 Seaborgium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	4		2?	
107 Bohrium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	5		2?	
108 Hassium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	6		2?	
109 Meitnerium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	7		2?	
110 Darmstadtium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	8		2?	
111 Unununium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	9		2?	
112 Ununbium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	10		2?	
114 Ununquadium	2	2	6	2	6	10	2	6	10	14	2	6	10	14	2	6	10		2?	2?

Table C-8

Names and Charges of Polyatomic Ions

1−

Acetate, CH_3COO^-
Amide, NH_2^-
Astatate, AtO_3^-
Azide, N_3^-
Benzoate, $C_6H_5COO^-$
Bismuthate, BiO_3^-
Bromate, BrO_3^-
Chlorate, ClO_3^-
Chlorite, ClO_2^-
Cyanide, CN^-
Formate, $HCOO^-$
Hydroxide, OH^-
Hypobromite, BrO^-
Hypochlorite, ClO^-
Hypophosphite, $H_2PO_2^-$
Iodate, IO_3^-
Nitrate, NO_3^-
Nitrite, NO_2^-
Perbromate, BrO_4^-
Perchlorate, ClO_4^-
Periodate, IO_4^-
Permanganate, MnO_4^-
Perrhenate, ReO_4^-
Thiocyanate, SCN^-
Vanadate, VO_3^-

2−

Carbonate, CO_3^{2-}
Chromate, CrO_4^{2-}
Dichromate, $Cr_2O_7^{2-}$
Hexachloroplatinate, $PtCl_6^{2-}$
Hexafluorosilicate, SiF_6^{2-}
Molybdate, MoO_4^{2-}
Oxalate, $C_2O_4^{2-}$
Peroxide, O_2^{2-}
Peroxydisulfate, $S_2O_8^{2-}$
Ruthenate, RuO_4^{2-}
Selenate, SeO_4^{2-}
Selenite, SeO_3^{2-}
Silicate, SiO_3^{2-}
Sulfate, SO_4^{2-}
Sulfite, SO_3^{2-}
Tartrate, $C_4H_4O_6^{2-}$
Tellurate, TeO_4^{2-}
Tellurite, TeO_3^{2-}
Tetraborate, $B_4O_7^{2-}$
Thiosulfate, $S_2O_3^{2-}$
Tungstate, WO_4^{2-}

3−

Arsenate, AsO_4^{3-}
Arsenite, AsO_3^{3-}
Borate, BO_3^{3-}
Citrate, $C_6H_5O_7^{3-}$
Hexacyanoferrate(III), $Fe(CN)_6^{3-}$
Phosphate, PO_4^{3-}
Phosphite, PO_3^{3-}

4−

Hexacyanoferrate(II), $Fe(CN)_6^{4-}$
Orthosilicate, SiO_4^{4-}
Diphosphate, $P_2O_7^{4-}$

1+

Ammonium, NH_4^+
Neptunyl(V), NpO_2^+
Plutonyl(V), PuO_2^+
Uranyl(V), UO_2^+
Vanadyl(V), VO_2^+

2+

Mercury(I), Hg_2^{2+}
Neptunyl(VI), NpO_2^{2+}
Plutonyl(VI), PuO_2^{2+}
Uranyl(VI), UO_2^{2+}
Vanadyl(IV), VO^{2+}

Table C-9

Ionization Constants

Substance	Ionization Constant	Substance	Ionization Constant	Substance	Ionization Constant
HCOOH	1.77×10^{-4}	HBO_3^{-2}	1.58×10^{-14}	HS^-	1.00×10^{-19}
CH_3COOH	1.75×10^{-5}	H_2CO_3	4.5×10^{-7}	HSO_4^-	1.02×10^{-2}
$CH_2ClCOOH$	1.36×10^{-3}	HCO_3^-	4.68×10^{-11}	H_2SO_3	1.29×10^{-2}
$CHCl_2COOH$	4.47×10^{-2}	HCN	6.17×10^{-10}	HSO_3^-	6.17×10^{-8}
CCl_3COOH	3.02×10^{-1}	HF	6.3×10^{-4}	$HSeO_4^-$	2.19×10^{-2}
HOOCCOOH	5.36×10^{-2}	HNO_2	5.62×10^{-4}	H_2SeO_3	2.29×10^{-3}
$HOOCCOO^-$	1.55×10^{-4}	H_3PO_4	7.08×10^{-3}	$HSeO_3^-$	4.79×10^{-9}
CH_3CH_2COOH	1.34×10^{-5}	$H_2PO_4^-$	6.31×10^{-8}	HBrO	2.51×10^{-9}
C_6H_5COOH	6.25×10^{-5}	HPO_4^{2-}	4.17×10^{-13}	HClO	2.9×10^{-8}
H_3AsO_4	6.03×10^{-3}	H_3PO_3	5.01×10^{-2}	HIO	3.16×10^{-11}
$H_2AsO_4^-$	1.05×10^{-7}	$H_2PO_3^-$	2.00×10^{-7}	NH_3	5.62×10^{-10}
H_3BO_3	5.75×10^{-10}	H_3PO_2	5.89×10^{-2}	H_2NNH_2	7.94×10^{-9}
$H_2BO_3^-$	1.82×10^{-13}	H_2S	9.1×10^{-8}	H_2NOH	1.15×10^{-6}

CONTENTS

Table C-10

Solubility Guidelines

A substance is considered soluble if more than three grams of the substance dissolves in 100 mL of water. The more common rules are listed below.

1. All common salts of the group 1A elements and ammonium ions are soluble.
2. All common acetates and nitrates are soluble.
3. All binary compounds of group 7A elements (other than F) with metals are soluble except those of silver, mercury(I), and lead.
4. All sulfates are soluble except those of barium, strontium, lead, calcium, silver, and mercury(I).
5. Except for those in Rule 1, carbonates, hydroxides, oxides, sulfides, and phosphates are insoluble.

Solubility of Compounds in Water

	Acetate	Bromide	Carbonate	Chlorate	Chloride	Chromate	Hydroxide	Iodide	Nitrate	Oxide	Perchlorate	Phosphate	Sulfate	Sufide
Aluminum	S	S	—	S	S	—	I	S	S	I	S	I	S	D
Ammonium	S	S	S	S	S	S	S	S	S	—	S	S	S	S
Barium	S	S	P	S	S	I	S	S	S	S	S	I	I	D
Calcium	S	S	P	S	S	S	S	S	S	P	S	P	P	P
Copper (II)	S	S	—	S	S	—	I	—	S	I	S	I	S	I
Hydrogen	S	S	—	S	S	—	—	S	S	S	S	S	S	S
Iron(II)	—	S	P	S	S	—	I	S	S	I	S	I	S	I
Iron(III)	—	S	—	S	S	I	I	S	S	I	S	P	P	D
Lead(II)	S	S	—	S	S	I	P	P	S	P	S	I	P	I
Lithium	S	S	S	S	S	?	S	S	S	S	S	P	S	S
Magnesium	S	S	P	S	S	S	I	S	S	I	S	P	S	D
Manganese(II)	S	S	P	S	S	—	I	S	S	I	S	P	S	I
Mercury(I)	P	I	I	S	I	P	—	I	S	I	S	I	P	I
Mercury(II)	S	S	—	S	S	P	I	P	S	P	S	I	D	I
Potassium	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Silver	P	I	I	S	I	P	—	I	S	P	S	I	P	I
Sodium	S	S	S	S	S	S	S	S	S	D	S	S	S	S
Strontium	S	S	P	S	S	P	S	S	S	S	S	I	P	S
Tin(II)	D	S	—	S	S	I		S	D	I	S	I	S	I
Tin(IV)	S	S	—	—	S	S	I	D	—	I	S	—	S	I
Zinc	S	S	P	S	S	P	P	S	S	P	S	I	S	I

S – soluble P – partially soluble I – insoluble D – decomposes

CONTENTS

Table C-11

Specific Heat Values (J/g·K)					
Substance	***c***	**Substance**	***c***	**Substance**	***c***
AlF_3	0.8948	Fe_3C	0.5898	$NaVO_3$	1.540
$BaTiO_3$	0.79418	$FeWO_4$	0.37735	$Ni(CO)_4$	1.198
BeO	1.020	HI	0.22795	PbI_2	0.1678
CaC_2	0.9785	K_2CO_3	0.82797	SF_6	0.6660
$CaSO_4$	0.7320	$MgCO_3$	0.8957	SiC	0.6699
CCl_4	0.85651	$Mg(OH)_2$	1.321	SiO_2	0.7395
CH_3OH	2.55	$MgSO_4$	0.8015	$SrCl_2$	0.4769
CH_2OHCH_2OH	2.413	MnS	0.5742	Tb_2O_3	0.3168
CH_3CH_2OH	2.4194	Na_2CO_3	1.0595	$TiCl_4$	0.76535
CdO	0.3382	NaF	1.116	Y_2O_3	0.45397
$CuSO_4 \cdot 5H_2O$	1.12				

Table C-12

Molal Freezing Point Depression and Boiling Point Elevation Constants				
Substance	K_{fp} **(C°kg/mol)**	**Freezing Point (°C)**	K_{bp} **(C°kg/mol)**	**Boiling Point (°C)**
Acetic acid	3.90	16.66	3.22	117.90
Benzene	5.12	5.533	2.53	80.100
Camphor	37.7	178.75	5.611	207.42
Cyclohexane	20.0	6.54	2.75	80.725
Cyclohexanol	39.3	25.15	--	--
Nitrobenzene	6.852	5.76	5.24	210.8
Phenol	7.40	40.90	3.60	181.839
Water	1.86	0.000	0.512	100.000

Table C-13

Heat of Formation Values ΔH°_f (kJ/mol) (concentration of aqueous solutions is 1*M*)							
Substance	ΔH°_f	**Substance**	ΔH°_f	**Substance**	ΔH°_f	**Substance**	ΔH°_f
Ag(s)	0	CsCl(s)	−443.04	H_3PO_4(aq)	−1279.0	NaBr(s)	−361.062
AgCl(s)	−127.068	Cs_2SO_4(s)	−1443.02	H_2S(g)	−20.63	NaCl(s)	−411.153
AgCN(s)	146.0	CuI(s)	−67.8	H_2SO_3(aq)	−608.81	$NaHCO_3$(s)	−950.8
Al_2O_3	−1675.7	CuS(s)	−53.1	H_2SO_4(aq)	−814.0	$NaNO_3$(aq)	−447.48
$BaCl_2$(aq)	−871.95	Cu_2S(s)	−79.5	$HgCl_2$(s)	−224. 3	NaOH(s)	−425.609
$BaSO_4$	−1473.2	$CuSO_4$(s)	−771.36	Hg_2Cl_2(s)	−265.22	Na_2CO_3(s)	−1130.7
BeO(s)	−609.6	F_2(g)	0	Hg_2SO_4(s)	−743.12	Na_2S(aq)	−447.3
$BiCl_3$(s)	−379.1	$FeCl_3$(s)	−399.49	I_2(s)	0	Na_2SO_4(s)	−1387.08
Bi_2S_3(s)	−143.1	FeO(s)	−272.0	K(s)	0	NH_4Cl(s)	−314.4
Br_2	0	FeS(s)	−100.0	KBr(s)	−393.798	O_2(g)	0
CCl_4(l)	−128.2	Fe_2O_3(s)	−824.2	$KMnO_4$(s)	−837.2	P_4O_6(s)	−1640.1
CH_4(g)	−74.81	Fe_3O_4(s)	−1118.4	KOH	−424.764	P_4O_{10}(s)	−2984.0
C_2H_2(g)	226.73	H(g)	217.965	LiBr(s)	−351.213	$PbBr_2$(s)	−278.7
C_2H_4(g)	52.26	H_2(g)	0	LiOH(s)	−484.93	$PbCl_2$(s)	−359.41
C_2H_6(g)	−84.68	HBr(g)	−36.40	Mn(s)	0	SF_6(g)	−1220.5
CO(g)	−110.525	HCl(g)	−92.307	$MnCl_2$(aq)	−555.05	SO_2(g)	−296.830
CO_2(g)	−393.509	HCl(aq)	−167.159	$Mn(NO_3)_2$(aq)	−635.5	SO_3(g)	−454.51
CS_2(l)	89.70	HCN(aq)	108.9	MnO_2(s)	−520.03	SrO(s)	−592.0
Ca(s)	0	HCHO	−108.57	MnS(s)	−214.2	TiO_3(s)	−939.7
$CaCO_3$(s)	−1206.9	HCOOH(l)	−424.72	N_2(g)	0	TlI(s)	−123.5
CaO(s)	−635.1	HF(g)	−271.1	NH_3(g)	−46.11	UCl_4(s)	−1019.2
$Ca(OH)_2$(s)	−986.09	HI(g)	26.48	NH_4Br(s)	−270.83	UCl_5(s)	−1059
Cl_2(g)	0	H_2O(l)	−285.830	NO(g)	90.25	Zn(s)	0
Co_3O_4(s)	−891	H_2O(g)	−241.818	NO_2(g)	33.18	$ZnCl_2$(aq)	−488.19
CoO(s)	−237.94	H_2O_2(l)	−187.8	N_2O(g)	82.05	ZnO(s)	−348.28
Cr_2O_3(s)	−1139.7	H_3PO_4(l)	−595.4	Na(s)	0	$ZnSO_4$(aq)	−1063.15

CONTENTS

APPENDIX D Solutions

Chapter 1

No practice problems

Chapter 2

1. $\text{density} = \frac{\text{mass}}{\text{volume}}$

$\text{volume} = 41\text{ mL} - 20\text{ mL} = 21\text{ mL}$

$\text{density} = \frac{147\text{ g}}{21\text{ mL}} = 7.0\text{ g/mL}$

2. $\text{volume} = \frac{\text{mass}}{\text{density}}$

$\text{volume} = \frac{20\,\cancel{\text{g}}}{4\,\cancel{\text{g}}/\text{mL}} = 5\text{ mL}$

3. $\text{density} = \frac{\text{mass}}{\text{volume}}$

$\text{density} = \frac{20\text{ g}}{5\text{ cm}^3} = 4\text{ g/cm}^3$

The density of pure aluminum is 2.7 g/cm^3, so the cube cannot be made of aluminum.

12. **a.** 7×10^2 m
b. 3.8×10^4 m
c. 4.5×10^6 m
d. 6.85×10^{11} m
e. 5.4×10^{-3} kg
f. 6.87×10^{-6} kg
g. 7.6×10^{-8} kg
h. 8×10^{-10} kg

13. **a.** 3.6×10^5 s
b. 5.4×10^{-5} s
c. 5.06×10^3 s
d. 8.9×10^{10} s

14. **a.** 7×10^{-5} m
b. 3×10^8 m
c. 2×10^2 m
d. 5×10^{-12} m
e. $1.26 \times 10^4\text{ kg} + 0.25 \times 10^4\text{ kg} = 1.51 \times 10^4\text{ kg}$
f. $7.06 \times 10^{-3}\text{ kg} + 0.12 \times 10^{-3}\text{ kg} = 7.18 \times 10^{-3}\text{ kg}$
g. $4.39 \times 10^5\text{ kg} - 0.28 \times 10^5\text{ kg} = 4.11 \times 10^5\text{ kg}$
h. $5.36 \times 10^{-1}\text{ kg} - 0.740 \times 10^{-1}\text{ kg} = 4.62 \times 10^{-1}\text{ kg}$

15. **a.** 4×10^{10} cm^2
b. 6×10^{-2} cm^2
c. 9×10^{-1} cm^2
d. 5×10^2 cm^2

16. **a.** 3×10^1 g/cm^3
b. 2×10^3 g/cm^3
c. 3×10^6 g/cm^3
d. 2×10^{-1} g/cm^3

17. **a.** $360\,\cancel{\text{s}} \times \frac{1000\text{ ms}}{1\,\cancel{\text{s}}} = 360\,000\text{ ms}$

b. $4800\,\cancel{\text{g}} \times \frac{1\text{ kg}}{1000\,\cancel{\text{g}}} = 4.8\text{ kg}$

c. $5600\,\cancel{\text{dm}} \times \frac{1\text{ m}}{10\,\cancel{\text{dm}}} = 560\text{ m}$

d. $72\,\cancel{\text{g}} \times \frac{1000\text{ mg}}{1\,\cancel{\text{g}}} = 72\,000\text{ mg}$

18. **a.** $245\,\cancel{\text{ms}} \times \frac{1\text{ s}}{1000\,\cancel{\text{ms}}} = 0.245\text{ s}$

b. $5\,\cancel{\text{m}} \times \frac{100\text{ cm}}{1\,\cancel{\text{m}}} = 500\text{ cm}$

c. $6800\,\cancel{\text{cm}} \times \frac{1\text{ m}}{100\,\cancel{\text{cm}}} = 68\text{ m}$

d. $25\,\cancel{\text{kg}} \times \frac{1\text{ Mg}}{1000\,\cancel{\text{kg}}} = 0.025\text{ Mg}$

19. $24\,\cancel{\text{h}} \times \frac{60\,\cancel{\text{min}}}{1\,\cancel{\text{h}}} \times \frac{60\text{ s}}{1\,\cancel{\text{min}}} = 86\,400\text{ s}$

20. $\frac{19.3\,\cancel{\text{g}}}{1\,\cancel{\text{mL}}} \times \frac{10\text{ dg}}{1\,\cancel{\text{g}}} \times \frac{1000\,\cancel{\text{mL}}}{1\text{L}} = 193\,000\text{ dg/L}$

21. $\frac{90.0\,\cancel{\text{km}}}{1\,\cancel{\text{h}}} \times \frac{0.62\text{ mi}}{1\,\cancel{\text{km}}} \times \frac{1\,\cancel{\text{h}}}{60\text{ min}} = 0.930\text{ mi/min}$

29. $\frac{0.19}{1.59} \times 100 = 11.9\%$

$\frac{0.09}{1.59} \times 100 = 5.66\%$

$\frac{0.14}{1.59} \times 100 = 8.80\%$

30. $\frac{0.11}{1.59} \times 100 = 6.92\%$

$\frac{0.10}{1.59} \times 100 = 6.29\%$

$\frac{0.12}{1.59} \times 100 = 7.55\%$

31. **a.** 4
b. 7
c. 5
d. 3

32. **a.** 5
b. 3
c. 5
d. 2

33. **a.** 84 790 kg
b. 38.54 g
c. 256.8 cm
d. 4.936 m

CONTENTS

34. **a.** 5.482×10^{-4} g
b. 1.368×10^{5} kg
c. 3.087×10^{8} mm
d. 2.014 mL

35. **a.** 142.9 cm
b. 768 kg
c. 0.1119 mg

36. **a.** 12.12 cm
b. 2.10 cm
c. 2.7×10^{3} cm

37. **a.** 78 m^2
b. 12 m^2
c. 2.5 m^2
d. 81.1 m^2

38. **a.** 2.0 m/s
b. 3.00 m/s
c. 2.00 m/s
d. 2.9 m/s

Chapter 3

6. $\text{mass}_{\text{reactants}} = \text{mass}_{\text{products}}$

$\text{mass}_{\text{reactants}} = \text{mass}_{\text{water electrolyzed}}$

$\text{mass}_{\text{products}} = \text{mass}_{\text{hydrogen}} + \text{mass}_{\text{oxygen}}$

$\text{mass}_{\text{water electrolyzed}} = \text{mass}_{\text{hydrogen}} + \text{mass}_{\text{oxygen}}$

$\text{mass}_{\text{water electrolyzed}} = 10.0\text{ g} + 79.4\text{ g} = 89.4\text{ g}$

7. $\text{mass}_{\text{reactants}} = \text{mass}_{\text{products}}$

$\text{mass}_{\text{sodium}} + \text{mass}_{\text{chlorine}} = \text{mass}_{\text{sodium chloride}}$

$\text{mass}_{\text{sodium}} = 15.6\text{ g}$

$\text{mass}_{\text{sodium chloride}} = 39.7\text{ g}$

Substituting and solving for $\text{mass}_{\text{chlorine}}$ yields,
$15.6\text{ g} + \text{mass}_{\text{chlorine}} = 39.7\text{ g}$

$\text{mass}_{\text{chlorine}} = 39.7\text{ g} - 15.6\text{ g} = 24.1\text{ g}$ used in the reaction.

Because the sodium reacts with excess chlorine, all of the sodium is used in the reaction; that is, 15.6 g of sodium are used in the reaction.

8. The reactants are aluminum and bromine. The product is aluminum bromide. The mass of bromine used in the reaction equals the initial mass minus the mass remaining after the reaction is complete. Thus,

$\text{mass}_{\text{bromine}}$ reacted $= 100.0\text{ g} - 8.5\text{ g} = 91.5\text{ g}$

Because no aluminum remains after the reaction, you know that all of the aluminum is used in the reaction. Thus,
$\text{mass}_{\text{aluminum}}$ = initial mass of aluminum = 10.3 g

To determine the mass of aluminum bromide formed, use conservation of mass.

$\text{mass}_{\text{products}} = \text{mass}_{\text{reactants}}$

$\text{mass}_{\text{aluminum bromide}} = \text{mass}_{\text{aluminum}} + \text{mass}_{\text{bromine}}$

$\text{mass}_{\text{aluminum bromide}} = 10.3\text{ g} + 91.5\text{ g} = 101.8\text{ g}$

9. Magnesium and oxygen are the reactants. Magnesium oxide is the product.

$\text{mass}_{\text{reactants}} = \text{mass}_{\text{products}}$

$\text{mass}_{\text{magnesium}} + \text{mass}_{\text{oxygen}} = \text{mass}_{\text{magnesium oxide}}$

$\text{mass}_{\text{magnesium}} = 10.0\text{ g}$

$\text{mass}_{\text{magnesium oxide}} = 16.6\text{ g}$

Substituting and solving for $\text{mass}_{\text{oxygen}}$ yields,
$10.0\text{ g} + \text{mass}_{\text{oxygen}} = 16.6\text{ g}$

$\text{mass}_{\text{oxygen}} = 16.6\text{ g} - 10.0\text{ g} = 6.6\text{ g}$

CONTENTS

20. $\text{percent by mass}_{\text{hydrogen}} = \dfrac{\text{mass}_{\text{hydrogen}}}{\text{mass}_{\text{compound}}} \times 100$

$\text{percent by mass}_{\text{hydrogen}} = \dfrac{12.4\ \cancel{g}}{78.0\ \cancel{g}} \times 100 = 15.9\%$

21. $\text{mass}_{\text{compound}} = 1.0\ g + 19.0\ g = 20.0\ g$

$\text{percent by mass}_{\text{hydrogen}} = \dfrac{\text{mass}_{\text{hydrogen}}}{\text{mass}_{\text{compound}}} \times 100$

$\text{percent by mass}_{\text{hydrogen}} = \dfrac{1.0\ \cancel{g}}{20.0\ \cancel{g}} \times 100 = 5.0\%$

22. $\text{mass}_{xy} = 3.50\ g + 10.5\ g = 14.0\ g$

$\text{percent by mass}_{x} = \dfrac{\text{mass}_{x}}{\text{mass}_{xy}} \times 100$

$\text{percent by mass}_{x} = \dfrac{3.50\ \cancel{g}}{14.0\ \cancel{g}} \times 100 = 25.0\%$

$\text{percent by mass}_{y} = \dfrac{\text{mass}_{y}}{\text{mass}_{xy}} \times 100$

$\text{percent by mass}_{y} = \dfrac{10.5\ \cancel{g}}{14.0\ \cancel{g}} \times 100 = 75.0\%$

23. Compound I

$\text{mass}_{\text{compound}} = 15.0\ g + 120.0\ g = 135.0\ g$

$\text{percent by mass}_{\text{hydrogen}} = \dfrac{\text{mass}_{\text{hydrogen}}}{\text{mass}_{\text{compound}}} \times 100$

$\text{percent by mass}_{\text{hydrogen}} = \dfrac{15.0\ \cancel{g}}{135.0\ \cancel{g}} \times 100 = 11.1\%$

Compound II

$\text{mass}_{\text{compound}} = 2.0\ g + 32.0\ g = 34.0\ g$

$\text{percent by mass}_{\text{hydrogen}} = \dfrac{\text{mass}_{\text{hydrogen}}}{\text{mass}_{\text{compound}}} \times 100$

$\text{percent by mass}_{\text{hydrogen}} = \dfrac{2.0\ \cancel{g}}{34.0\ \cancel{g}} \times 100 = 5.8\%$

The composition by percent by mass is not the same for the two compounds. Therefore, they must be different compounds.

24. No, you cannot be sure. The fact that two compounds have the same percent by mass of a single element does not guarantee that the composition of the two compounds is the same.

Chapter 4

11.

Element	Protons	Electrons
a. boron	5	5
b. radon	86	86
c. platinum	78	78
d. magnesium	12	12

12. dysprosium

13. silicon

14.

	Protons and electrons	Neutrons	Isotope	Symbol
b.	20	26	calcium-46	$^{46}_{20}\text{Ca}$
c.	8	9	oxygen-17	$^{17}_{8}\text{O}$
d.	26	31	iron-57	$^{57}_{26}\text{Fe}$
e.	30	34	zinc-64	$^{64}_{30}\text{Zn}$
f.	80	124	mercury-204	$^{204}_{80}\text{Hg}$

15. For ^{10}B: mass contribution = (10.013 amu)(0.198) = 1.98 amu

For ^{11}B: mass contribution = (11.009 amu)(0.802) = 8.83 amu

Atomic mass of B = 1.98 amu + 8.83 amu = 10.81 amu

16. Helium-4 is more abundant in nature because the atomic mass of naturally occurring helium is closer to the mass of helium-4 (approximately 4 amu) than to the mass of helium-3 (approximately 3 amu).

17. For ^{24}Mg: mass contribution = (23.985 amu)(0.7899) = 18.95 amu

For ^{25}Mg: mass contribution = (24.986 amu)(0.1000) = 2.498 amu

For ^{26}Mg: mass contribution = (25.982 amu)(0.1101) = 2.861 amu

Atomic mass of Mg = 18.95 amu + 2.498 amu + 2.861 amu = 24.31 amu

CONTENTS

Chapter 5

1. $c = \lambda\nu$

$$3.00 \times 10^8 \text{ m/s} = (4.90 \times 10^{-7} \text{ m})\nu$$

$$\nu = \frac{3.00 \times 10^8 \cancel{\text{m}}\text{/s}}{4.90 \times 10^{-7} \cancel{\text{m}}} = 6.12 \times 10^{14} \text{ s}^{-1}$$

2. $c = \lambda\nu$

$$3.00 \times 10^8 \text{ m/s} = (1.15 \times 10^{-10} \text{ m})\nu$$

$$\nu = \frac{3.00 \times 10^8 \cancel{\text{m}}\text{/s}}{1.15 \times 10^{-10} \cancel{\text{m}}} = 2.61 \times 10^{18} \text{ s}^{-1}$$

3. The speed of all electromagnetic waves is 3.00×10^8 m/s.

4. $c = \lambda\nu$

$$94.7 \text{ MHz} = 9.47 \times 10^7 \text{ Hz}$$

$$3.00 \times 10^8 \text{ m/s} = \lambda(9.47 \times 10^7 \text{ Hz})$$

$$\lambda = \frac{3.00 \times 10^8 \text{ m/}\cancel{\text{s}}}{9.47 \times 10^7 \cancel{\text{s}^{-1}}} = 3.17 \text{ m}$$

5. a. $E_{\text{photon}} = h\nu =$
$(6.626 \times 10^{-34} \text{ J}\cdot\cancel{\text{s}})(6.32 \times 10^{20} \cancel{\text{s}^{-1}})$
$E_{\text{photon}} = 4.19 \times 10^{-13}$ J

b. $E_{\text{photon}} = h\nu =$
$(6.626 \times 10^{-34} \text{ J}\cdot\cancel{\text{s}})(9.50 \times 10^{13} \cancel{\text{s}^{-1}})$
$E_{\text{photon}} = 6.29 \times 10^{-20}$ J

c. $E_{\text{photon}} = h\nu =$
$(6.626 \times 10^{-34} \text{ J}\cdot\cancel{\text{s}})(1.05 \times 10^{16} \cancel{\text{s}^{-1}})$
$E_{\text{photon}} = 6.96 \times 10^{-18}$ J

6. a. gamma ray or X ray
b. infrared
c. ultraviolet

18. a. bromine (35 electrons): $[\text{Ar}]4s^23d^{10}4p^5$
b. strontium (38 electrons): $[\text{Kr}]5s^2$
c. antimony (51 electrons): $[\text{Kr}]5s^24d^{10}5p^3$
d. rhenium (75 electrons): $[\text{Xe}]6s^24f^{14}5d^5$
e. terbium (65 electrons): $[\text{Xe}]6s^24f^9$
f. titanium (22 electrons): $[\text{Ar}]4s^23d^2$

19. Sulfur (16 electrons) has the electron configuration $[\text{Ne}]3s^23p^4$. Therefore, 6 electrons are in orbitals related to the third energy level of the sulfur atom.

20. Chlorine (17 electrons) has the electron configuration $[\text{Ne}]3s^23p^5$, or $1s^22s^22p^63s^23p^5$. Therefore, 11 electrons occupy p orbitals in a chlorine atom.

21. indium (In)

22. barium (Ba)

23. a. $\cdot\text{Mg}\cdot$
b. $:\underset{\cdot}{\dot{\text{S}}}:$
c. $\cdot\underset{\cdot\cdot}{\overset{\cdot\cdot}{\text{Br}}}:$
d. $\text{Rb}\cdot$
e. $\cdot\dot{\text{Tl}}\cdot$
f. $:\underset{\cdot\cdot}{\overset{\cdot\cdot}{\text{Xe}}}:$

Chapter 6

7.

Electron configuration	Group	Period	Block
a. $[\text{Ne}]3s^2$	2A	3	s-block
b. $[\text{He}]2s^2$	2A	2	s-block
c. $[\text{Kr}]5s^24d^{10}5p^5$	7A	5	p-block

8. a. $[\text{Ar}]4s^2$
b. [Xe]
c. $[\text{Ar}]\ 4s^23d^{10}$
d. $[\text{He}]2s^22p^4$

9. a. Sc, Y, La, Ac
b. N, P, As, Sb, Bi
c. Ne, Ar, Kr, Xe, Rn

16. Largest: Na
Smallest: S

17. Largest: Xe
Smallest: He

18. No. If all you know is that the atomic number of one element is 20 greater than that of the other, then you will be unable to determine the specific groups and periods that the elements are in. Without this information, you cannot apply the periodic trends in atomic size to determine which element has the larger radius.

Chapter 7

No Practice Problems

Chapter 8

7. $3\ \cancel{\text{Na ions}}\left(\frac{1+}{\cancel{\text{Na ion}}}\right) + 1\ \cancel{\text{N ion}}\left(\frac{3-}{\cancel{\text{N ion}}}\right) =$

$3(1+) + 1(3-) = 0$

The overall charge on one formula unit of Na_3N is zero.

8. $2\ \cancel{\text{Li ions}}\left(\frac{1+}{\cancel{\text{Li ion}}}\right) + 1\ \cancel{\text{O ion}}\left(\frac{2-}{\cancel{\text{O ion}}}\right) =$

$2(1+) + 1(2-) = 0$

The overall charge on one formula unit of Li_2O is zero.

9. $1\ \cancel{\text{Sr ion}}\left(\frac{2+}{\cancel{\text{Sr ion}}}\right) + 2\ \cancel{\text{F ions}}\left(\frac{1-}{\cancel{\text{F ion}}}\right) =$

$1(2+) + 2(1-) = 0$

The overall charge on one formula unit of SrF_2 is zero.

10. $2\ \cancel{\text{Al ions}}\left(\frac{3+}{\cancel{\text{Al ion}}}\right) + 3\ \cancel{\text{S ions}}\left(\frac{2-}{\cancel{\text{S ion}}}\right) =$

$2(3+) + 3(2-) = 0$

The overall charge on one formula unit of Al_2S_3 is zero.

11. $3\ \cancel{\text{Cs ions}}\left(\frac{1+}{\cancel{\text{Cs ion}}}\right) + 1\ \cancel{\text{P ion}}\left(\frac{3-}{\cancel{\text{P ion}}}\right) =$

$3(1+) + 1(3-) = 0$

The overall charge on one formula unit of Cs_3P is zero.

19. KI

20. $MgCl_2$

21. $AlBr_3$

22. Cs_3N

23. BaS

24. $NaNO_3$

25. $Ca(ClO_3)_2$

26. $Al_2(CO_3)_3$

27. K_2CrO_4

28. $MgCO_3$

29. sodium bromide

30. calcium chloride

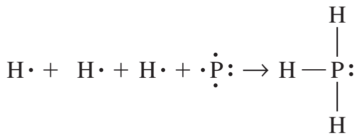
31. potassium hydroxide

32. copper(II) nitrate

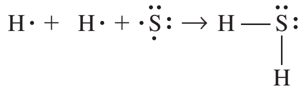
33. silver chromate

Chapter 9

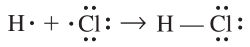
1.



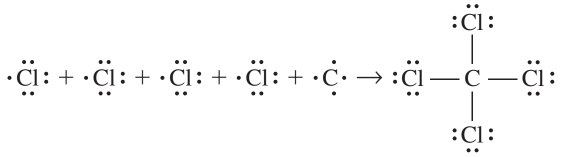
2.



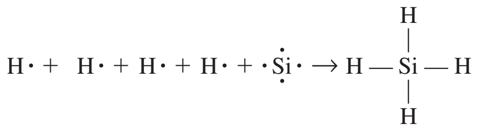
3.



4.



5.



13. carbon tetrachloride

14. diarsenic trioxide

15. carbon monoxide

16. sulfur dioxide

17. nitrogen trifluoride

18. hydroiodic acid

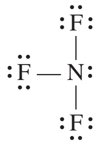
19. chloric acid

20. chlorous acid

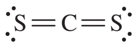
21. sulfuric acid

22. hydrosulfuric acid

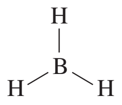
30.



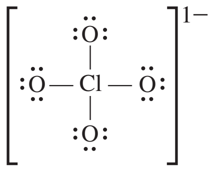
31.



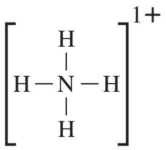
32.



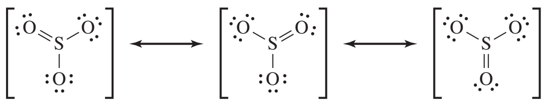
33.



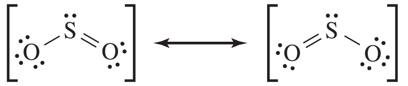
34.



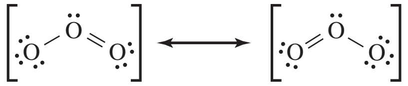
35.



36.

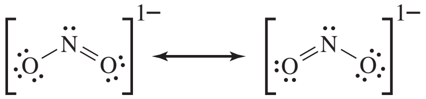


37.

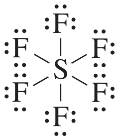


CONTENTS

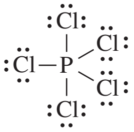
38.



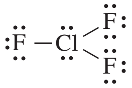
39.

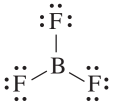
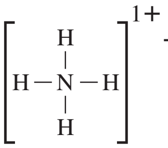
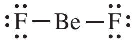
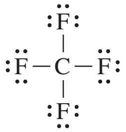


40.

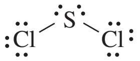


41.



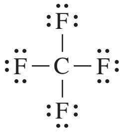
	Molecule	Geometry		Bond angle	Hybridization
49.	BF_3		Trigonal planar	120°	sp^2
50.	NH_4^+		Tetrahedral	109°	sp^3
51.	OCl_2		Bent	104.5°	sp^3
52.	BeF_2		Linear	180°	sp
53.	CF_4		Tetrahedral	109°	sp^3

60. SCl_2 is polar because the molecule is asymmetric (bent).

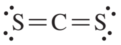


61. H_2S is polar because the molecule is asymmetric (bent).

62. CF_4 is nonpolar because the molecule is symmetric (tetrahedral).



63. CS_2 is nonpolar because the molecule is symmetric (linear).



Chapter 10

1. $H_2(g) + Br_2(g) \rightarrow HBr(g)$

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

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

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

5. $CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$

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

14. $2Al(s) + 3S(s) \rightarrow Al_2S_3(s)$ synthesis

15. $H_2O(l) + N_2O_5(g) \rightarrow 2HNO_3(aq)$ synthesis

16. $4NO_2(g) + O_2(g) \rightarrow 2N_2O_5(g)$ synthesis and combustion

17. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$ combustion

18. $2Al_2O_3(s) \rightarrow 4Al(s) + 3O_2(g)$

19. $Ni(OH)_2(s) \rightarrow NiO(s) + H_2O(l)$

20. $2NaHCO_3(s) \rightarrow Na_2CO_3(aq) + CO_2(g) + H_2O(l)$

21. Yes. K is above Zn in the metal activity series. $2K(s) + ZnCl_2(aq) \rightarrow Zn(s) + 2KCl(aq)$

22. No. Cl is below F in the halogen activity series.

23. No. Fe is below Na in the metal activity series.

24. $LiI(aq) + AgNO_3(aq) \rightarrow AgI(s) + LiNO_3(aq)$

25. $BaCl_2(aq) + K_2CO_3(aq) \rightarrow BaCO_3(s) + 2KCl(aq)$

26. $Na_2C_2O_4(aq) + Pb(NO_3)_2(aq) \rightarrow PbC_2O_4(s) + 2NaNO_3(aq)$

33. chemical equation:
$KI(aq) + AgNO_3(aq) \rightarrow KNO_3(aq) + AgI(s)$

complete ionic equation:
$\cancel{K^+}(aq) + I^-(aq) + Ag^+(aq) + \cancel{NO_3^-}(aq) \rightarrow \cancel{K^+}(aq) + \cancel{NO_3^-}(aq) + AgI(s)$

net ionic equation: $I^-(aq) + Ag^+(aq) \rightarrow AgI(s)$

34. chemical equation: $2(NH_4)_3PO_4(aq) + 3Na_2SO_4(aq) \rightarrow 3(NH_4)_2SO_4(aq) + 2Na_3PO_4(aq)$

complete ionic equation: $6\cancel{NH_4^+}(aq) + 2\cancel{PO_4^{3-}}(aq) + 6\cancel{Na^+}(aq) + 3\cancel{SO_4^{2-}}(aq) \rightarrow 6\cancel{NH_4^+}(aq) + 3\cancel{SO_4^{2-}}(aq) + 6\cancel{Na^+}(aq) + 2\cancel{PO_4^{3-}}(aq)$

No reaction occurs; therefore, there is no net ionic equation.

35. chemical equation:
$AlCl_3(aq) + 3NaOH(aq) \rightarrow Al(OH)_3(s) + 3NaCl(aq)$

complete ionic equation:
$Al^{3+}(aq) + 3\cancel{Cl^-}(aq) + 3\cancel{Na^+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s) + 3\cancel{Na^+}(aq) + 3\cancel{Cl^-}(aq)$

net ionic equation:
$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$

CONTENTS

36. chemical equation:
$Li_2SO_4(aq) + Ca(NO_3)_2(aq) \rightarrow 2LiNO_3(aq) + CaSO_4(s)$

complete ionic equation:
$\cancel{2Li^+}(aq) + SO_4^{2-}(aq) + Ca^{2+}(aq) + \cancel{2NO_3^-}(aq) \rightarrow \cancel{2Li^+}(aq) + \cancel{2NO_3^-}(aq) + CaSO_4(s)$

net ionic equation:
$SO_4^{2-}(aq) + Ca^{2+}(aq) \rightarrow CaSO_4(s)$

37. chemical equation: $5Na_2CO_3(aq) + 2MnCl_5(aq) \rightarrow 10NaCl(aq) + Mn_2(CO_3)_5(s)$

complete ionic equation:
$\cancel{10Na^+}(aq) + 5CO_3^{2-}(aq) + 2Mn^{5+}(aq) + \cancel{10Cl^-}(aq) \rightarrow \cancel{10Na^+}(aq) + \cancel{10Cl^-}(aq) + Mn_2(CO_3)_5(s)$

net ionic equation:
$5CO_3^{2-}(aq) + 2Mn^{5+}(aq) \rightarrow Mn_2(CO_3)_5(s)$

38. chemical equation:
$H_2SO_4(aq) + 2KOH(aq) \rightarrow 2H_2O(l) + K_2SO_4(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{SO_4^{2-}}(aq) + \cancel{2K^+}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + \cancel{2K^+}(aq) + \cancel{SO_4^{2-}}(aq)$

net ionic equation:
$2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$
or $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

39. chemical equation:
$2HCl(aq) + Ca(OH)_2(aq) \rightarrow 2H_2O(l) + CaCl_2(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{2Cl^-}(aq) + \cancel{Ca^{2+}}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + \cancel{Ca^{2+}}(aq) + \cancel{2Cl^-}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

40. chemical equation:
$HNO_3(aq) + NH_4OH(aq) \rightarrow H_2O(l) + NH_4NO_3(aq)$

complete ionic equation:
$H^+(aq) + \cancel{NO_3^-}(aq) + \cancel{NH_4^+}(aq) + OH^-(aq) \rightarrow H_2O(l) + \cancel{NH_4^+}(aq) + \cancel{NO_3^-}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

41. chemical equation:
$H_2S(aq) + Ca(OH)_2(aq) \rightarrow 2H_2O(l) + CaS(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{S^{2-}}(aq) + \cancel{Ca^{2+}}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + \cancel{Ca^{2+}}(aq) + \cancel{S^{2-}}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

42. chemical equation: $2H_3PO_4(aq) + 3Mg(OH)_2(aq) \rightarrow 6H_2O(l) + Mg_3(PO_4)_2(aq)$

complete ionic equation:
$6H^+(aq) + 2PO_4^{3-}(aq) + 3Mg^{2+}(aq) + 6OH^-(aq) \rightarrow 6H_2O(l) + 3Mg^{2+}(aq) + 2PO_4^{3-}(aq)$

net ionic equation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

43. chemical equation: $2HClO_4(aq) + K_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g) + 2KClO_4(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{2ClO_4^-}(aq) + \cancel{2K^+}(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g) + \cancel{2K^+}(aq) + \cancel{2ClO_4^-}(aq)$

net ionic equation:
$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

44. chemical equation:
$H_2SO_4(aq) + 2NaCN(aq) \rightarrow 2HCN(g) + Na_2SO_4(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{SO_4^{2-}}(aq) + \cancel{2Na^+}(aq) + 2CN^-(aq) \rightarrow 2HCN(g) + \cancel{2Na^+}(aq) + \cancel{SO_4^{2-}}(aq)$

net ionic equation:
$2H^+(aq) + 2CN^-(aq) \rightarrow 2HCN(g)$
or $H^+(aq) + CN^-(aq) \rightarrow HCN(g)$

45. chemical equation: $2HBr(aq) + (NH_4)_2CO_3(aq) \rightarrow H_2O(l) + CO_2(g) + 2NH_4Br(aq)$

complete ionic equation:
$2H^+(aq) + \cancel{2Br^-}(aq) + \cancel{2NH_4^+}(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g) + \cancel{2NH_4^+}(aq) + \cancel{2Br^-}(aq)$

net ionic equation:
$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$

46. chemical equation:
$2HNO_3(aq) + KRbS(aq) \rightarrow H_2S(g) + KRb(NO_3)_2(aq)$

complete ionic equation: $2H^+(aq) + \cancel{2NO_3^-}(aq) + \cancel{K^+}(aq) + \cancel{Rb^+}(aq) + S^{2-}(aq) \rightarrow H_2S(g) + \cancel{K^+}(aq) + \cancel{Rb^+}(aq) + \cancel{2NO_3^-}(aq)$

net ionic equation: $2H^+(aq) + S^{2-}(aq) \rightarrow H_2S(g)$

CONTENTS

Chapter 11

1. $2.50\ \cancel{\text{mol}}\ \text{Zn} \times \frac{6.02 \times 10^{23}\ \text{atoms}}{1\ \cancel{\text{mol}}}$

$= 1.51 \times 10^{24}$ atoms of Zn

2. $3.25\ \cancel{\text{mol}}\ \text{AgNO}_3 \times \frac{6.02 \times 10^{23}\ \text{formula units}}{1\ \cancel{\text{mol}}}$

$= 1.96 \times 10^{24}$ formula units of AgNO_3

3. $11.5\ \cancel{\text{mol}}\ \text{H}_2\text{O} \times \frac{6.02 \times 10^{23}\ \text{molecules}}{1\ \cancel{\text{mol}}}$

$= 6.92 \times 10^{24}$ molecules of H_2O

4. a. $5.75 \times 10^{24}\ \cancel{\text{atoms}}\ \text{Al} \times \frac{1\ \text{mol}}{6.02 \times 10^{23}\ \cancel{\text{atoms}}}$

$= 9.55$ mol Al

b. $3.75 \times 10^{24}\ \cancel{\text{molecules}}\ \text{CO}_2 \times$

$\frac{1\ \text{mol}}{6.02 \times 10^{23}\ \cancel{\text{molecules}}} = 6.23\ \text{mol CO}_2$

c. $3.58 \times 10^{23}\ \cancel{\text{formula units}}\ \text{ZnCl}_2 \times$

$\frac{1\ \text{mol}}{6.02 \times 10^{23}\ \cancel{\text{formula units}}} = 0.595\ \text{mol ZnCl}_2$

d. $2.50 \times 10^{20}\ \cancel{\text{atoms}}\ \text{Fe} \times \frac{1\ \text{mol}}{6.02 \times 10^{23}\ \cancel{\text{atoms}}}$

$= 4.15 \times 10^{-4}$ mol Fe

11. a. $3.57\ \cancel{\text{mol}}\ \text{Al} \times \frac{26.98\ \text{g Al}}{1\ \cancel{\text{mol}}\ \text{Al}} = 96.3\ \text{g Al}$

b. $42.6\ \cancel{\text{mol Si}} \times \frac{28.09\ \text{g Si}}{1\ \cancel{\text{mol Si}}} = 1.20 \times 10^3\ \text{g Si}$

c. $3.45\ \cancel{\text{mol Co}} \times \frac{58.93\ \text{g Co}}{1\ \cancel{\text{mol Co}}} = 203\ \text{g Co}$

d. $2.45\ \cancel{\text{mol Zn}} \times \frac{65.38\ \text{g Zn}}{1\ \cancel{\text{mol Zn}}} = 1.60 \times 10^2\ \text{g Zn}$

12. a. $25.5\ \cancel{\text{g Ag}} \times \frac{1\ \text{mol Ag}}{107.9\ \cancel{\text{g Ag}}} = 0.236\ \text{mol Ag}$

b. $300.0\ \cancel{\text{g S}} \times \frac{1\ \text{mol S}}{32.07\ \cancel{\text{g S}}} = 9.355\ \text{mol S}$

c. $125\ \cancel{\text{g Zn}} \times \frac{1\ \text{mol Zn}}{65.38\ \cancel{\text{g Zn}}} = 1.91\ \text{mol Zn}$

d. $1.00\ \cancel{\text{kg Fe}} \times \frac{1000\ \text{g Fe}}{1\ \cancel{\text{kg Fe}}} \times \frac{1\ \text{mol Fe}}{55.85\ \text{g Fe}}$

$= 17.9$ mol Fe

13. a. $55.2\ \cancel{\text{g Li}} \times \frac{1\ \cancel{\text{mol}}\ \text{Li}}{6.941\ \cancel{\text{g Li}}} \times \frac{6.02 \times 10^{23}\ \text{atoms}}{1\ \cancel{\text{mol}}}$

$= 4.79 \times 10^{24}$ atoms Li

b. $0.230\ \cancel{\text{g Pb}} \times \frac{1\ \cancel{\text{mol}}\ \text{Pb}}{207.2\ \cancel{\text{g Pb}}} \times \frac{6.02 \times 10^{23}\ \text{atoms}}{1\ \cancel{\text{mol}}}$

$= 6.68 \times 10^{20}$ atoms Pb

c. $11.5\ \cancel{\text{g Hg}} \times \frac{1\ \cancel{\text{mol}}\ \text{Hg}}{200.6\ \cancel{\text{g Hg}}} \times \frac{6.02 \times 10^{23}\ \text{atoms}}{1\ \cancel{\text{mol}}}$

$= 3.45 \times 10^{22}$ atoms Hg

d. $45.6\ \cancel{\text{g Si}} \times \frac{1\ \cancel{\text{mol}}\ \text{Si}}{28.09\ \cancel{\text{g Si}}} \times \frac{6.02 \times 10^{23}\ \text{atoms}}{1\ \cancel{\text{mol}}}$

$= 9.77 \times 10^{23}$ atoms Si

e. $0.120\ \cancel{\text{kg Ti}} \times \frac{1000\ \cancel{\text{g Ti}}}{1\ \cancel{\text{kg Ti}}} \times \frac{1\ \cancel{\text{mol}}\ \text{Ti}}{47.88\ \cancel{\text{g Ti}}} \times$

$\frac{6.02 \times 10^{23}\ \text{atoms}}{1\ \cancel{\text{mol}}} = 1.51 \times 10^{24}\ \text{atoms Ti}$

14. a. $6.02 \times 10^{24}\ \cancel{\text{atoms}}\ \text{Bi} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\ \cancel{\text{atoms}}} \times$

$\frac{209.0\ \text{g Bi}}{1\ \cancel{\text{mol}}\ \text{Bi}} = 2.09 \times 10^3\ \text{g Bi}$

b. $1.00 \times 10^{24}\ \cancel{\text{atoms}}\ \text{Mn} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\ \cancel{\text{atoms}}} \times$

$\frac{54.94\ \text{g Mn}}{1\ \cancel{\text{mol}}\ \text{Mn}} = 91.3\ \text{g Mn}$

c. $3.40 \times 10^{22}\ \cancel{\text{atoms}}\ \text{He} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\ \cancel{\text{atoms}}} \times$

$\frac{4.003\ \text{g He}}{1\ \cancel{\text{mol}}\ \text{He}} = 0.226\ \text{g He}$

d. $1.50 \times 10^{15}\ \cancel{\text{atoms}}\ \text{N} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\ \cancel{\text{atoms}}} \times$

$\frac{14.01\ \text{g N}}{1\ \cancel{\text{mol}}\ \text{N}} = 3.49 \times 10^{-8}\ \text{g N}$

e. $1.50 \times 10^{15}\ \cancel{\text{atoms}}\ \text{U} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\ \cancel{\text{atoms}}} \times$

$\frac{238.0\ \text{g U}}{1\ \cancel{\text{mol}}\ \text{U}} = 5.93 \times 10^{-7}\ \text{g U}$

20. $2.50\ \cancel{\text{mol ZnCl}_2} \times \frac{2\ \text{mol Cl}^-}{1\ \cancel{\text{mol ZnCl}_2}} = 5.00\ \text{mol Cl}^-$

21. $1.25\ \cancel{\text{mol C}_6\text{H}_{12}\text{O}_6} \times \frac{6\ \text{mol C}}{1\ \cancel{\text{mol C}_6\text{H}_{12}\text{O}_6}} = 7.50\ \text{mol C}$

$1.25\ \cancel{\text{mol C}_6\text{H}_{12}\text{O}_6} \times \frac{12\ \text{mol H}}{1\ \cancel{\text{mol C}_6\text{H}_{12}\text{O}_6}} = 15.0\ \text{mol H}$

$1.25\ \cancel{\text{mol C}_6\text{H}_{12}\text{O}_6} \times \frac{6\ \text{mol O}}{1\ \cancel{\text{mol C}_6\text{H}_{12}\text{O}_6}} = 7.50\ \text{mol O}$

22. $3.00\ \cancel{\text{mol Fe}_2(\text{SO}_4)_3} \times \frac{3\ \text{mol SO}_4{}^{2-}}{1\ \cancel{\text{mol Fe}_2(\text{SO}_4)_3}}$

$= 9.00\ \text{mol SO}_4{}^{2-}$

23. $5.00\ \cancel{\text{mol P}_2\text{O}_5} \times \frac{5\ \text{mol O}}{1\ \cancel{\text{mol P}_2\text{O}_5}} = 25.0\ \text{mol O}$

24. $11.5\ \cancel{\text{mol H}_2\text{O}} \times \frac{2\ \text{mol H}}{1\ \cancel{\text{mol H}_2\text{O}}} = 23.0\ \text{mol H}$

CONTENTS

25. NaOH

$$1\ \cancel{\text{mol Na}} \times \frac{22.99\ \text{g Na}}{1\ \cancel{\text{mol Na}}} = 22.99\ \text{g}$$

$$1\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = 16.00\ \text{g}$$

$$1\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = \underline{1.008\ \text{g}}$$

$$\text{molar mass NaOH} = 40.00\ \text{g/mol}$$

$CaCl_2$

$$1\ \cancel{\text{mol Ca}} \times \frac{40.08\ \text{g Ca}}{1\ \cancel{\text{mol Ca}}} = 40.08\ \text{g}$$

$$2\ \cancel{\text{mol Cl}} \times \frac{35.45\ \text{g Cl}}{1\ \cancel{\text{mol Cl}}} = \underline{70.90\ \text{g}}$$

$$\text{molar mass CaCl}_2 = 110.98\ \text{g/mol}$$

$KC_2H_3O_2$

$$1\ \cancel{\text{mol K}} \times \frac{39.10\ \text{g K}}{1\ \cancel{\text{mol K}}} = 39.10\ \text{g}$$

$$2\ \cancel{\text{mol C}} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = 24.02\ \text{g}$$

$$3\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 3.024\ \text{g}$$

$$2\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{32.00\ \text{g}}$$

$$\text{molar mass KC}_2\text{H}_3\text{O}_2 = 98.14\ \text{g/mol}$$

$Sr(NO_3)_2$

$$1\ \cancel{\text{mol Sr}} \times \frac{87.62\ \text{g Sr}}{1\ \cancel{\text{mol Sr}}} = 87.62\ \text{g}$$

$$2\ \cancel{\text{mol N}} \times \frac{14.01\ \text{g N}}{1\ \cancel{\text{mol N}}} = 28.02\ \text{g}$$

$$6\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{96.00\ \text{g}}$$

$$\text{molar mass Sr(NO}_3)_2 = 211.64\ \text{g/mol}$$

$(NH_4)_3PO_4$

$$3\ \cancel{\text{mol N}} \times \frac{14.01\ \text{g N}}{1\ \cancel{\text{mol N}}} = 42.03\ \text{g}$$

$$12\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 12.096\ \text{g}$$

$$1\ \cancel{\text{mol P}} \times \frac{30.97\ \text{g P}}{1\ \cancel{\text{mol P}}} = 30.97\ \text{g}$$

$$4\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{64.00\ \text{g}}$$

$$\text{molar mass (NH}_4)_3\text{PO}_4 = 149.10\ \text{g/mol}$$

26. C_2H_5OH

$$2\ \cancel{\text{mol C}} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = 24.02\ \text{g}$$

$$6\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 6.048\ \text{g}$$

$$1\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{\cancel{\text{mol O}}} = \underline{16.00\ \text{g}}$$

$$\text{molar mass C}_2\text{H}_5\text{OH} = 46.07\ \text{g/mol}$$

$C_{12}H_{22}O_{11}$

$$12\ \cancel{\text{mol C}} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = 144.12\ \text{g}$$

$$22\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 22.176\ \text{g}$$

$$11\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{176.00\ \text{g}}$$

$$\text{molar mass C}_{12}\text{H}_{22}\text{O}_{11} = 342.30\ \text{g/mol}$$

HCN

$$1\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 1.008\ \text{g}$$

$$1\ \cancel{\text{mol C}} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = 12.01\ \text{g}$$

$$1\ \cancel{\text{mol N}} \times \frac{14.01\ \text{g N}}{1\ \cancel{\text{mol N}}} = \underline{14.01\ \text{g}}$$

$$\text{molar mass HCN} = 27.03\ \text{g/mol}$$

CCl_4

$$1\ \cancel{\text{mol C}} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = 12.01\ \text{g}$$

$$4\ \cancel{\text{mol Cl}} \times \frac{35.45\ \text{g Cl}}{1\ \cancel{\text{mol Cl}}} = \underline{141.80\ \text{g}}$$

$$\text{molar mass CCl}_4 = 153.81\ \text{g/mol}$$

H_2O

$$2\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 2.016\ \text{g}$$

$$1\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{16.00\ \text{g}}$$

$$\text{molar mass H}_2\text{O} = 18.02\ \text{g/mol}$$

27. Step 1: Find the molar mass of H_2SO_4.

$$2\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 2.016\ \text{g}$$

$$1\ \cancel{\text{mol S}} \times \frac{32.07\ \text{g S}}{1\ \cancel{\text{mol S}}} = 32.07\ \text{g}$$

$$4\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{64.00\ \text{g}}$$

$$\text{molar mass H}_2\text{SO}_4 = 98.09\ \text{g/mol}$$

Step 2: Make mole → mass conversion.

$$3.25\ \cancel{\text{mol}}\ \text{H}_2\text{SO}_4 \times \frac{98.09\ \text{g H}_2\text{SO}_4}{1\ \cancel{\text{mol}}\ \text{H}_2\text{SO}_4} = 319\ \text{g H}_2\text{SO}_4$$

CONTENTS

28. Step 1: Find the molar mass of $ZnCl_2$.

$$1\ \cancel{\text{mol Zn}} \times \frac{65.38\text{ g Zn}}{1\ \cancel{\text{mol Zn}}} = 65.38\text{ g}$$

$$2\ \cancel{\text{mol Cl}} \times \frac{35.45\text{ g Cl}}{1\ \cancel{\text{mol Cl}}} = \underline{70.90\text{ g}}$$

$$\text{molar mass ZnCl}_2 = 136.28\text{ g/mol}$$

Step 2: Make mole → mass conversion.

$$4.35 \times 10^{-2}\ \cancel{\text{mol ZnCl}_2} \times \frac{136.28\text{ g ZnCl}_2}{1\ \cancel{\text{mol ZnCl}_2}}$$

$$= 5.93\text{ g ZnCl}_2$$

29. Step 1: Find the molar mass of $KMnO_4$.

$$1\ \cancel{\text{mol K}} \times \frac{39.10\text{ g K}}{1\ \cancel{\text{mol K}}} = 39.10\text{ g}$$

$$1\ \cancel{\text{mol Mn}} \times \frac{54.94\text{ g Mn}}{1\ \cancel{\text{mol Mn}}} = 54.94\text{ g}$$

$$4\ \cancel{\text{mol O}} \times \frac{16.00\text{ g O}}{1\ \cancel{\text{mol O}}} = \underline{64.00\text{ g}}$$

$$\text{molar mass KMnO}_4 = 158.04\text{ g/mol}$$

Step 2: Make mole → mass conversion.

$$2.55\ \cancel{\text{mol KMnO}_4} \times \frac{158.04\text{ g KMnO}_4}{1\ \cancel{\text{mol KMnO}_4}}$$

$$= 403\text{ g KMnO}_4$$

30. **a.** Step 1: Find the molar mass of $AgNO_3$.

$$1\ \cancel{\text{mol Ag}} \times \frac{107.9\text{ g Ag}}{1\ \cancel{\text{mol Ag}}} = 107.9\text{ g}$$

$$1\ \cancel{\text{mol N}} \times \frac{14.01\text{ g N}}{1\ \cancel{\text{mol N}}} = 14.01\text{ g}$$

$$3\ \cancel{\text{mol O}} \times \frac{16.00\text{ g O}}{1\ \cancel{\text{mol O}}} = \underline{48.00\text{ g}}$$

$$\text{molar mass AgNO}_3 = 169.9\text{ g/mol}$$

Step 2: Make mass → mole conversion.

$$22.6\ \cancel{\text{g AgNO}_3} \times \frac{1\text{ mol AgNO}_3}{169.9\ \cancel{\text{g AgNO}_3}}$$

$$= 0.133\text{ mol AgNO}_3$$

b. Step 1: Find molar mass of $ZnSO_4$.

$$1\ \cancel{\text{mol Zn}} \times \frac{65.39\text{ g Zn}}{1\ \cancel{\text{mol Zn}}} = 65.39\text{ g}$$

$$1\ \cancel{\text{mol S}} \times \frac{32.07\text{ g S}}{1\ \cancel{\text{mol S}}} = 32.07\text{ g}$$

$$4\ \cancel{\text{mol O}} \times \frac{16.00\text{ g O}}{1\ \cancel{\text{mol O}}} = \underline{64.00\text{ g}}$$

$$\text{molar mass ZnSO}_4 = 161.46\text{ g/mol}$$

Step 2: Make mass → mole conversion.

$$6.50\ \cancel{\text{g ZnSO}_4} \times \frac{1\text{ mol ZnSO}_4}{161.46\ \cancel{\text{g ZnSO}_4}}$$

$$= 0.0403\text{ mol ZnSO}_4$$

c. Step 1: Find the molar mass of HCl.

$$1\ \cancel{\text{mol H}} \times \frac{1.008\text{ g H}}{1\ \cancel{\text{mol H}}} = 1.008\text{ g}$$

$$1\ \cancel{\text{mol Cl}} \times \frac{35.45\text{ g Cl}}{1\ \cancel{\text{mol Cl}}} = \underline{35.45\text{ g}}$$

$$\text{molar mass HCl} = 36.46\text{ g/mol}$$

Step 2: Make mass → mole conversion.

$$35.0\ \cancel{\text{g HCl}} \times \frac{1\text{ mol HCl}}{36.46\ \cancel{\text{g HCl}}} = 0.960\text{ mol HCl}$$

d. Step 1: Find the molar mass of Fe_2O_3.

$$2\ \cancel{\text{mol Fe}} \times \frac{55.85\text{ g Fe}}{1\ \cancel{\text{mol Fe}}} = 111.70\text{ g}$$

$$3\ \cancel{\text{mol O}} \times \frac{16.00\text{ g O}}{1\ \cancel{\text{mol O}}} = \underline{48.00\text{ g}}$$

$$\text{molar mass Fe}_2\text{O}_3 = 159.70\text{ g/mol}$$

Step 2: Make mass → mole conversion.

$$25.0\text{ g Fe}_2\text{O}_3 \times \frac{1\text{ mol Fe}_2\text{O}_3}{159.70\ \cancel{\text{g Fe}_2\text{O}_3}}$$

$$= 0.157\text{ mol Fe}_2\text{O}_3$$

e. Step 1: Find the molar mass of $PbCl_4$.

$$1\text{ mol Pb} \times \frac{207.2\text{ g Pb}}{1\text{ mol Pb}} = 207.2\text{ g}$$

$$4\text{ mol Cl} \times \frac{35.45\text{ g Cl}}{1\ \cancel{\text{mol Cl}}} = \underline{141.80\text{ g}}$$

$$\text{molar mass PbCl}_4 = 349.0\text{ g/mol}$$

Step 2: Make mass → mole conversion.

$$254\ \cancel{\text{g PbCl}_4} \times \frac{1\text{ mol PbCl}_4}{349.0\ \cancel{\text{g PbCl}_4}} = 0.728\text{ mol PbCl}_4$$

31. Step 1: Find the molar mass of Ag_2CrO_4.

$$2\ \cancel{\text{mol Ag}} \times \frac{107.9\text{ g Ag}}{1\ \cancel{\text{mol Ag}}} = 215.8\text{ g}$$

$$1\ \cancel{\text{mol Cr}} \times \frac{52.00\text{ g Cr}}{1\ \cancel{\text{mol Cr}}} = 52.00\text{ g}$$

$$4\ \cancel{\text{mol O}} \times \frac{16.00\text{ g O}}{1\ \cancel{\text{mol O}}} = \underline{64.00\text{ g}}$$

$$\text{molar mass Ag}_2\text{CrO}_4 = 331.8\text{ g/mol}$$

Step 2: Make mass → mole conversion.

$$25.8\ \cancel{\text{g Ag}_2\text{CrO}_4} \times \frac{1\text{ mol Ag}_2\text{CrO}_4}{331.8\ \cancel{\text{g Ag}_2\text{CrO}_4}}$$

$$= 0.0778\text{ mol Ag}_2\text{CrO}_4$$

Step 3: Make mole → formula unit conversion.

$$0.0778\ \cancel{\text{mol}}\text{ Ag}_2\text{CrO}_4 \times \frac{6.02 \times 10^{23}\text{ formula units}}{1\ \cancel{\text{mol}}}$$

$$= 4.68 \times 10^{22}\text{ formula units Ag}_2\text{CrO}_4$$

a. $$4.68 \times 10^{22}\ \cancel{\text{formula units}}\text{ Ag}_2\text{CrO}_4 \times \frac{2\text{ Ag}^+\text{ ions}}{1\ \cancel{\text{formula unit}}\text{ Ag}_2\text{CrO}_4} = 9.36 \times 10^{22}\text{ Ag}^+\text{ ions}$$

b. $$4.68 \times 10^{22}\ \cancel{\text{formula units}}\text{ Ag}_2\text{CrO}_4 \times \frac{1\text{ CrO}_4^{\,2-}\text{ ion}}{1\ \cancel{\text{formula unit}}\text{ Ag}_2\text{CrO}_4}$$

$$= 4.68 \times 10^{22}\text{ CrO}_4^{\,2-}\text{ ions}$$

c. $$\frac{331.8\text{ g Ag}_2\text{CrO}_4}{1\ \cancel{\text{mol}}\text{ Ag}_2\text{CrO}_4} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\text{ formula units}}$$

$$= 5.51 \times 10^{-22}\text{ g Ag}_2\text{CrO}_4\text{/formula unit}$$

CONTENTS

32. Step 1: Find the number of moles of NaCl.

$$4.59 \times 10^{24}\ \cancel{\text{formula units}}\ \text{NaCl} \times \frac{1\ \text{mol}}{6.02 \times 10^{23}\ \cancel{\text{formula units}}} = 7.62\ \text{mol NaCl}$$

Step 2: Find the molar mass of NaCl.

$$1\ \cancel{\text{mol Na}} \times \frac{22.99\ \text{g Na}}{1\ \cancel{\text{mol Na}}} = 22.99\ \text{g}$$

$$1\ \cancel{\text{mol Cl}} \times \frac{35.45\ \text{g Cl}}{1\ \cancel{\text{mol Cl}}} = \underline{35.45\ \text{g}}$$

molar mass NaCl = 58.44 g/mol

Step 3: Make mole → mass conversion.

$$7.62\ \cancel{\text{mol NaCl}} \times \frac{58.44\ \text{g NaCl}}{1\ \cancel{\text{mol NaCl}}} = 445\ \text{g NaCl}$$

33. Step 1: Find molar mass of C_2H_5OH.

$$2\ \cancel{\text{mol C}} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = 24.02\ \text{g}$$

$$6\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 6.048\ \text{g}$$

$$1\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{16.00\ \text{g}}$$

molar mass C_2H_5OH = 46.07 g/mol

Step 2: Make mass → mole conversion.

$$45.6\ \cancel{\text{g } C_2H_5OH} \times 1\ \frac{\text{mol } C_2H_5OH}{46.07\ \cancel{\text{g } C_2H_5OH}}$$

$= 0.990$ mol C_2H_5OH

Step 3: Make mole → molecule conversion.

$$0.990\ \cancel{\text{mol}}\ C_2H_5OH \times \frac{6.02 \times 10^{23}\ \text{molecules}}{1\ \cancel{\text{mol}}}$$

$= 5.96 \times 10^{23}$ molecules C_2H_5OH

a. $$5.96 \times 10^{23}\ \cancel{\text{molecules } C_2H_5OH} \times \frac{2\ \text{C atoms}}{1\ \cancel{\text{molecule } C_2H_5OH}} = 1.19 \times 10^{24}\ \text{C atoms}$$

b. $$5.96 \times 10^{23}\ \cancel{\text{molecules } C_2H_5OH} \times \frac{6\ \text{H atoms}}{1\ \cancel{\text{molecule } C_2H_5OH}} = 3.58 \times 10^{24}\ \text{H atoms}$$

c. $$5.96 \times 10^{23}\ \cancel{\text{molecules } C_2H_5OH} \times \frac{1\ \text{O atom}}{1\ \cancel{\text{molecule } C_2H_5OH}} = 5.96 \times 10^{23}\ \text{O atoms}$$

34. Step 1: Find the molar mass of Na_2SO_3.

$$2\ \cancel{\text{mol Na}} \times \frac{22.99\ \text{g Na}}{1\ \cancel{\text{mol Na}}} = 45.98\ \text{g}$$

$$1\ \cancel{\text{mol S}} \times \frac{32.07\ \text{g S}}{1\ \cancel{\text{mol S}}} = 32.07\ \text{g}$$

$$3\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{48.00\ \text{g}}$$

molar mass Na_2SO_3 = 126.04 g/mol

Step 2: Make mass → mole conversion.

$$2.25\ \text{g}\ \cancel{Na_2SO_3} \times \frac{1\ \text{mol } Na_2SO_3}{126.04\ \text{g}\ \cancel{Na_2SO_3}}$$

$= 0.0179$ mol Na_2SO_3

Step 3: Make mole → formula unit conversion.

$$0.0179\ \cancel{\text{mol}}\ Na_2SO_3 \times \frac{6.02 \times 10^{23}\ \text{formula units}}{1\ \cancel{\text{mol}}}$$

$= 1.08 \times 10^{22}$ formula units Na_2SO_3

a. $$1.08 \times 10^{22}\ \cancel{\text{formula units } Na_2SO_3} \times \frac{2\ Na^{+}\ \text{ions}}{1\ \cancel{\text{formula unit } Na_2SO_3}} = 2.16 \times 10^{22}\ Na^{+}\ \text{ions}$$

b. $$1.08 \times 10^{22}\ \cancel{\text{formula units } Na_2SO_3} \times \frac{1\ SO_3^{2-}\ \text{ions}}{1\ \cancel{\text{formula unit } Na_2SO_3}} = 1.08 \times 10^{22}\ SO_3^{2-}\ \text{ions}$$

c. $$\frac{126.08\ \text{g } Na_2SO_3}{1\ \cancel{\text{mol}}\ Na_2SO_3} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\ \text{formula units}}$$

$= 2.09 \times 10^{-22}$ g Na_2SO_3 /formula unit

35. Step 1: Find the molar mass of CO_2.

$$1\ \cancel{\text{mol C}} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = 12.01\ \text{g}$$

$$2\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{32.00\ \text{g}}$$

molar mass CO_2 = 44.01 g/mol

Step 2: Make mass → mole conversion.

$$52.0\ \cancel{\text{g } CO_2} \times \frac{1\ \text{mol } CO_2}{44.01\ \cancel{\text{g } CO_2}} = 1.18\ \text{mol } CO_2$$

Step 3: Make mole → molecule conversion.

$$1.18\ \cancel{\text{mol}}\ CO_2 \times \frac{6.02 \times 10^{23}\ \text{molecules}}{1\ \cancel{\text{mol}}}$$

$= 7.11 \times 10^{23}$ molecules CO_2

a. $$7.11 \times 10^{23}\ \cancel{\text{molecules } CO_2} \times \frac{1\ \text{C atom}}{1\ \cancel{\text{molecule } CO_2}}$$

$= 7.11 \times 10^{23}$ C atoms

b. $$7.11 \times 10^{23}\ \cancel{\text{molecules } CO_2} \times \frac{2\ \text{O atoms}}{1\ \cancel{\text{molecule } CO_2}}$$

$= 1.42 \times 10^{24}$ O atoms

c. $$\frac{44.01\ \text{g } CO_2}{1\ \cancel{\text{mol}}\ CO_2} \times \frac{1\ \cancel{\text{mol}}}{6.02 \times 10^{23}\ \text{molecules}}$$

$= 7.31 \times 10^{-23}$ g CO_2/molecule

42. Steps 1 and 2: Assume 1 mole; calculate molar mass of $CaCl_2$.

$$1\ \cancel{\text{mol Ca}} \times \frac{40.08\ \text{g Ca}}{1\ \cancel{\text{mol Ca}}} = 40.08\ \text{g}$$

$$2\ \cancel{\text{mol Cl}} \times \frac{35.45\ \text{g Cl}}{1\ \cancel{\text{mol Cl}}} = \underline{70.90\ \text{g}}$$

molar mass $CaCl_2$ = 110.98 g/mol

CONTENTS

Step 3: Determine percent by mass of each element.

$$\text{percent Ca} = \frac{40.08\ \cancel{\text{g Ca}}}{110.98\ \cancel{\text{g CaCl}_2}} \times 100 = 36.11\%\ \text{Ca}$$

$$\text{percent Cl} = \frac{70.90\ \cancel{\text{g Cl}}}{110.98\ \cancel{\text{g CaCl}_2}} \times 100 = 63.89\%\ \text{Cl}$$

43. Steps 1 and 2: Assume 1 mole; calculate molar mass of Na_2SO_4.

$$2\ \cancel{\text{mol Na}} \times \frac{22.99\ \text{g Na}}{1\ \cancel{\text{mol Na}}} = 45.98\ \text{g}$$

$$1\ \cancel{\text{mol S}} \times \frac{32.06\ \text{g S}}{1\ \cancel{\text{mol S}}} = 32.07\ \text{g}$$

$$4\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{64.00\ \text{g}}$$

$$\text{molar mass Na}_2\text{SO}_4 = 142.05\ \text{g/mol}$$

Step 3: Determine percent by mass of each element.

$$\text{percent Na} = \frac{45.98\ \cancel{\text{g Na}}}{142.05\ \cancel{\text{g Na}_2\text{SO}_4}} \times 100 = 32.37\%\ \text{Na}$$

$$\text{percent S} = \frac{32.07\cancel{\text{g S}}}{142.05\ \text{g}\cancel{\text{Na}_2\text{SO}_4}} \times 100 = 22.58\%\ \text{S}$$

$$\text{percent O} = \frac{64.00\ \text{g O}}{142.05\ \text{g Na}_2\text{SO}_4} \times 100 = 45.05\%\ \text{O}$$

44. Steps 1 and 2: Assume 1 mole; calculate molar mass of H_2SO_3.

$$2\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 2.016\ \text{g}$$

$$1\ \cancel{\text{mol S}} \times \frac{32.06\ \text{g S}}{1\ \cancel{\text{mol S}}} = 32.06\ \text{g}$$

$$3\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{48.00\ \text{g}}$$

$$\text{molar mass H}_2\text{SO}_3 = 82.08\ \text{g/mol}$$

Step 3: Determine percent by mass of S.

$$\text{percent S} = \frac{32.06\ \cancel{\text{g S}}}{82.08\ \text{g}\ \cancel{\text{H}_2\text{SO}_3}} \times 100 = 39.06\%\ \text{S}$$

Repeat steps 1 and 2 for $H_2S_2O_8$. Assume 1 mole; calculate molar mass of $H_2S_2O_8$.

$$2\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 2.016\ \text{g}$$

$$2\ \cancel{\text{mol S}} \times \frac{32.06\ \text{g S}}{1\ \cancel{\text{mol S}}} = 64.12\ \text{g}$$

$$8\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{128.00\ \text{g}}$$

$$\text{molar mass H}_2\text{S}_2\text{O}_8 = 194.14\ \text{g/mol}$$

Step 3: Determine percent by mass of S.

$$\text{percent S} = \frac{64.12\ \cancel{\text{g S}}}{194.14\ \text{g}\ \cancel{\text{H}_2\text{S}_2\text{O}_8}} \times 100 = 33.03\%\ \text{S}$$

H_2SO_3 has a larger percent by mass of S.

45. Steps 1 and 2: Assume 1 mole; calculate molar mass of H_3PO_4.

$$3\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = 3.024\ \text{g}$$

$$1\ \cancel{\text{mol P}} \times \frac{30.97\ \text{g P}}{1\ \cancel{\text{mol P}}} = 30.97\ \text{g}$$

$$4\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = 64.00\ \text{g}$$

$$\text{molar mass H}_3\text{PO}_4 = 97.99\ \text{g/mol}$$

Step 3: Determine percent by mass of each element.

$$\text{percent H} = \frac{3.024\ \cancel{\text{g H}}}{97.99\ \cancel{\text{g H}_3\text{PO}_4}} \times 100 = 3.08\%\ \text{H}$$

$$\text{percent P} = \frac{30.97\ \cancel{\text{g P}}}{97.99\ \cancel{\text{g H}_3\text{PO}_4}} \times 100 = 31.61\%\ \text{P}$$

$$\text{percent O} = \frac{64.00\ \cancel{\text{g O}}}{97.99\ \cancel{\text{g H}_3\text{PO}_4}} \times 100 = 65.31\%\ \text{O}$$

46. Step 1: Assume 100 g sample; calculate moles of each element.

$$36.84\ \cancel{\text{g N}} \times \frac{1\ \text{mol N}}{14.01\ \cancel{\text{g N}}} = 2.630\ \text{mol N}$$

$$63.16\ \cancel{\text{g O}} \times \frac{1\ \text{mol O}}{16.00\ \cancel{\text{g O}}} = 3.948\ \text{mol O}$$

Step 2: Calculate mole ratios.

$$\frac{2.630\ \text{mol N}}{2.630\ \text{mol N}} = \frac{1.000\ \text{mol N}}{1.000\ \text{mol N}} = \frac{1\ \text{mol N}}{1\ \text{mol N}}$$

$$\frac{3.948\ \text{mol O}}{2.630\ \text{mol N}} = \frac{1.500\ \text{mol O}}{1.000\ \text{mol N}} = \frac{1.5\ \text{mol O}}{1\ \text{mol N}}$$

The simplest ratio is 1 mol N: 1.5 mol O.

Step 3: Convert decimal fraction to whole number.

In this case, multiply by 2, because 1.5 × 2 = 3. Therefore, the empirical formula is N_2O_3.

CONTENTS

47. Step 1: Assume 100 g sample; calculate moles of each element

$$35.98\ \cancel{\text{g Al}} \times \frac{\text{1 mol Al}}{26.98\ \cancel{\text{g Al}}} = \text{1.334 mol Al}$$

$$64.02\ \cancel{\text{g S}} \times \frac{\text{1 mol S}}{32.06\ \cancel{\text{g S}}} = \text{1.996 mol S}$$

Step 2: Calculate mole ratios.

$$\frac{\text{1.334 mol Al}}{\text{1.334 mol Al}} = \frac{\text{1.000 mol Al}}{\text{1.000 mol Al}} = \frac{\text{1 mol Al}}{\text{1 mol Al}}$$

$$\frac{\text{1.996 mol S}}{\text{1.334 mol Al}} = \frac{\text{1.500 mol S}}{\text{1.000 mol Al}} = \frac{\text{1.5 mol S}}{\text{1 mol Al}}$$

The simplest ratio is 1 mol Al: 1.5 mol S.

Step 3: Convert decimal fraction to whole number.

In this case, multiply by 2, because 1.5 × 2 = 3. Therefore, the empirical formula is Al_2S_3.

48. Step 1: Assume 100 g sample; calculate moles of each element.

$$81.82\ \cancel{\text{g C}} \times \frac{\text{1 mol C}}{12.01\ \cancel{\text{g C}}} = \text{6.813 mol C}$$

$$18.18\ \cancel{\text{g H}} \times \frac{\text{1 mol H}}{1.008\ \cancel{\text{g H}}} = \text{18.04 mol H}$$

Step 2: Calculate mole ratios.

$$\frac{\text{6.813 mol C}}{\text{6.813 mol C}} = \frac{\text{1.000 mol C}}{\text{1.000 mol C}} = \frac{\text{1 mol C}}{\text{1 mol C}}$$

$$\frac{\text{18.04 mol H}}{\text{6.813 mol C}} = \frac{\text{2.649 mol H}}{\text{1.000 mol C}} = \frac{\text{2.65 mol H}}{\text{1 mol C}}$$

The simplest ratio is 1 mol: 2.65 mol H.

Step 3: Convert decimal fraction to whole number.

In this case, multiply by 3, because 2.65 × 3 = 7.95 ≈ 8. Therefore, the empirical formula is C_3H_8.

49. Step 1: Assume 100 g sample; calculate moles of each element.

$$60.00\ \cancel{\text{g C}} \times \frac{\text{1 mol C}}{12.01\ \cancel{\text{g C}}} = \text{5.00 mol C}$$

$$4.44\ \cancel{\text{g H}} \times \frac{\text{1 mol H}}{1.008\ \cancel{\text{g H}}} = \text{4.40 mol H}$$

$$35.56\ \cancel{\text{g O}} \times \frac{\text{1 mol O}}{16.00\ \cancel{\text{g O}}} = \text{2.22 mol O}$$

Step 2: Calculate mole ratios.

$$\frac{\text{5.00 mol C}}{\text{2.22 mol O}} = \frac{\text{2.25 mol C}}{\text{1.00 mol O}} = \frac{\text{2.25 mol C}}{\text{1 mol O}}$$

$$\frac{\text{4.40 mol H}}{\text{2.22 mol O}} = \frac{\text{1.98 mol H}}{\text{1.00 mol O}} = \frac{\text{2 mol H}}{\text{1 mol O}}$$

$$\frac{\text{2.22 mol O}}{\text{2.22 mol O}} = \frac{\text{1.00 mol O}}{\text{1.00 mol O}} = \frac{\text{1 mol O}}{\text{1 mol O}}$$

The simplest ratio is 2.25 mol C: 2 mol H: 1 mol O.

Step 3: Convert decimal fraction to whole number.

In this case, multiply by 4, because 2.25 × 4 = 9. Therefore, the empirical formula is $C_9H_8O_4$.

50. Step 1: Assume 100 g sample; calculate moles of each element.

$$10.89\ \cancel{\text{g Mg}} \times \frac{\text{1 mol Mg}}{24.31\ \cancel{\text{g Mg}}} = \text{0.4480 mol Mg}$$

$$31.77\ \cancel{\text{g Cl}} \times \frac{\text{1 mol Cl}}{35.45\ \cancel{\text{g Cl}}} = \text{0.8962 mol Cl}$$

$$57.34\ \cancel{\text{g O}} \times \frac{\text{1 mol O}}{16.00\ \cancel{\text{g O}}} = \text{3.584 mol O}$$

Step 2: Calculate mole ratios.

$$\frac{\text{0.4480 mol Mg}}{\text{0.4480 mol Mg}} = \frac{\text{1.000 mol Mg}}{\text{1.000 mol Mg}} = \frac{\text{1 mol Mg}}{\text{1 mol Mg}}$$

$$\frac{\text{0.8962 mol Cl}}{\text{0.4480 mol Mg}} = \frac{\text{2.000 mol Cl}}{\text{1.000 mol Mg}} = \frac{\text{2 mol Cl}}{\text{1 mol Mg}}$$

$$\frac{\text{3.584 mol O}}{\text{0.4480 mol Mg}} = \frac{\text{7.999 mol O}}{\text{1.000 mol Mg}} = \frac{\text{8 mol O}}{\text{1 mol Mg}}$$

The empirical formula is $MgCl_2O_8$.

The simplest ratio is 1 mol Mg: 2 mol Cl: 8 mol O.

51. Step 1: Assume 100 g sample; calculate moles of each element

$$65.45\ \cancel{\text{g C}} \times \frac{\text{1 mol C}}{12.01\ \cancel{\text{g C}}} = \text{5.450 mol C}$$

$$5.45\ \cancel{\text{g H}} \times \frac{\text{1 mol H}}{1.008\ \cancel{\text{g H}}} = \text{5.41 mol H}$$

$$29.09\ \cancel{\text{g O}} \times \frac{\text{1 mol O}}{16.00\ \cancel{\text{g O}}} = \text{1.818 mol O}$$

Step 2: Calculate mole ratios

$$\frac{\text{5.450 mol C}}{\text{1.818 mol O}} = \frac{\text{3.000 mol C}}{\text{1.000 mol O}} = \frac{\text{3 mol C}}{\text{1 mol O}}$$

$$\frac{\text{5.41 mol H}}{\text{1.818 mol O}} = \frac{\text{2.97 mol H}}{\text{1.00 mol O}} = \frac{\text{3 mol H}}{\text{1 mol O}}$$

$$\frac{\text{1.818 mol O}}{\text{1.818 mol O}} = \frac{\text{1.000 mol O}}{\text{1.000 mol O}} = \frac{\text{1 mol O}}{\text{1 mol O}}$$

The simplest ratio is 1 mol:2.65 mol H.

Therefore, the empirical formula is C_3H_3O.

Step 3: Calculate the molar mass of the empirical formula.

$$3\ \cancel{\text{mol C}} \times \frac{\text{12.01 g C}}{1\ \cancel{\text{mol C}}} = \text{36.03 g}$$

$$3\ \cancel{\text{mol H}} \times \frac{\text{1.008 g H}}{1\ \cancel{\text{mol H}}} = \text{3.024 g}$$

$$1\ \cancel{\text{mol O}} \times \frac{\text{16.00 g O}}{1\ \cancel{\text{mol O}}} = \underline{\text{16.00 g}}$$

molar mass C_3H_3O = 55.05 g/mol

Step 4: Determine whole number multiplier.

$$\frac{\text{110.0 g/mol}}{\text{55.05 g/mol}} = \text{1.998, or 2}$$

The molecular formula is $C_6H_6O_2$.

CONTENTS

52. Step 1: Assume 100 g sample; calculate moles of each element.

$$49.98\ \cancel{\text{g C}} \times \frac{1\ \text{mol C}}{12.01\ \cancel{\text{g C}}} = 4.162\ \text{mol C}$$

$$10.47\ \cancel{\text{g H}} \times \frac{1\ \text{mol H}}{1.008\ \cancel{\text{g H}}} = 10.39\ \text{mol H}$$

Step 2: Calculate mole ratios.

$$\frac{4.162\ \text{mol C}}{4.162\ \text{mol C}} = \frac{1.000\ \text{mol C}}{1.000\ \text{mol C}} = \frac{1\ \text{mol C}}{1\ \text{mol C}}$$

$$\frac{10.39\ \text{mol H}}{4.162\ \text{mol C}} = \frac{2.50\ \text{mol H}}{1.000\ \text{mol C}} = \frac{2.5\ \text{mol H}}{1\ \text{mol C}}$$

The simplest ratio is 1 mol C: 2.5 mol H.

Because 2.5 × 2 = 5, the empirical formula is C_2H_5.

Step 3: Calculate the molar mass of the empirical formula.

$$2\ \cancel{\text{mol C}} \times \frac{12.01\ \text{g C}}{1\ \cancel{\text{mol C}}} = 24.02\ \text{g}$$

$$5\ \cancel{\text{mol H}} \times \frac{1.008\ \text{g H}}{1\ \cancel{\text{mol H}}} = \underline{5.040\ \text{g}}$$

$$\text{molar mass } C_2H_5 = 29.06\ \text{g/mol}$$

Step 4: Determine whole number multiplier.

$$\frac{58.12\ \cancel{\text{g/mol}}}{29.06\ \cancel{\text{g/mol}}} = 2.000$$

The molecular formula is C_4H_{10}.

53. Step 1: Assume 100 g sample; calculate moles of each element.

$$46.68\ \cancel{\text{g N}} \times \frac{1\ \text{mol N}}{14.01\ \cancel{\text{g N}}} = 3.332\ \text{mol N}$$

$$53.32\ \cancel{\text{g O}} \times \frac{1\ \text{mol O}}{16.00\ \cancel{\text{g O}}} = 3.333\ \text{mol O}$$

Step 2: Calculate mole ratios.

$$\frac{3.332\ \text{mol N}}{3.332\ \text{mol N}} = \frac{1.000\ \text{mol N}}{1.000\ \text{mol N}} = \frac{1\ \text{mol N}}{1\ \text{mol N}}$$

$$\frac{3.333\ \text{mol O}}{3.332\ \text{mol N}} = \frac{1.000\ \text{mol O}}{1.000\ \text{mol N}} = \frac{1\ \text{mol O}}{1\ \text{mol N}}$$

The simplest ratio is 1 mol N: 1 mol O.

The empirical formula is NO.

Step 3: Calculate the molar mass of the empirical formula.

$$1\ \cancel{\text{mol N}} \times \frac{14.01\ \text{g N}}{1\ \cancel{\text{mol N}}} = 14.01\ \text{g}$$

$$1\ \cancel{\text{mol O}} \times \frac{16.00\ \text{g O}}{1\ \cancel{\text{mol O}}} = \underline{16.00}\ \text{g}$$

$$\text{molar mass NO} = 30.01\ \text{g /mol}$$

Step 4: Determine whole number multiplier.

$$\frac{60.01\ \cancel{\text{g/mol}}}{30.01\ \cancel{\text{g/mol}}} = 2.000$$

The molecular formula is N_2O_2.

54. Step 1: Calculate moles of each element.

$$19.55\ \cancel{\text{g K}} \times \frac{1\ \text{mol K}}{39.10\ \cancel{\text{g K}}} = 0.5000\ \text{mol K}$$

$$4.00\ \cancel{\text{g O}} \times \frac{1\ \text{mol O}}{16.00\ \cancel{\text{g O}}} = 0.250\ \text{mol O}$$

Step 2: Calculate mole ratios.

$$\frac{0.5000\ \text{mol K}}{0.250\ \text{mol O}} = \frac{2.00\ \text{mol K}}{1.00\ \text{mol O}} = \frac{2\ \text{mol K}}{1\ \text{mol O}}$$

$$\frac{0.250\ \text{mol O}}{0.250\ \text{mol O}} = \frac{1.00\ \text{mol O}}{1.00\ \text{mol O}} = \frac{1\ \text{mol O}}{1\ \text{mol O}}$$

The simplest ratio is 2 mol K: 1 mol O.

The empirical formula is K_2O.

55. Step 1: Calculate moles of each element

$$174.86\ \cancel{\text{g Fe}} \times \frac{1\ \text{mol Fe}}{55.85\ \cancel{\text{g Fe}}} = 3.131\ \text{mol Fe}$$

$$75.14\ \cancel{\text{g O}} \times \frac{1\ \text{mol O}}{16.00\ \cancel{\text{g O}}} = 4.696\ \text{mol O}$$

Step 2: Calculate mole ratios.

$$\frac{3.131\ \text{mol Fe}}{3.131\ \text{mol Fe}} = \frac{1.000\ \text{mol Fe}}{1.000\ \text{mol Fe}} = \frac{1\ \text{mol Fe}}{1\ \text{mol Fe}}$$

$$\frac{4.696\ \text{mol O}}{3.131\ \text{mol Fe}} = \frac{1.500\ \text{mol O}}{1.000\ \text{mol Fe}} = \frac{1.5\ \text{mol O}}{1\ \text{mol Fe}}$$

The simplest ratio is 1 mol Fe: 1.5 mol O.

Because 1.5 × 2 = 3, the empirical formula is Fe_2O_3.

56. Step 1: Calculate moles of each element.

$$17.900\ \cancel{\text{g C}} \times \frac{1\ \text{mol C}}{12.01\ \cancel{\text{g C}}} = 1.490\ \text{mol C}$$

$$1.680\ \cancel{\text{g H}} \times \frac{1\ \text{mol H}}{1.008\ \cancel{\text{g H}}} = 1.667\ \text{mol H}$$

$$4.225\ \cancel{\text{g O}} \times \frac{1\ \text{mol O}}{16.00\ \cancel{\text{g O}}} = 0.2641\ \text{mol O}$$

$$1.228\ \cancel{\text{g N}} \times \frac{1\ \text{mol N}}{14.01\ \cancel{\text{g N}}} = 0.08765\ \text{mol N}$$

Step 2: Calculate mole ratios.

$$\frac{0.08765\ \text{mol N}}{0.08765\ \text{mol N}} = \frac{1.000\ \text{mol N}}{1.000\ \text{mol N}} = \frac{1\ \text{mol N}}{1\ \text{mol N}}$$

$$\frac{1.490\ \text{mol C}}{0.08765\ \text{mol N}} = \frac{17.00\ \text{mol C}}{1.000\ \text{mol N}} = \frac{17\ \text{mol C}}{1\ \text{mol N}}$$

$$\frac{1.667\ \text{mol H}}{0.08765\ \text{mol N}} = \frac{19.02\ \text{mol H}}{1.000\ \text{mol N}} = \frac{19\ \text{mol H}}{1\ \text{mol N}}$$

$$\frac{0.2641\ \text{mol O}}{0.08765\ \text{mol N}} = \frac{3.013\ \text{mol O}}{1.000\ \text{mol N}} = \frac{3\ \text{mol O}}{1\ \text{mol N}}$$

The simplest ratio is 17 mol C: 19 mol H: 3 mol O: 1 mol N.

The empirical formula is $C_{17}H_{19}O_3N$.

CONTENTS

57. Step 1: Calculate moles of each element.

$$0.545\ \cancel{\text{g Al}} \times \frac{1\text{ mol Al}}{26.98\ \cancel{\text{g Al}}} = 0.0202\text{ mol Al}$$

$$0.485\ \cancel{\text{g O}} \times \frac{1\text{ mol O}}{16.00\ \cancel{\text{g O}}} = 0.0303\text{ mol O}$$

Step 2: Calculate mole ratios.

$$\frac{0.0202\text{ mol Al}}{0.0202\text{ mol Al}} = \frac{1.00\text{ mol Al}}{1.00\text{ mol Al}} = \frac{1\text{ mol Al}}{1\text{ mol Al}}$$

$$\frac{0.0303\text{ mol O}}{0.0202\text{ mol Al}} = \frac{1.50\text{ mol O}}{1.00\text{ mol Al}} = \frac{1.5\text{ mol O}}{1\text{ mol Al}}$$

The simplest ratio is 1 mol Al: 1.5 mol O.

Because 1.5 × 2 = 3, the empirical formula is Al_2O_3.

63. Step 1: Assume 100 g sample; calculate moles of each component.

$$48.8\ \cancel{\text{g } MgSO_4} \times \frac{1\text{ mol } MgSO_4}{120.38\ \cancel{\text{g } MgSO_4}}$$

$$= 0.405\text{ mol } MgSO_4$$

$$51.2\ \cancel{\text{g } H_2O} \times \frac{1\text{ mol } H_2O}{18.02\ \cancel{\text{g } H_2O}} = 2.84\text{ mol } H_2O$$

Step 2: Calculate mole ratios.

$$\frac{0.405\text{ mol } MgSO_4}{0.405\text{ mol } MgSO_4} = \frac{1.00\text{ mol } MgSO_4}{1.00\text{ mol } MgSO_4}$$

$$= \frac{1\text{ mol } MgSO_4}{1\text{ mol } MgSO_4}$$

$$\frac{2.84\text{ mol } H_2O}{0.405\text{ mol } MgSO_4} = \frac{7.01\text{ mol } H_2O}{1.00\text{ mol } MgSO_4}$$

$$= \frac{7\text{ mol } H_2O}{1\text{ mol } MgSO_4}$$

The formula of the hydrate is $MgSO_4{\cdot}7H_2O$. Its name is magnesium sulfate heptahydrate.

64. Step 1: Calculate the mass of water driven off.

mass of hydrated compound − mass of anhydrous compound remaining

$= 11.75\text{ g } CoCl_2{\cdot}xH_2O - 9.25\text{ g } CoCl_2$

$= 2.50\text{ g } H_2O$

Step 2: Calculate moles of each component.

$$9.25\ \cancel{\text{g } CoCl_2} \times \frac{1\text{ mol } CoCl_2}{129.83\ \cancel{\text{g } CoCl_2}} = 0.0712\text{ mol } CoCl_2$$

$$2.50\ \cancel{\text{g } H_2O} \times \frac{1\text{ mol } H_2O}{18.02\ \cancel{\text{g } H_2O}} = 0.139\text{ mol } H_2O$$

Step 2: Calculate mole ratios.

$$\frac{0.0712\text{ mol } CoCl_2}{0.0712\text{ mol } CoCl_2} = \frac{1.00\text{ mol } CoCl_2}{1.00\text{ mol } CoCl_2} = \frac{1\text{ mol } CoCl_2}{1\text{ mol } CoCl_2}$$

$$\frac{0.139\text{ mol } H_2O}{0.0712\text{ mol } CoCl_2} = \frac{1.95\text{ mol } H_2O}{1.00\text{ mol } CoCl_2} = \frac{2\text{ mol } H_2O}{1\text{ mol } CoCl_2}$$

The formula of the hydrate is $CoCl_2{\cdot}2H_2O$. Its name is cobalt(II) chloride dihydrate.

Chapter 12

1. a. 1 molecule N_2 + 3 molecules H_2 → 2 molecules NH_3

1 mole N_2 + 3 moles H_2 → 2 moles NH_3

28.02 g N_2 + 6.06 g H_2 → 34.08 g NH_3

b. 1 molecule HCl + 1 formula unit KOH → 1 formula unit KCl + 1 molecule H_2O

1 mole HCl + 1 mole KOH → 1 mole KCl + 1 mole H_2O

36.46 g HCl + 56.11 g KOH → 74.55 g KCl + 18.02 g H_2O

c. 4 atoms Zn + 10 molecules HNO_3 → 4 formula units $Zn(NO_3)_2$ + 1 molecule N_2O + 5 molecules H_2O

4 moles Zn + 10 moles HNO_3 → 4 moles $Zn(NO_3)_2$ + 1 mole N_2O + 5 moles H_2O

261.56 g Zn + 630.2 g HNO_3 → 757.56 g $Zn(NO_3)_2$ + 44.02 g N_2O + 90.10 g H_2O

d. 2 atoms Mg + 1 molecule O_2 → 2 formula units MgO

2 moles Mg + 1 mole O_2 → 2 moles MgO

48.62 g Mg + 32.00 g O_2 → 80.62 g MgO

e. 2 atoms Na + 2 molecules H_2O → 2 formula units NaOH + 1 molecule H_2

2 moles Na + 2 moles H_2O → 2 moles NaOH + 1 mole H_2

45.98 g Na + 36.04 g H_2O → 80.00 g NaOH + 2.02 g H_2

2. a.

$$\frac{4\text{ mol Al}}{3\text{ mol } O_2} \qquad \frac{3\text{ mol } O_2}{2\text{ mol } Al_2O_3} \qquad \frac{2\text{ mol } Al_2O_3}{4\text{ mol Al}}$$

$$\frac{3\text{ mol } O_2}{4\text{ mol Al}} \qquad \frac{2\text{ mol } Al_2O_3}{3\text{ mol } O_2} \qquad \frac{4\text{ mol Al}}{2\text{ mol } Al_2O_3}$$

b.

$$\frac{3\text{ mol Fe}}{4\text{ mol } H_2O} \qquad \frac{3\text{ mol Fe}}{4\text{ mol } H_2} \qquad \frac{3\text{ mol Fe}}{1\text{ mol } Fe_3O_4}$$

$$\frac{4\text{ mol } H_2O}{3\text{ mol Fe}} \qquad \frac{4\text{ mol } H_2}{3\text{ mol Fe}} \qquad \frac{1\text{ mol } Fe_3O_4}{3\text{ mol Fe}}$$

$$\frac{1\text{ mol } Fe_3O_4}{4\text{ mol } H_2} \qquad \frac{1\text{ mol } Fe_3O_4}{4\text{ mol } H_2O} \qquad \frac{4\text{ mol } H_2O}{4\text{ mol } H_2}$$

$$\frac{4\text{ mol } H_2}{1\text{ mol } Fe_3O_4} \qquad \frac{4\text{ mol } H_2O}{1\text{ mol } Fe_3O_4} \qquad \frac{4\text{ mol } H_2}{4\text{ mol } H_2O}$$

c.

$$\frac{2\text{ mol HgO}}{2\text{ mol Hg}} \qquad \frac{1\text{ mol } O_2}{2\text{ mol Hg}} \qquad \frac{1\text{ mol } O_2}{2\text{ mol HgO}}$$

$$\frac{2\text{ mol Hg}}{2\text{ mol HgO}} \qquad \frac{2\text{ mol Hg}}{1\text{ mol } O_2} \qquad \frac{2\text{ mol HgO}}{1\text{ mol } O_2}$$

CONTENTS

3. a. $\text{ZnO(s)} + 2\text{HCl(aq)} \rightarrow \text{ZnCl}_2\text{(aq)} + \text{H}_2\text{O(l)}$

$$\frac{1\text{ mol ZnO}}{2\text{ mol HCl}} \qquad \frac{1\text{ mol ZnO}}{1\text{ mol ZnCl}_2} \qquad \frac{1\text{ mol ZnO}}{1\text{ mol H}_2\text{O}}$$

$$\frac{2\text{ mol HCl}}{1\text{ mol ZnO}} \qquad \frac{2\text{ mol HCl}}{1\text{ mol ZnCl}_2} \qquad \frac{2\text{ mol HCl}}{1\text{ mol H}_2\text{O}}$$

$$\frac{1\text{ mol ZnCl}_2}{1\text{ mol ZnO}} \qquad \frac{1\text{ mol ZnCl}_2}{2\text{ mol HCl}} \qquad \frac{1\text{ mol ZnCl}_2}{1\text{ mol H}_2\text{O}}$$

$$\frac{1\text{ mol H}_2\text{O}}{1\text{ mol ZnO}} \qquad \frac{1\text{ mol H}_2\text{O}}{2\text{ mol HCl}} \qquad \frac{1\text{ mol H}_2\text{O}}{1\text{ mol ZnCl}_2}$$

b. $2\text{C}_4\text{H}_{10}\text{(g)} + 13\text{O}_2\text{(g)} \rightarrow 8\text{CO}_2\text{(g)} + 10\text{H}_2\text{O(l)}$

$$\frac{2\text{ mol C}_4\text{H}_{10}}{13\text{ mol O}_2} \qquad \frac{2\text{ mol C}_4\text{H}_{10}}{8\text{ mol CO}_2} \qquad \frac{2\text{ mol C}_4\text{H}_{10}}{10\text{ mol H}_2\text{O}}$$

$$\frac{13\text{ mol O}_2}{2\text{ mol C}_4\text{H}_{10}} \qquad \frac{8\text{ mol CO}_2}{2\text{ mol C}_4\text{H}_{10}} \qquad \frac{10\text{ mol H}_2\text{O}}{2\text{ mol C}_4\text{H}_{10}}$$

$$\frac{10\text{ mol H}_2\text{O}}{13\text{ mol O}_2} \qquad \frac{10\text{ mol H}_2\text{O}}{8\text{ mol CO}_2} \qquad \frac{8\text{ mol CO}_2}{13\text{ mol O}_2}$$

$$\frac{13\text{ mol O}_2}{10\text{ mol H}_2\text{O}} \qquad \frac{8\text{ mol CO}_2}{10\text{ mol H}_2\text{O}} \qquad \frac{13\text{ mol O}_2}{8\text{ mol CO}_2}$$

9. $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{H}_2\text{SO}_4\text{(aq)}$

$$12.5\ \cancel{\text{mol SO}_2} \times \frac{2\text{ mol H}_2\text{SO}_4}{2\ \cancel{\text{mol SO}_2}}$$

$= 12.5\text{ mol H}_2\text{SO}_4$ produced

$$12.5\ \cancel{\text{mol SO}_2} \times \frac{1\text{ mol O}_2}{2\ \cancel{\text{mol SO}_2}} = 6.25\text{ mol O}_2\text{ needed}$$

10. a. $2\text{CH}_4\text{(g)} + \text{S}_8\text{(s)} \rightarrow 2\text{CS}_2\text{(l)} + 4\text{H}_2\text{S(g)}$

b. $1.50\ \cancel{\text{mol S}_8} \times \dfrac{2\text{ mol CS}_2}{1\ \cancel{\text{mol S}_8}} = 3.00\text{ mol CS}_2$

c. $1.50\ \cancel{\text{mol S}_8} \times \dfrac{4\text{ mol H}_2\text{S}}{1\ \cancel{\text{mol S}_8}} = 6.00\text{ mol H}_2\text{S}$

11. $\text{TiO}_2\text{(s)} + \text{C(s)} + 2\text{Cl}_2\text{(g)} \rightarrow \text{TiCl}_4\text{(s)} + \text{CO}_2\text{(g)}$

Step 1: Make mole → mole conversion.

$$1.25\ \cancel{\text{mol TiO}_2} \times \frac{2\text{ mol Cl}_2}{1\ \cancel{\text{mol TiO}_2}} = 2.50\text{ mol Cl}_2$$

Step 2: Make mole → mass conversion.

$$2.50\ \cancel{\text{mol Cl}_2} \times \frac{70.9\text{ g Cl}_2}{1\ \cancel{\text{mol Cl}_2}} = 177\text{ g Cl}_2$$

12. Step 1: Balance the chemical equation.

$2\text{NaCl(s)} \rightarrow 2\text{Na(s)} + \text{Cl}_2\text{(g)}$

Step 2: Make mole → mole conversion.

$$2.50\ \cancel{\text{mol NaCl}} \times \frac{1\text{ mol Cl}_2}{2\ \cancel{\text{mol NaCl}}} = 1.25\text{ mol Cl}_2$$

Step 3: Make mole → mass conversion.

$$1.25\ \cancel{\text{mol Cl}_2} \times \frac{70.9\text{ g Cl}_2}{1\ \cancel{\text{mol Cl}_2}} = 88.6\text{ g Cl}_2$$

13. $2\text{NaN}_3\text{(s)} \rightarrow 2\text{Na(s)} + 3\text{N}_2\text{(g)}$

Step 1: Make mass → mole conversion.

$$100.0\ \cancel{\text{g NaN}_3} \times \frac{1\text{ mol NaN}_3}{65.02\ \cancel{\text{g NaN}_3}} = 1.538\text{ mol NaN}_3$$

Step 2: Make mole → mole conversion.

$$1.538\ \cancel{\text{mol NaN}_3} \times \frac{3\text{ mol N}_2}{2\ \cancel{\text{mol NaN}_3}} = 2.307\text{ mol N}_2$$

Step 3: Make mole → mass conversion.

$$2.307\ \cancel{\text{mol N}_2} \times \frac{28.02\text{ g N}_2}{1\ \cancel{\text{mol N}_2}} = 64.64\text{ g N}_2$$

14. Step 1: Balance the chemical equation.

$2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{H}_2\text{SO}_4\text{(aq)}$

Step 2: Make mass → mole conversion.

$$2.50\ \cancel{\text{g SO}_2} \times \frac{1\text{ mol SO}_2}{64.07\ \cancel{\text{g SO}_2}} = 0.0390\text{ mol SO}_2$$

Step 3: Make mole → mole conversion.

$$0.0390\ \cancel{\text{mol SO}_2} \times \frac{2\text{ mol H}_2\text{SO}_4}{2\ \cancel{\text{mol SO}_2}} =$$

$0.0390\text{ mol H}_2\text{SO}_4$

Step 4: Make mole → mass conversion.

$$0.0390\ \cancel{\text{mol H}_2\text{SO}_4} \times \frac{98.09\text{ g H}_2\text{SO}_4}{1\ \cancel{\text{mol H}_2\text{SO}_4}}$$

$= 3.83\text{ g H}_2\text{SO}_4$

20. $6\text{Na(s)} + \text{Fe}_2\text{O}_3\text{(s)} \rightarrow 3\text{Na}_2\text{O(s)} + 2\text{Fe(s)}$

Step 1: Make mass → mole conversion.

$$100.0\ \cancel{\text{g Na}} \times \frac{1\text{ mol Na}}{22.99\ \cancel{\text{g Na}}} = 4.350\text{ mol Na}$$

$$100.0\ \cancel{\text{g Fe}_2\text{O}_3} \times \frac{1\text{ mol Fe}_2\text{O}_3}{159.7\ \cancel{\text{g Fe}_2\text{O}_3}}$$

$= 0.6261\text{ mol Fe}_2\text{O}_3$

Step 2: Make mole ratio comparison.

$$\frac{0.6261\text{ mol Fe}_2\text{O}_3}{4.350\text{ mol Na}} \quad \text{compared to} \quad \frac{1\text{ mol Fe}_2\text{O}_3}{6\text{ mol Na}}$$

$$0.1439 \quad \text{compared to} \quad 0.1667$$

a. The actual ratio is less than the needed ratio, so iron(III) oxide is the limiting reactant.

b. Sodium is the excess reactant.

c. Step 1: Make mole → mole conversion.

$$0.6261\ \cancel{\text{mol Fe}_2\text{O}_3} \times \frac{2\text{ mol Fe}}{1\ \cancel{\text{mol Fe}_2\text{O}_3}} = 1.252\text{ mol Fe}$$

Step 2: Make mole → mass conversion.

$$1.252\ \cancel{\text{mol Fe}} \times \frac{55.85\text{ g Fe}}{1\ \cancel{\text{mol Fe}}} = 69.92\text{ g Fe}$$

d. Step 1: Make mole → mole conversion.

$$0.6261\ \cancel{\text{mol Fe}_2\text{O}_3} \times \frac{6\text{ mol Na}}{1\ \cancel{\text{mol Fe}_2\text{O}_3}}$$

$= 3.757\text{ mol Na}$ needed

Step 2: Make mole → mass conversion.

$$3.757\ \cancel{\text{mol Na}} \times \frac{22.99\text{ g Na}}{1\ \cancel{\text{mol Na}}} = 86.36\text{ g Na needed}$$

100.0 g Na given − 86.36 g Na needed
= 13.6 g Na in excess

21. Step 1: Write the balanced chemical equation.

$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$

Step 2: Make mass → mole conversion.

$$88.0\ \cancel{\text{g CO}_2} \times \frac{1\text{ mol CO2}}{44.01\ \cancel{\text{g CO}_2}} = 2.00\text{ mol CO}_2$$

$$64.0\ \cancel{\text{g H}_2\text{O}} \times \frac{1\text{ mol H}_2\text{O}}{18.02\ \cancel{\text{g H}_2\text{O}}} = 3.55\text{ mol H}_2\text{O}$$

Step 3: Make mole ratio comparison.

$$\frac{2.00\text{ mol CO}_2}{3.55\text{ mol H}_2\text{O}} \quad \text{compared to} \quad \frac{6\text{ mol CO}_2}{6\text{ mol H}_2\text{O}}$$

0.563 compared to 1.00

a. The actual ratio is less than the needed ratio, so carbon dioxide is the limiting reactant.

b. Water is the excess reactant.

Step 1: Make mole → mole conversion.

$$2.00\ \cancel{\text{mol CO}_2} \times \frac{6\text{ mol H}_2\text{O}}{6\ \cancel{\text{mol CO}_2}} = 2.00\text{ mol H}_2\text{O}$$

Step 2: Make mole → mass conversion.

$$2.00\ \cancel{\text{mol H}_2\text{O}} \times \frac{18.02\text{ g H}_2\text{O}}{1\ \cancel{\text{mol H}_2\text{O}}}$$

= 36.0 g H_2O needed

64.0 g H_2O given − 36.0 g H_2O needed
= 28.0 g H_2O in excess

c. Step 1: Make mole → mole conversion.

$$2.00\ \cancel{\text{mol CO}_2} \times \frac{1\text{ mol C}_6\text{H}_{12}\text{O}_6}{6\ \cancel{\text{mol CO}_2}}$$

= 0.333 mol $C_6H_{12}O_6$

Step 2: Make mole → mass conversion.

$$0.333\ \cancel{\text{mol C}_6\text{H}_{12}\text{O}_6} \times \frac{180.2\text{ g C}_6\text{H}_{12}\text{O}_6}{1\ \cancel{\text{mol C}_6\text{H}_{12}\text{O}_6}}$$

= 60.0 g $C_6H_{12}O_6$

27. $Al(OH)_3(s) + 3HCl(aq) \rightarrow AlCl_3(aq) + 3H_2O(l)$

Step 1: Make mass → mole conversion.

$$14.0\ \cancel{\text{g Al(OH)}_3} \times \frac{1\text{ mol Al(OH)}_3}{78.0\ \cancel{\text{g Al(OH)}_3}}$$

= 0.179 mol $Al(OH)_3$

Step 2: Make mole → mole conversion.

$$0.179\ \cancel{\text{mol Al(OH)}_3} \times \frac{1\text{ mol AlCl}_3}{1\ \cancel{\text{mol Al(OH)}_3}}$$

= 0.179 mol $AlCl_3$

Step 3: Make mole → mass conversion.

$$0.179\ \cancel{\text{mol AlCl}_3} \times \frac{133.3\text{ g AlCl}_3}{1\ \cancel{\text{mol AlCl}_3}} = 23.9\text{ g AlCl}_3$$

23.9 g of $AlCl_3$ is the theoretical yield.

$$\%\text{ yield} = \frac{22.0\ \cancel{\text{g AlCl}_3}}{23.9\ \cancel{\text{g AlCl}_3}} \times 100 = 92.1\%\text{ yield of AlCl}_3$$

28. Step 1: Write the balanced chemical equation.

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

Step 2: Make mass → mole conversion.

$$20.0\ \cancel{\text{g Cu}} \times \frac{1\text{ mol Cu}}{63.55\ \cancel{\text{g Cu}}} = 0.315\text{ mol Cu}$$

Step 3: Make mole → mole conversion.

$$0.315\ \cancel{\text{mol Cu}} \times \frac{2\text{ mol Ag}}{1\ \cancel{\text{mol Cu}}} = 0.630\text{ mol Ag}$$

Step 4: Make mole → mass conversion.

$$0.630\ \cancel{\text{mol Ag}} \times \frac{107.9\text{ g Ag}}{1\ \cancel{\text{mol Ag}}} = 68.0\text{ g Ag}$$

68.0 g of Ag is the theoretical yield.

$$\%\text{ yield} = \frac{60.0\ \cancel{\text{g Ag}}}{68.0\ \cancel{\text{g Ag}}} \times 100 = 88.2\%\text{ yield of Ag}$$

29. Step 1: Write the balanced chemical equation.

$Zn(s) + I_2(s) \rightarrow ZnI_2(s)$

Step 2: Make mass → mole conversion.

$$125.0\ \cancel{\text{g Zn}} \times \frac{1\text{ mol Zn}}{65.38\ \cancel{\text{g Zn}}} = 1.912\text{ mol Zn}$$

Step 3: Make mole → mole conversion.

$$1.912\ \cancel{\text{mol Zn}} \times \frac{1\text{ mol ZnI}_2}{1\ \cancel{\text{mol Zn}}} = 1.912\text{ mol ZnI}_2$$

Step 4: Make mole → mass conversion.

$$1.912\ \cancel{\text{mol ZnI}_2} \times \frac{319.2\text{ g ZnI}_2}{1\ \cancel{\text{mol ZnI}_2}} = 610.3\text{ g ZnI}_2$$

610.3 g of ZnI_2 is the theoretical yield.

$$\%\text{ yield} = \frac{515.6\ \cancel{\text{g ZnI}_2}}{610.3\ \cancel{\text{g ZnI}_2}} \times 100$$

= 84.48% yield of ZnI_2

CONTENTS

Chapter 13

1. $\frac{\text{Rate}_{\text{nitrogen}}}{\text{Rate}_{\text{neon}}} = \sqrt{\frac{20.2\ \cancel{\text{g/mol}}}{28.0\ \cancel{\text{g/mol}}}} = \sqrt{0.721} = 0.849$

2. $\frac{\text{Rate}_{\text{carbon monoxide}}}{\text{Rate}_{\text{carbon dioxide}}} = \sqrt{\frac{44.0\ \cancel{\text{g/mol}}}{28.0\ \cancel{\text{g/mol}}}}$

$= \sqrt{1.57}$

$= 1.25$

3. Rearrange Graham's law to solve for Rate_A.

$\text{Rate}_\text{A} = \text{Rate}_\text{B} \times \sqrt{\frac{\text{molar mass}_\text{B}}{\text{molar mass}_\text{A}}}$

$\text{Rate}_\text{B} = 3.6\ \text{mol/min}$

$\frac{\text{molar mass}_\text{B}}{\text{molar mass}_\text{A}} = 0.5$

$\text{Rate}_\text{A} = 3.6\ \text{mol/min} \times \sqrt{0.5}$

$= 3.6\ \text{mol/min} \times 0.71$

$= 2.5\ \text{mol/min}$

4. $P_{\text{hydrogen}} = P_{\text{total}} - P_{\text{helium}}$

$= 600\ \text{mm Hg} - 439\ \text{mm Hg}$

$= 161\ \text{mm Hg}$

5. $P_{\text{total}} = 5.00\ \text{kPa} + 4.56\ \text{kPa} + 3.02\ \text{kPa} + 1.20\ \text{kPa}$

$= 13.78\ \text{kPa}$

6. $P_{\text{carbon dioxide}} = 30.4\ \text{kPa} - (16.5\ \text{kPa} + 3.7\ \text{kPa})$

$= 30.4\ \text{kPa} - 20.2\ \text{kPa} = 10.2\ \text{kPa}$

Chapter 14

1. $V_2 = \frac{V_1P_1}{P_2} = \frac{(300.0\ \text{mL})(99.0\ \cancel{\text{kPa}})}{188\ \cancel{\text{kPa}}} = 158\ \text{mL}$

2. $P_2 = \frac{V_1P_1}{V_2} = \frac{(1.00\ \cancel{\text{L}})(0.988\ \text{atm})}{2.00\ \cancel{\text{L}}} = 0.494\ \text{atm}$

3. $V_2 = \frac{V_1P_1}{P_2} = \frac{(145.7\ \text{mL})(1.08\ \cancel{\text{atm}})}{1.43\ \cancel{\text{atm}}}$

$= 1.10 \times 10^2\ \text{mL}$

4. $P_2 = \frac{V_1P_1}{V_2} = \frac{(4.00\ \cancel{\text{L}})(0.980\ \text{atm})}{0.0500\ \cancel{\text{L}}} = 78.4\ \text{atm}$

5. $29.2\ \cancel{\text{kPa}} \times \frac{1\ \text{atm}}{101.3\ \cancel{\text{kPa}}} = 0.288\ \text{atm}$

$V_2 = \frac{V_1P_1}{P_2} = \frac{(0.220\ \text{L})(0.860\ \cancel{\text{atm}})}{0.288\ \cancel{\text{atm}}} = 0.657\ \text{L}$

6. $T_1 = 89°\text{C} + 273 = 362\ \text{K}$

$T_2 = \frac{T_1V_2}{\cancel{V_1}} = \frac{(362\ \text{K})(1.12\ \cancel{\text{L}})}{0.67\ \cancel{\text{L}}} = 605\ \text{K}$

$605 - 273 = 330°\text{C}$

7. $T_1 = 80.0°\text{C} + 273 = 353\ \text{K}$

$T_2 = 30.0°\text{C} + 273 = 303\ \text{K}$

$V_2 = \frac{V_1T_2}{T_1} = \frac{(3.00\ \text{L})(303\ \cancel{\text{K}})}{353\ \cancel{\text{K}}} = 2.58\ \text{L}$

8. $T_1 = 25°\text{C} + 273 = 298\ \text{K}$

$T_2 = 0.00°\text{C} + 273 = 273\ \text{K}$

$V_2 = \frac{V_1T_2}{T_1} = \frac{(0.620\ \text{L})(273\ \cancel{\text{K}})}{298\ \cancel{\text{K}}} = 0.57\ \text{L}$

9. $T_1 = 30.0°\text{C} + 273 = 303\ \text{K}$

$T_2 = \frac{T_1P_2}{P_1} = \frac{(303\ \text{K})(201\ \cancel{\text{kPa}})}{125\ \cancel{\text{kPa}}} = 487\ \text{K}$

$487\ \text{K} - 273 = 214°\text{C}$

10. $T_1 = 25.0°\text{C} + 273 = 298\ \text{K}$

$T_2 = 37.0°\text{C} + 273 = 310\ \text{K}$

$P_2 = \frac{P_1T_2}{T_1} = \frac{(1.88\ \text{atm})(310\ \cancel{\text{K}})}{298\ \cancel{\text{K}}} = 1.96\ \text{atm}$

11. $T_2 = 36.5°\text{C} + 273 = 309.5\ \text{K}$

$T_1 = \frac{T_2P_1}{P_2} = \frac{(309.5\ \text{K})(1.12\ \cancel{\text{atm}})}{2.56\ \cancel{\text{atm}}} = 135\ \text{K}$

$135\ \text{K} - 273 = -138°\text{C}$

12. $T_1 = 0.00°\text{C} + 273 = 273\ \text{K}$

$T_2 = \frac{T_1P_2}{P_1} = \frac{(273\ \text{K})(28.4\ \cancel{\text{kPa}})}{30.7\ \cancel{\text{kPa}}} = 252.5\ \text{K}$

$252.5\ \text{K} - 273 = -20.5°\text{C} = -21°\text{C}$

The temperature must be lowered by 21°C.

13. $T_1 = 22.0°\text{C} + 273 = 295\ \text{K}$

$T_2 = 44.6°\text{C} + 273 = 318\ \text{K}$

$P_2 = \frac{P_1T_2}{P_1} = \frac{(660\ \text{torr})(318\ \cancel{\text{K}})}{295\ \cancel{\text{K}}} = 711\ \text{torr}$

$711\ \text{torr} - 660\ \text{torr} = 51\ \text{torr more}$

Solutions

CONTENTS

19. $T_1 = 36°\text{C} + 273 = 309\ \text{K}$

$T_2 = 28°\text{C} + 273 = 301\ \text{K}$

$$V_2 = \frac{P_1T_2V_1}{P_2T_1} = \frac{(0.998\ \cancel{\text{atm}})(301\ \cancel{\text{K}})(2.1\ \text{L})}{(0.900\ \cancel{\text{atm}})(309\ \cancel{\text{K}})} = 2.3\ \text{L}$$

20. $T_1 = 0.00°\text{C} + 273 = 273\ \text{K}$

$T_2 = 30.00°\text{C} + 273 = 303\ \text{K}$

$$P_2 = \frac{V_1T_2P_1}{V_2T_1} = \frac{(30.0\ \cancel{\text{mL}})(303\ \cancel{\text{K}})(1.00\ \text{atm})}{(20.0\ \cancel{\text{mL}})(273\ \cancel{\text{K}})}$$

$= 1.66\ \text{atm}$

21. $T_1 = 22.0°\text{C} + 273 = 295\ \text{K}$

$T_2 = 100.0°\text{C} + 273 = 373\ \text{K}$

$$V_1 = \frac{V_2T_1P_2}{T_2P_1} = \frac{(0.224\ \text{mL})(295\ \cancel{\text{K}})(1.23\ \cancel{\text{atm}})}{(373\ \text{K})(1.02\ \cancel{\text{atm}})}$$

$= 0.214\ \text{mL}$

22. $T_1 = 5.0°\text{C} + 273 = 278\ \text{K}$

$T_2 = 2.09°\text{C} + 273 = 275\ \text{K}$

$$V_2 = \frac{P_1T_2V_1}{P_2T_1} = \frac{(1.30\ \cancel{\text{atm}})(275\ \cancel{\text{K}})(46.0\ \text{mL})}{(1.52\ \cancel{\text{atm}})(278\ \cancel{\text{K}})}$$

$= 39\ \text{mL}$

23. $$P_1 = \frac{V_2T_1P_2}{V_1T_2} = \frac{(0.644\ \cancel{\text{L}})(298\ \cancel{\text{K}})(32.6\ \text{kPa})}{(0.766\ \cancel{\text{L}})(303\ \cancel{\text{K}})} =$$

$= 27.0\ \text{kPa}$

24. $2.4\ \cancel{\text{mol}} \times \frac{22.4\ \text{L}}{\cancel{\text{mol}}} = 54\ \text{L}$

25. $0.0459\ \cancel{\text{mol}} \times \frac{22.4\ \text{L}}{\cancel{\text{mol}}} = 1.03\ \text{L}$

26. $1.02\ \cancel{\text{mol}} \times \frac{22.4\ \text{L}}{\cancel{\text{mol}}} = 22.8\ \text{L}$

27. $2.00\ \cancel{\text{L}} \times \frac{1\ \text{mol}}{22.4\ \cancel{\text{L}}} = 0.0893\ \text{mol}$

28. Set up problem as a ratio.

$$\frac{?\ \text{mol He}}{0.865\ \cancel{\text{L}}} = \frac{0.0226\ \text{mol He}}{0.460\ \cancel{\text{L}}}$$

Solve for mol He.

$$?\ \text{mol He} = \frac{0.0226\ \text{mol He}}{0.460\ \cancel{\text{L}}} \times 0.865\ \cancel{\text{L}}$$

$= 0.0425\ \text{mol He}$

29. $1.0\ \cancel{\text{L}} \times \frac{1\ \text{mol}}{22.4\ \cancel{\text{L}}} = 0.045\ \text{mol}$

$0.045\ \cancel{\text{mol}} \times \frac{44.0\ \text{g}}{\cancel{\text{mol}}} = 2.0\ \text{g}$

30. $0.00922\ \cancel{\text{g}} \times \frac{1\ \text{mol}}{2.016\ \cancel{\text{g}}} = 0.00457\ \text{mol}$

$0.00457\ \cancel{\text{mol}} \times \frac{22.4\ \text{L}}{\cancel{\text{mol}}} = 0.102\ \text{L or 102 mL}$

31. $0.416\ \cancel{\text{g}} \times \frac{1\ \text{mol}}{83.8\ \cancel{\text{g}}} = 0.00496\ \text{mol}$

$0.00496\ \cancel{\text{mol}} \times \frac{22.4\ \text{L}}{\cancel{\text{mol}}} = 0.111\ \text{L}$

32. $0.860\ \text{g} - 0.205\ \text{g} = 0.655\ \text{g He remaining}$

Set up problem as a ratio.

$$\frac{V}{0.655\ \text{g}} = \frac{19.2\ \text{L}}{0.860\ \text{g}}$$

Solve for V.

$$V = \frac{(19.2\ \text{L})(0.655\ \cancel{\text{g}})}{0.860\ \cancel{\text{g}}} = 14.6\ \text{L}$$

33. $4.5\ \cancel{\text{kg}} \times \frac{1000\ \cancel{\text{g}}}{1\ \cancel{\text{kg}}} \times \frac{1\ \cancel{\text{mol}}}{28.0\ \cancel{\text{g}}} \times \frac{22.4\ \text{L}}{1\ \cancel{\text{mol}}} = 3.6 \times 10^3\ \text{L}$

41. $$n = \frac{PV}{RT} = \frac{(3.81\ \cancel{\text{atm}})(0.44\ \cancel{\text{L}})}{\left(0.0821\ \frac{\cancel{\text{L}}\cdot\cancel{\text{atm}}}{\text{mol}\cdot\cancel{\text{K}}}\right)(298\ \cancel{\text{K}})}$$

$= 6.9 \times 10^{-3}\ \text{mol}$

42. $143\ \cancel{\text{kPa}} \times \frac{1.00\ \text{atm}}{101.3\ \cancel{\text{kPa}}} = 1.41\ \text{atm}$

$$T = \frac{PV}{nR} = \frac{(1.41\ \cancel{\text{atm}})(1.00\ \cancel{\text{L}})}{(2.49\ \cancel{\text{mol}})\left(0.0821\frac{\cancel{\text{L}}\cdot\cancel{\text{atm}}}{\cancel{\text{mol}}\cdot\text{K}}\right)} = 6.90\ \text{K}$$

$6.90\ \text{K} - 273 = -266°\text{C}$

43. $$V = \frac{nRT}{P} = \frac{(0.323\ \cancel{\text{mol}})\left(0.0821\ \frac{\text{L}\cdot\cancel{\text{atm}}}{\cancel{\text{mol}}\cdot\cancel{\text{K}}}\right)(265\ \cancel{\text{K}})}{0.900\ \cancel{\text{atm}}}$$

$= 7.81\ \text{L}$

44. $T = 20.0°\text{C} + 273 = 293\ \text{K}$

$$P = \frac{nRT}{V} = \frac{(0.108\ \cancel{\text{mol}})\left(0.0821\frac{\cancel{\text{L}}\cdot\text{atm}}{\cancel{\text{mol}}\cdot\cancel{\text{K}}}\right)(293\ \cancel{\text{K}})}{0.505\ \cancel{\text{L}}}$$

$= 5.14\ \text{atm}$

45. $$T = \frac{PV}{nR} = \frac{(0.988\ \cancel{\text{atm}})(1.20\ \cancel{\text{L}})}{(0.0470\ \cancel{\text{mol}})\left(0.0821\frac{\cancel{\text{L}}\cdot\cancel{\text{atm}}}{\cancel{\text{mol}}\cdot\text{K}}\right)} = 307\ \text{K}$$

46. $117\ \cancel{\text{kPa}} \times \frac{1.00\ \cancel{\text{atm}}}{101.3\ \cancel{\text{kPa}}} = 1.15\ \text{atm}$

$T = 35.1°\text{C} + 273 = 308\ \text{K}$

$$m = \frac{PMV}{RT} = \frac{(1.15\ \cancel{\text{atm}})(70.0\ \text{g}/\cancel{\text{mol}})(2.00\ \cancel{\text{L}})}{\left(0.0821\frac{\cancel{\text{L}}\cdot\cancel{\text{atm}}}{\cancel{\text{mol}}\cdot\cancel{\text{K}}}\right)(308\ \cancel{\text{K}})}$$

$= 6.39\ \text{g}$

47. $T = 22.0°\text{C} + 273 = 295\ \text{K}$

$$m = \frac{MPV}{RT} = \frac{(28.0\ \text{g}/\cancel{\text{mol}})(1.00\ \text{atm})(0.600\ \cancel{\text{L}})}{\left(0.0821\frac{\cancel{\text{L}}\cdot\cancel{\text{atm}}}{\cancel{\text{mol}}\cdot\cancel{\text{K}}}\right)(295\ \text{K})}$$

$= 0.694\ \text{g}$

CONTENTS

48. $$D = \frac{PM}{RT} = \frac{(1.00\ \cancel{\text{atm}})(44.0\ \text{g}/\cancel{\text{mol}})}{\left(0.0821\frac{\text{L}\cdot\text{atm}}{\cancel{\text{mol}\cdot\text{K}}}\right)(273\ \cancel{\text{K}})} = 1.96\ \text{g/L}$$

49. $T = 25.0°\text{C} + 273 = 298\ \text{K}$

$$M = \frac{DRT}{P} = \frac{(1.09\ \text{g}/\cancel{\text{L}})\left(0.0821\frac{\cancel{\text{L}}\cdot\cancel{\text{atm}}}{\text{mol}\cdot\cancel{\text{K}}}\right)(298\ \cancel{\text{K}})}{1.02\ \cancel{\text{atm}}}$$

$$= 26.1\ \text{g/mol}$$

50. $$D = \frac{MP}{RT} = \frac{(39.9\ \text{g}/\cancel{\text{mol}})(1.00\ \cancel{\text{atm}})}{\left(0.0821\frac{\text{L}\cdot\text{atm}}{\cancel{\text{mol}\cdot\text{K}}}\right)(273\ \cancel{\text{K}})} = 1.78\ \text{g/L}$$

56. $S(s) + O_2(g) \longrightarrow SO_2(g)$

$$3.5\ \text{L}\ SO_2 \times + \frac{1\ \cancel{\text{volume}}\ O_2}{1\ \cancel{\text{volume}}\ SO_2} = 3.5\ \text{L}\ O_2$$

57. $2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$

$$5.00\ \text{L}\ O_2 \times \frac{2\ \cancel{\text{volumes}}\ H_2}{1\ \cancel{\text{volume}}\ O_2} = 10.0\ \text{L}\ H_2$$

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

$$34.0\ \text{L}\ O_2 \times \frac{1\ \cancel{\text{volume}}\ C_3H_8}{5\ \cancel{\text{volumes}}\ O_2} = 6.80\ \text{L}\ C_3H_8$$

59. $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$

$$2.36\ \text{L}\ CH_4 \times \frac{2\ \cancel{\text{volumes}}\ O_2}{1\ \cancel{\text{volume}}\ CH_4} = 4.72\ \text{L}\ O_2$$

60. $$0.100\ \text{L}\ N_2O \times \frac{1\ \text{mol}}{22.4\ \text{L}} = 0.00446\ \text{mol}\ N_2O$$

$$0.00446\ \cancel{\text{mol}\ N_2O} \times \frac{1\ \text{mol}\ NH_4NO_3}{1\ \cancel{\text{mol}\ N_2O}}$$

$$= 0.00446\ \text{mol}\ NH_4NO_3$$

$$0.00446\ \cancel{\text{mol}}\ NH_4NO_3 \times 80.0\ \text{g}/\cancel{\text{mol}}$$

$$= 0.357\ \text{g}\ NH_4NO_3$$

61. $$2.38\ \cancel{\text{kg}} \times \frac{1000\ \cancel{\text{g}}}{\cancel{\text{kg}}} \times \frac{1\ \text{mol}\ \cancel{CaCO_3}}{100.0\ \cancel{\text{g}}} \times$$

$$\frac{1\ \cancel{\text{mol}\ CO_2}}{1\ \cancel{\text{mol}\ CaCO_3}} \times \frac{22.4\ \text{L}}{1\ \cancel{\text{mol}}} = 533\ \text{L}\ CO_2$$

62. $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$

$$n = \frac{PV}{RT} = \frac{(1.00\ \cancel{\text{atm}})(10.5\ \cancel{\text{L}})}{\left(0.0821\frac{\cancel{\text{L}}\cdot\text{atm}}{\text{mol}\cdot\cancel{\text{K}}}\right)(473\ \cancel{\text{K}})}$$

$$= 0.271\ \text{mol}\ CH_4$$

$$0.271\ \cancel{\text{mol}\ CH_4} \times \frac{2\ \text{mol}\ H_2O}{1\ \cancel{\text{mol}\ CH_4}} = 0.541\ \text{mol}\ H_2O$$

63. $$52.0\ \cancel{\text{g Fe}} \times \frac{1\ \cancel{\text{mol Fe}}}{55.85\ \cancel{\text{g Fe}}} \times \frac{3\ \cancel{\text{mol}\ O_2}}{4\ \cancel{\text{mol Fe}}} \times \frac{22.4\ \text{L}}{1\ \cancel{\text{mol}}}$$

$$= 15.6\ \text{L}\ O_2$$

64. $2K(s) + Cl_2(g) \longrightarrow 2KCl(s)$

$$0.204\ \cancel{\text{g K}} \times \frac{1\ \cancel{\text{mol K}}}{39.1\ \cancel{\text{g K}}} \times \frac{1\ \cancel{\text{mol}\ Cl_2}}{2\ \cancel{\text{mol K}}} \times \frac{22.4\ \text{L}}{1\ \cancel{\text{mol}}}$$

$$= 0.0584\ \text{L}\ Cl_2$$

Chapter 15

1. $S_1 = \frac{0.55\text{ g}}{1.0\text{ L}} = 0.55\text{ g/L}$

$S_2 = P_2 \times \frac{S_1}{P_1} = 110.0\,\cancel{\text{kPa}} \times \frac{0.55\text{ g/L}}{20.0\,\cancel{\text{kPa}}} = 3.0\text{ g/L}$

2. $S_2 = \frac{1.5\text{ g}}{1.0\text{ L}} = 1.5\text{ g/L}$

$P_2 = \frac{S_2}{S_1} \times P_1 = \frac{1.5\,\cancel{\text{g/L}}}{0.66\,\cancel{\text{g/L}}} \times 10.0\text{ atm} = 23\text{ atm}$

8. 600 mL H_2O × 1.0 g/mL = 600 g H_2O

$$\frac{20\text{ g NaHCO}_3}{600\text{ g H}_2\text{O} + 20\text{ g Na HCO}_3} \times 100 = 3\%$$

9. $3.62\% = 100 \times \frac{\text{mass NaOCl}}{1500.0\text{ g}}$

mass NaOCl = 54.3 g

10. 1500.0 g − 54.3 g = 1445.7 g solvent

11. $\frac{35\text{ mL}}{115\text{ mL} + 35\text{ mL}} \times 100 = 23\%$

12. $30.0\% = 100 \times \frac{\text{volume ethanol}}{\text{volume solution}}$

volume ethanol = 0.300 × (volume solution) = 0.300 × 100.0 mL

volume ethanol = 30.0 mL

volume water = 100.0 mL − 30.0 mL = 70.0 mL

13. $\frac{24\text{ mL}}{24\text{ mL} + 1100\text{ mL}} \times 100 = 2.1\%$

14. mol $C_6H_{12}O_6$ $= 40.0\text{ g} \times \frac{1\text{ mol}}{180.16\text{ g}} = 0.222\text{ mol}$

$\text{molarity} = \frac{\text{mol C}_6\text{H}_{12}\text{O}_6}{1.5\text{ L solution}} = \frac{0.222\text{ mol}}{1.5\text{ L}} = 0.148M$

15. mol NaOCl $= 9.5\,\cancel{\text{g}} \times \frac{1\text{ mol}}{74.44\,\cancel{\text{g}}} = 0.128\text{ mol}$

$\text{molarity} = \frac{\text{mol NaOCl}}{1.00\text{ L solution}} = \frac{0.128\text{ mol}}{1.00\text{ L}} = 0.128M$

16. mol KBr $= 1.55\,\cancel{\text{g}} \times \frac{1\text{ mol}}{119.0\,\cancel{\text{g}}} = 0.0130\text{ mol KBr}$

$\text{molarity} = \frac{\text{mol KBr}}{1.60\text{ L solution}} = \frac{0.0130\text{ mol}}{01.60\text{ L}}$

$= 8.13 \times 10^{-3}M$

17. mol $CaCl_2$ $= (0.10M)(1.0\text{ L}) = (0.10\text{ mol}/\cancel{\text{L}})(1.0\,\cancel{\text{L}})$

$= 0.10\text{ mol CaCl}_2$

mass $CaCl_2$ $= 0.10\,\cancel{\text{mol}}\,\text{CaCl}_2 \times \frac{110.98\text{ g}}{1\,\cancel{\text{mol}}}$

$= 11\text{ g CaCl}_2$

18. mol NaOH $= (2M)(1\text{ L}) = (2\text{ mol}/\cancel{\text{L}})(1\,\cancel{\text{L}}) = 2\text{ mol}$

mass NaOH $= 2\,\cancel{\text{mol}}\,\text{NaOH} \times \frac{40.00\text{ g}}{1\,\cancel{\text{mol}}}$

$= 80\text{ g NaOH}$

19. mol $CaCl_2$ $= 500.0\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times 0.20M$

$= 500.0\,\cancel{\text{mL}} \times \frac{1\,\cancel{\text{L}}}{1000\,\cancel{\text{mL}}} \times \frac{0.20\text{ mol}}{1\,\cancel{\text{L}}}$

$= 0.10\text{ mol}$

mass $CaCl_2$ $= 0.10\,\cancel{\text{mol}}\,\text{CaCl}_2 \times \frac{110.98\text{ g}}{1\,\cancel{\text{mol}}}$

$= 11\text{ g CaCl}_2$

20. mol NaOH $= 250\text{ mL} \times \frac{1\text{ L}}{1000\text{ mL}} \times 3.0M$

$= 250\,\cancel{\text{mL}} \times \frac{1\,\cancel{\text{L}}}{1000\,\cancel{\text{mL}}} \times \frac{3.0\text{ mol}}{1\,\cancel{\text{L}}}$

$= 0.75\text{ mol}$

mass NaOH $= 0.75\text{ mol NaOH} \times \frac{40.00\text{ g}}{1\text{ mol}}$

$= 3.0 \times 10^1\text{ g NaOH}$

21. $(3.00M)V_1 = (1.25M)(0.300\text{ L})$

$V_1 = \frac{(1.25\cancel{M})(0.300\text{ L})}{3.00\cancel{M}} = 0.125\text{ L} = 125\text{ mL}$

22. $(5.0M)V_1 = (0.25M)(100.0\text{ mL})$

$V_1 = \frac{(0.25\cancel{M})(100.0\text{ mL})}{5.0\cancel{M}} = 5.0\text{ mL}$

23. $(3.5M)(20.0\text{ mL}) = M_2(100.0\text{ mL})$

$M_2 = \frac{(3.5M)(20.0\,\cancel{\text{mL}})}{100.0\,\cancel{\text{mL}}} = 0.70M$

24. mol Na_2SO_4 $= 10.0\,\cancel{\text{g}}\,\text{Na}_2\text{SO}_4 \times \frac{1\text{ mol}}{142.04\,\cancel{\text{g}}}$

$= 0.0704\text{ mol Na}_2\text{SO}_4$

$\text{molality} = \frac{0.0704\text{ mol Na}_2\text{SO}_4}{1000.0\text{ g H}_2\text{O}} = 0.0704m$

25. mol $C_{10}H_8$ $= 30.0\,\cancel{\text{g}}\,\text{C}_{10}\text{H}_8 \times \frac{1\text{ mol}}{128.16\,\cancel{\text{g}}}$

$= 0.234\text{ mol C}_{10}\text{H}_8$

$\text{molality} = \frac{0.234\text{ mol C}_{10}\text{H}_8}{500.0\,\cancel{\text{g toluene}}} \times \frac{1000.0\,\cancel{\text{g toluene}}}{1.0000\text{ kg toluene}}$

$= 0.468m$

26. $22.8\% = \frac{\text{mass NaOH}}{\text{mass NaOH} + \text{mass H}_2\text{O}} \times 100$

Assume 100.0 g sample.

Then, mass NaOH = 22.8 g and mass H_2O = 100.0 g − (mass NaOH) = 77.2 g

mol NaOH $= 22.8\,\cancel{\text{g}} \times \frac{1\text{ mol}}{40.00\,\cancel{\text{g}}} = 0.570\text{ mol NaOH}$

mol H_2O $= 77.2\,\cancel{\text{g}} \times \frac{1\text{ mol}}{18.02\,\cancel{\text{g}}} = 4.28\text{ mol H}_2\text{O}$

mol fraction NaOH $= \frac{\text{mol NaOH}}{\text{mol NaOH} + \text{mol H}_2\text{O}}$

$= \frac{0.570\text{ mol NaOH}}{0.570\text{ mol NaOH} + 4.28\text{ mol H}_2\text{O}} = \frac{0.570}{4.85}$

$= 0.118$

The mole fraction of NaOH is 0.118.

27. $0.21 = \frac{\text{mol NaCl}}{\text{mol NaCl} + \text{mol } H_2O}$

$0.21(\text{mol NaCl}) + 0.21(\text{mol } H_2O) = \text{mol NaCl}$

$0.79(\text{mol NaCl}) = 0.21(\text{mol } H_2O)$

$\text{mol } H_2O = 100.0 \cancel{\text{mL}} \times \frac{1.0 \text{ g}}{1 \cancel{\text{mL}}} \times \frac{1 \text{ mol}}{18.016 \cancel{\text{g}}}$

$= 5.55 \text{ mol } H_2O$

Therefore, $\text{mol NaCl} = \frac{0.21 \times 5.55 \text{ mol}}{0.79}$

$= 1.48 \text{ mol}$

$\text{mass NaCl} = 1.48 \cancel{\text{mol}} \times 58.44 \text{ g}/\cancel{\text{mol}} = 86.5 \text{ g}$

The mass of dissolved NaCl is 86.5 g.

33. $\Delta T_b = 0.512°\text{C}/\cancel{m} \times 0.625\cancel{m} = 0.320°\text{C}$
$T_b = 100°\text{C} + 0.320°\text{C} = 100.320°\text{C}$
$\Delta T_f = 1.86°\text{C}/\cancel{m} \times 0.625\cancel{m} = 1.16°\text{C}$
$T_f = 0.0°\text{C} - 1.16°\text{C} = -1.16°\text{C}$

34. $\Delta T_b = 1.22°\text{C}/\cancel{m} \times 0.40\cancel{m} = 0.49°\text{C}$
$T_b = 78.5°\text{C} + 0.49°\text{C} = 79.0°\text{C}$
$\Delta T_f = 1.99°\text{C}/\cancel{m} \times 0.40\cancel{m} = 0.80°\text{C}$
$T_f = -114.1°\text{C} - 0.80°\text{C} = -114.9°\text{C}$

35. $1.12°\text{C} = 0.512°\text{C}/m \times m$
$m = 2.19m$

36. $0.500 \text{ mol}/1 \text{ kg} = 0.500m$
$\Delta T_b = 2.53°\text{C}/m \times 0.500m = 1.26°\text{C}$

Chapter 16

1. 142 Calories = 142 kcal
$142 \cancel{\text{kcal}} \times \frac{1000 \text{ cal}}{1 \cancel{\text{kcal}}} = 142\,000 \text{ cal}$

2. $86.5 \text{ kJ} \times \frac{1 \text{ kcal}}{4.184 \cancel{\text{kJ}}} = 20.7 \text{ kcal}$

3. $256 \cancel{\text{J}} \times \frac{1 \cancel{\text{cal}}}{4.184 \cancel{\text{J}}} \times \frac{1 \text{ kcal}}{1000 \cancel{\text{cal}}} = 6.12 \times 10^{-2} \text{ kcal}$

4. $q = c \times m \times \Delta T$
$q = 2.44 \text{ J}/(\cancel{\text{g}} \cdot \cancel{°\text{C}}) \times 34.4 \cancel{\text{g}} \times 53.8\cancel{°\text{C}} = 4.52 \times 10^3 \text{ J}$

5. $q = c \times m \times \Delta T$
$276 \cancel{\text{J}} = 0.129 \cancel{\text{J}}/(\cancel{\text{g}} \cdot °\text{C}) \times 4.50 \cancel{\text{g}} \times \Delta T$
$\Delta T = 475°\text{C}$

$\Delta T = T_f - T_i$
Because the gold gains heat, let $\Delta T = +475°\text{C}$
$475\ °\text{C} = T_f - 25.0°\text{C}$
$T_f = 5.00 \times 10^2 °\text{C}$

6. $q = c \times m \times \Delta T$
$5696 \text{ J} = c \times 155 \text{ g} \times 15.0°\text{C}$
$c = 2.45 \text{ J}/(\text{g} \cdot °\text{C})$
The specific heat is very close to the value for ethanol.

12. $q = c \times m \times \Delta T$
$9750 \cancel{\text{J}} = 4.184 \cancel{\text{J}}/(\cancel{\text{g}} \cdot °\text{C}) \times 335 \cancel{\text{g}} \times \Delta T$
$\Delta T = 6.96°\text{C}$

Because the water lost heat, let $\Delta T = -6.96°\text{C}$
$\Delta T = -6.96°\text{C} = T_f - 65.5°\text{C}$
$T_f = 58.5°\text{C}$

13. $q = c \times m \times \Delta T$

$5650 \cancel{\text{J}} = 4.184 \cancel{\text{J}}/(\text{g} \cdot \cancel{°\text{C}}) \times m \times 26.6\cancel{°\text{C}}$

$m = 50.8 \text{ g}$

20. $25.7 \cancel{\text{g } CH_3OH} \times \frac{1 \cancel{\text{mol } CH_3OH}}{32.04 \cancel{\text{g } CH_3OH}} \times \frac{3.22 \text{ kJ}}{1 \cancel{\text{mol } CH_3OH}}$
$= 2.58 \text{ kJ}$

21. $275 \cancel{\text{g } NH_3} \times \frac{1 \cancel{\text{mol } NH_3}}{17.03 \cancel{\text{g } NH_3}} \times \frac{23.3 \text{ kJ}}{1 \cancel{\text{mol } NH_3}} = 376 \text{ kJ}$

22. $12\,880 \text{ kJ} = m \times \frac{1 \cancel{\text{mol } CH_4}}{16.04 \text{ g } CH_4} \times \frac{891 \text{ kJ}}{1 \cancel{\text{mol } CH_4}}$
$m = 12\,880 \cancel{\text{kJ}} \times \frac{16.04 \text{ g } CH_4}{1 \cancel{\text{mol } CH_4}} \times \frac{1 \cancel{\text{mol } CH_4}}{891 \cancel{\text{kJ}}}$
$m = 232 \text{ g } CH_4$

28. Add the first equation to the second equation reversed.

$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ $\Delta H = -566.0 \text{ kJ}$
$2NO(g) \rightarrow N_2(g) + O_2(g)$ $\Delta H = -180.6 \text{ kJ}$

$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N2(g)$ $\Delta H = -746.6 \text{ kJ}$

CONTENTS

29. Add the first equation to the second equation reversed and tripled.

$$\begin{array}{ll} 4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s) & \Delta H = -3352 \text{ kJ} \\ 3MnO_2(s) \rightarrow 3Mn(s) + 3O_2(g) & \Delta H = +1563 \text{ kJ} \\ \hline 4Al(s) + 3MnO_2(s) \rightarrow 2Al_2O_3(s) + 3Mn(s) & \Delta H = -1789 \text{ kJ} \end{array}$$

30. a. One mole of $O_2(g)$ in the first equation cancels the $O_2(g)$ in the second equation.

$$\begin{array}{l} 2[\tfrac{1}{2}\,N_2(g) + O_2(g) \rightarrow NO_2(g)] \\ 2[NO(g) \rightarrow \tfrac{1}{2}\,O_2(g) + \tfrac{1}{2}\,N_2(g)] \\ \hline 2NO(g) + O_2(g) \rightarrow 2NO_2(g) \end{array}$$

b.

$$\begin{array}{l} H_2(g) + S(s) + 2O_2(g) \rightarrow H_2SO_4(l) \\ SO_3(g) \rightarrow S(s) + \tfrac{3}{2}O_2(g) \\ H_2O(l) \rightarrow H_2(g) + \tfrac{1}{2}O_2(g) \\ \hline SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l) \end{array}$$

31. a. $\Delta H^\circ_{rxn} = \Sigma\Delta H_f{}^\circ$ (products) $- \Sigma\Delta H_f{}^\circ$ (reactants)
$\Delta H^\circ_{rxn} = (-635.1 \text{ kJ} - 393.509 \text{ kJ}) - (-1206.9 \text{ kJ})$
$= 178.3 \text{ kJ}$

b. $\Delta H^\circ_{rxn} = (-128.2 \text{ kJ}) - (-74.81 \text{ kJ}) = -53.4 \text{ kJ}$

c. $\Delta H^\circ_{rxn} = 2(33.18 \text{ kJ}) - (0 \text{ kJ}) = 66.36 \text{ kJ}$

d. $\Delta H^\circ_{rxn} = 2(-285.830 \text{ kJ}) - 2(-187.8 \text{ kJ}) = -196.1 \text{ kJ}$

e. $\Delta H^\circ_{rxn} = [4(33.18 \text{ kJ}) + 6(-285.830 \text{ kJ})] - 4(-46.11) \text{ kJ} = -1397.82 \text{ kJ}$

38. a. ΔS_{system} is negative because the system's entropy decreases.

b. ΔS_{system} is negative because the system's entropy decreases.

c. ΔS_{system} is positive because the system's entropy increases.

d. ΔS_{system} is negative because the system's entropy decreases.

39. a. $\Delta G_{system} = \Delta H_{system} - T\Delta S_{system}$
$\Delta G_{system} = -75\,900 \text{ J} - (273 \text{ K})(138 \text{ J/K})$
$\Delta G_{system} = -75\,900 \text{ J} - 37\,700 \text{ J} = -113\,600 \text{ J}$
spontaneous reaction

b. $\Delta G_{system} = \Delta H_{system} - T\Delta S_{system}$
$\Delta G_{system} = -27\,600 \text{ J} - (535 \text{ K})(-55.2 \text{ J/K})$
$\Delta G_{system} = -27\,600 \text{ J} + 29\,500 \text{ J} = 1900 \text{ J}$
nonspontaneous reaction

c. $\Delta G_{system} = \Delta H_{system} - T\Delta S_{system}$
$\Delta G_{system} = 365\,000 \text{ J} - (388 \text{ K})(-55.2 \text{ J/K})$
$\Delta G_{system} = 365\,000 \text{ J} + 21\,400 \text{ J} = 386\,000 \text{ J}$
nonspontaneous reaction

Chapter 17

1. Average reaction rate =

$$-\frac{[H_2] \text{ at time } t_2 - [H_2] \text{ at time } t_1}{t_2 - t_1} = -\frac{\Delta[H_2]}{\Delta t}$$

$$\text{Average reaction rate} = -\frac{0.020M - 0.030M}{4.00 \text{ s} - 0.00 \text{ s}}$$

$$= -\frac{-0.010M}{4.00 \text{ s}} = 0.0025 \text{ mol/(L·s)}$$

2. Average reaction rate =

$$-\frac{[Cl_2] \text{ at time } t_2 - [Cl_2] \text{ at time } t_1}{t_2 - t_1} = -\frac{\Delta[Cl_2]}{\Delta t}$$

$$\text{Average reaction rate} = -\frac{0.040M - 0.050M}{4.00 \text{ s} - 0.00 \text{ s}}$$

$$= -\frac{-0.010M}{4.00 \text{ s}} = 0.0025 \text{ mol/(L·s)}$$

3. Average reaction rate =

$$\frac{[HCl] \text{ at time } t_2 - [HCl] \text{ at time } t_1}{t_2 - t_1} = \frac{\Delta[HCl]}{\Delta t}$$

$$\text{Average reaction rate} = \frac{0.020M - 0.000M}{4.00 \text{ s} - 0.00 \text{ s}}$$

$$= \frac{0.020M}{4.00 \text{ s}} = 0.0050 \text{ mol/(L·s)}$$

16. Rate $= k[A]^3$

17. Examining trials 1 and 2, doubling [A] has no effect on the rate; therefore, the reaction is zero order in A. Examining trials 2 and 3, doubling [B] doubles the rate; therefore, the reaction is first order in B. Rate $= k[A]^0[B] = k[B]$

18. Examining trials 1 and 2, doubling $[CH_3CHO]$ increases the rate by a factor of four. Examining trials 2 and 3, doubling $[CH_3CHO]$ again increases the rate by a factor of four. Therefore, the reaction is second order in CH_3CHO.
Rate $= k[CH_3CHO]^2$

24. $[NO] = 0.00500M$
$[H_2] = 0.00200M$
$k = 2.90 \times 10^2 \text{ L}^2/(\text{mol}^2\text{·s})$

Rate $= k\,[NO]^2[H_2]$
$= [2.90 \times 10^2 \text{ L}^2/(\text{mol}^2\text{·s})](0.00500M)^2 (0.00200M)$
$= [2.90 \times 10^2 \cancel{\text{L}^2}/(\cancel{\text{mol}^2}\text{·s})](0.00500 \cancel{\text{mol}}/\cancel{L})^2 (0.00200 \text{ mol/L})$
$= 1.45 \times 10^{-5} \text{ mol/(L·s)}$

25. $[NO] = 0.0100M$

$[H_2] = 0.00125M$

$k = 2.90 \times 10^2\ L^2/(mol^2 \cdot s)$

$\text{Rate} = k\,[NO]^2[H_2]$

$= [2.90 \times 10^2\ L^2/(mol^2 \cdot s)]\ (0.0100M)^2(0.00125M)$

$= [2.90 \times 10^2\ \cancel{L^2}/\cancel{(mol^2}\cdot s)]\ (0.0100\ \cancel{mol/L})^2$
$(0.00125\ mol/L)$

$= 3.63 \times 10^{-5}\ mol/(L \cdot s)$

26. $[NO] = 0.00446M$

$[H_2] = 0.00282M$

$k = 2.90 \times 10^2\ L^2/(mol^2 \cdot s)$

$\text{Rate} = k\,[NO]^2[H_2]$

$= [2.90 \times 10^2\ L^2/(mol^2 \cdot s)](0.00446M)^2(0.00282M)$

$= [2.90 \times 10^2\ \cancel{L^2}/\cancel{(mol^2}\cdot s)](0.00446\ \cancel{mol/L})^2$
$(0.00282 mol/L)$

$\text{Rate} = 1.63 \times 10^{-5}\ mol/(L \cdot s)$

Chapter 18

1. a. $K_{eq} = \dfrac{[NO_2]^2}{[N_2O_4]}$

b. $K_{eq} = \dfrac{[CH_4][H_2O]}{[CO][H_2]^3}$

c. $K_{eq} = \dfrac{[H_2]^2[S_2]}{[H_2S]^2}$

2. a. $K_{eq} = [C_{10}H_8(g)]$

b. $K_{eq} = [CO_2(g)]$

c. $K_{eq} = [H_2O(g)]$

d. $K_{eq} = \dfrac{[H_2(g)][CO(g)]}{[H_2O(g)]}$

e. $K_{eq} = \dfrac{[CO_2(g)]}{[CO(g)]}$

3. $K_{eq} = \dfrac{[NO_2]^2}{[N_2O_4]} = \dfrac{(0.0627)^2}{(0.0185)} = 0.213$

4. $K_{eq} = \dfrac{[CH_4][O_2H]}{[CO][H_2]^3} = \dfrac{(0.0387)(0.0387)}{(0.0613)(0.1839)^3} = 3.93$

16. a. $K_{eq} = \dfrac{[CH_3OH]}{[CO][H_2]^2}$

$10.5 = \dfrac{(1.32)}{[CO](0.933)^2}$

$[CO] = 0.144M$

b. $K_{eq} = \dfrac{[CH_3OH]}{[CO][H_2]^2}$

$10.5 = \dfrac{(0.325)}{(1.09)[H_2]^2}$

$[H_2] = 0.169M$

c. $K_{eq} = \dfrac{[CH_3OH]}{[CO][H_2]^2}$

$10.5 = \dfrac{[CH_3OH]}{(3.85)(0.0661)^2}$

$[CH_3OH] = 0.177M$

17. a. $PbCrO_4(s) \rightleftharpoons Pb^{2+}(aq) + CrO_4{}^{2-}(aq)$

s mol/L dissolves *s* mol/L *s* mol/L

$K_{sp} = [Pb^{2+}][CrO_4{}^{2-}]$

$2.3 \times 10^{-13} = (s)(s) = s^2$

$s = \sqrt{2.3 \times 10^{-13}} = 4.8 \times 10^{-7}M$

b. $AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq)$

s mol/L dissolves *s* mol/L *s* mol/L

$K_{sp} = [Ag^+][Cl^-]$

$1.8 \times 10^{-10} = (s)(s) = s^2$

$s = \sqrt{1.8 \times 10^{-10}} = 1.3 \times 10^{-5}M$

c. $CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + CO_3{}^{2-}(aq)$

s mol/L dissolves *s* mol/L *s* mol/L

$K_{sp} = [Ca^{2+}][CO_3{}^{2-}]$

$3.4 \times 10^{-9} = (s)(s) = s^2$

$s = \sqrt{3.4 \times 10^{-9}} = 5.8 \times 10^{-5}M$

d. $CaSO_4(s) \rightleftharpoons Ca^{2+}(aq) + SO_4{}^{2-}(aq)$

s mol/L dissolves *s* mol/L *s* mol/L

$K_{sp} = [Ca^{2+}][SO_4{}^{2-}]$

$4.9 \times 10^{-5} = (s)(s) = s^2$

$s = \sqrt{4.9 \times 10^{-5}} = 7.0 \times 10^{-3}M$

18. a. $AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$

s mol/L dissolves *s* mol/L *s* mol/L

$K_{sp} = [Ag^+][Br^-]$

$5.4 \times 10^{-13} = (s)(s) = s^2$

$s = \sqrt{5.4 \times 10^{-13}} = 7.3 \times 10^{-7}M = [Ag^+]$

b. $CaF_2(s) \rightleftharpoons Ca^{2+}(aq) + 2F^-(aq)$

s mol/L dissolves *s* mol/L 2*s* mol/L

$[CaF_2] = \frac{1}{2}[F^-]$

$K_{sp} = [Ca^{2+}][F^-]^2$

$3.5 \times 10^{-11} = (s)(2s)^2 = 4s^3$

$s = \sqrt[3]{\dfrac{3.5 \times 10^{-11}}{4}} = 2.1 \times 10^{-4}M$

$\frac{1}{2}[F^-] = 2.1 \times 10^{-4}M$

$[F^-] = 4.2 \times 10^{-4}M$

Solutions

c. $$\begin{array}{llll} Ag_2CrO_4(s) & \rightleftharpoons\ 2Ag^+(aq) & + & CrO_4^{2-}(aq) \\ s \text{ mol/L dissolves} & \quad 2s \text{ mol/L} & & s \text{ mol/L} \end{array}$$

$[Ag_2CrO_4] = \frac{1}{2}[Ag^+]$

$K_{sp} = [Ag^+]^2[CrO_4^{2-}]$

$1.1 \times 10^{-12} = (2s)^2(s) = 4s^3$

$s = \sqrt[3]{\frac{1.1 \times 10^{-12}}{4}} = 6.5 \times 10^{-5}M$

$\frac{1}{2}[Ag^+] = 6.5 \times 10^{-5}M$

$[Ag^+] = 1.3 \times 10^{-4}M$

d. $$\begin{array}{llll} PbI_2(s) & \rightleftharpoons\ Pb^{2+}(aq) & + & 2I^-(aq) \\ s \text{ mol/L dissolves} & \quad s \text{ mol/L} & & 2s \text{ mol/L} \end{array}$$

$K_{sp} = [Pb^{2+}][I^-]^2$

$9.8 \times 10^{-9} = (s)(2s)^2 = 4s^3$

$s = \sqrt[3]{\frac{9.8 \times 10^{-9}}{4}} = 1.3 \times 10^{-3}M$

19. a. $PbF_2(s) \rightleftharpoons Pb^{2+}(aq) + 2F^-(aq)$

$Q_{sp} = [Pb^{2+}][F^-]^2 = (0.050M)(0.015M)^2$

$= 1.12 \times 10^{-5}$

$K_{sp} = 3.3 \times 10^{-8}$

$Q_{sp} > K_{sp}$ so a precipitate will form.

b. $Ag_2SO_4(s) \rightleftharpoons 2Ag^+(aq) + SO_4^{2-}(aq)$

$Q_{sp} = [Ag^+]^2[SO_4^{2-}] = (0.0050M)^2(0.125M)$

$= 3.1 \times 10^{-6}$

$K_{sp} = 1.2 \times 10^{-5}$

$Q_{sp} < K_{sp}$ so no precipitate will form.

c. $Mg(OH)_2(s) \rightleftharpoons Mg^{2+}(aq) + 2OH^-(aq)$

$Q_{sp} = [Mg^{2+}][OH^-]^2 = (0.10M)(0.00125M)^2$

$= 1.56 \times 10^{-7}$

$K_{sp} = 5.6 \times 10^{-12}$

$Q_{sp} > K_{sp}$ so a precipitate will form.

Chapter 19

1. a. $Mg(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2(g)$

b. $2Al(s) + 3H_2SO_4(aq) \rightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$

c. $CaCO_3(s) + 2HBr(aq) \rightarrow CaBr_2(aq) + H_2O(l) + CO_2(g)$

d. $KHCO_3(s) + HCl(aq) \rightarrow KCl(aq) + H_2O(l) + CO_2(g)$

2.

Acid	Conjugate base	Base	Conjugate acid
a. NH_4^+	NH_3	OH^-	H_2O
b. HBr	Br^-	H_2O	H_3O^+
c. H_2O	OH^-	CO_3^{2-}	HCO_3^-
d. HSO_4^-	SO_4^{2-}	H_2O	H_3O^+

3. a. $H_2Se(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HSe^-(aq)$
$HSe^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Se^{2-}(aq)$

b. $H_3AsO_4(aq) + H_2O(l) \quad H_3O^+(aq) + H_2AsO_4^-(aq)$

$H_2AsO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HAsO_4^{2-}(aq)$

$HAsO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + AsO_4^{3-}(aq)$

c. $H_2SO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HSO_3^-(aq)$
$HSO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + SO_3^{2-}(aq)$

10. a. $HClO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + ClO_2^-(aq)$

$K_a = \frac{[H_3O^+][ClO_2^-]}{[HClO_2]}$

b. $HNO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NO_2^-(aq)$

$K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2]}$

c. $HIO(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + IO^-(aq)$

$K_a = \frac{[H_3O^+][IO^-]}{[HIO]}$

11. a. $C_6H_{13}NH_2(aq) + H_2O(l) \rightleftharpoons C_6H_{13}NH_3^+(aq) + OH^-(aq)$

$K_b = \frac{[C_6H_{13}NH_3^+][OH^-]}{[C_6H_{13}NH_2]}$

b. $C_3H_7NH_2(aq) + H_2O(l) \rightleftharpoons C_3H_7NH_3+(aq) + OH^-(aq)$

$K_b = \frac{[C_3H_7NH_3^+][OH^-]}{[C_3H_7NH_2]}$

c. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$

$K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}]}$

d. $HSO_3^-(aq) + H_2O(l) \rightleftharpoons H_2SO_3(aq) + OH^-(aq)$

CONTENTS

$$K_b = \frac{[H_2SO_3{}^-][OH^-]}{[HSO_3{}^-]}$$

18. a. $[H^+] = 1.0 \times 10^{-13}M$

$K_w = [H^+][OH^-]$

$1.0 \times 10^{-14} = (1.0 \times 10^{-13})[OH^-]$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-13}} = \frac{(1.0 \times 10^{-13})[OH^-]}{1.0 \times 10^{-13}}$$

$[OH^-] = 1.0 \times 10^{-1}M$

$[OH^-] > [H^+]$, so the solution is basic.

b. $[OH^-] = 1.0 \times 10^{-7}M$

$K_w = [H^+][OH^-]$

$1.0 \times 10^{-14} = [H^+](1.0 \times 10^{-7})$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-7}} = \frac{[H^+](1.0 \times 10^{-7})}{1.0 \times 10^{-7}}$$

$[H^+] = 1.0 \times 10^{-7}M$

$[OH^-] = [H^+]$, so the solution is neutral.

c. $[OH^-] = 1.0 \times 10^{-3}M$

$K_w = [H+][OH^-]$

$1.0 \times 10^{-14} = [H^+](1.0 \times 10^{-3})$

$$\frac{1.0 \times 10^{-14}}{1.0 \times 10^{-3}} = \frac{[H^+](1.0 \times 10^{-3})}{1.0 \times 10^{-3}}$$

$[H^+] = 1.0 \times 10^{-11}M$

$[OH^-] > [H^+]$, so the solution is basic.

19. a. $pH = -\log(1.0 \times 10^{-2}) = -(-2.00) = 2.00$

b. $pH = -\log(3.0 \times 10^{-6}) = -(-5.52) = 5.52$

c. $K_w = [H^+][OH^-] = [H^+](8.2 \times 10^{-6})$

$$[H^+] = \frac{1.0 \times 10^{-14}}{8.2 \times 10^{-6}} = 1.2 \times 10^{-9}$$

$pH = -\log(1.2 \times 10^{-9}) = -(-8.92) = 8.92$

20. a. $pOH = -\log(1.0 \times 10^{-6}) = -(-6.00) = 6.00$
$pH = 14.00 - pOH = 14.00 - 6.00 = 8.00$

b. $pOH = -\log(6.5 \times 10^{-4}) = -(-3.19) = 3.19$
$pH = 14.00 - pOH = 14.00 - 3.19 = 10.81$

c. $pH = -\log(3.6 \times 10^{-9}) = -(-8.44) = 8.44$
$pOH = 14.00 - pH = 14.00 - 8.44 = 5.56$

d. $pH = -\log(0.025) = -(-1.60) = 1.60$
$pOH = 14.00 - pH = 14.00 - 1.60 = 12.40$

21. a. $[H^+] = \text{antilog}\,(-2.37) = 4.3 \times 10^{-3}M$
$pOH = 14.00 - pH = 14.00 - 2.37 = 11.63$
$[OH^-] = \text{antilog}\,(-11.63) = 2.3 \times 10^{-12}M$

b. $[H^+] = \text{antilog}\,(-11.05) = 8.9 \times 10^{-12}M$
$pOH = 14.00 - pH = 14.00 - 11.05 = 2.95$
$[OH^-] = \text{antilog}\,(-2.95) = 1.1 \times 10^{-3}M$

c. $[H^+] = \text{antilog}\,(-6.50) = 3.2 \times 10^{-7}M$
$pOH = 14.00 - pH = 14.00 - 6.50 = 7.50$

$[OH^-] = \text{antilog}\,(-7.50) = 3.2 \times 10^{-8}M$

22. a. $[H^+] = [HI] \times \dfrac{1 \text{ mol } H^+}{1 \text{ mol HI}} = 1.0M$

$pH = -\log(1.0) = 0.00$

b. $[H^+] = [HNO_3] \times \dfrac{1 \text{ mol } H^+}{1 \text{ mol } HNO_3} = 0.050M$

$pH = -\log(0.050) = 1.30$

c. $[OH^-] = [KOH] \times \dfrac{1 \text{ mol } OH^-}{1 \text{ mol KOH}} = 1.0M$

$pOH = -\log(1.0) = 0.00$

$pH = 14.00 - 0.00 = 14.00$

d. $[OH^-] = [Mg(OH)_2] \times \dfrac{2 \text{ mol } OH^-}{1 \text{ mol } Mg(OH)_2}$

$= 4.8 \times 10^{-5}M$

$pOH = -\log(4.8 \times 10^{-5}) = 4.32$

$pH = 14.00 - 4.32 = 9.68$

23. a. $K_a = \dfrac{[H^+][H_2AsO_4]}{[H_3AsO_4]}$

$[H^+] = \text{antilog}\,(-1.50) = 3.2 \times 10^{-2}M$

$[H_3AsO_4] = [H^+] = 3.2 \times 10^{-2}M$

$[H_3AsO_4] = 0.220M - 3.2 \times 10^{-2}M = 0.188M$

$$K_a = \frac{(3.2 \times 10^{-2})(3.2 \times 10^{-2})}{0.188}$$

$= 5.4 \times 10^{-3}$

b. $K_a = \dfrac{[H^+][ClO_2{}^-]}{[HClO_2]}$

$[H^+] = \text{antilog}\,(-1.80) = 1.6 \times 10^{-2}M$

$[ClO_2] = [H^+] = 1.6 \times 10^{-2}M$

$[HClO_2] = 0.0.0400M - 1.6 \times 10^{-2}M$
$= 0.024M$

$$K_a = \frac{(1.6 \times 10^{-2})(1.6 \times 10^{-2})}{0.024}$$

$= 1.1 \times 10^{-2}$

29. a. $HNO_3(aq) + CsOH(aq) \rightarrow CsNO_3(aq) + H_2O(l)$
b. $2HBr(aq) + Ca(OH)_2(aq) \rightarrow CaBr_2(aq) + 2H_2O(l)$
c. $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$
d. $CH_3COOH(aq) + NH_4OH(aq) \rightarrow$
$CH_3COONH_4(aq) + H_2O(l)$

CONTENTS

30. $26.4\ \cancel{\text{mL}}\ \text{HBr} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times \frac{0.250\ \text{mol HBr}}{1\ \cancel{\text{L}}\ \text{HBr}}$

$= 6.60 \times 10^{-3}\ \text{mol HBr}$

$6.60 \times 10^{-3}\ \cancel{\text{mol HBr}} \times \frac{1\ \text{mol CsOH}}{1\ \cancel{\text{mol HBr}}}$

$= 6.60 \times 10^{-3}\ \text{mol CsOH}$

$M_{\text{CsOH}} = \frac{6.60 \times 10^{-3}\ \text{mol CsOH}}{0.0300\ \text{L CsOH}} = 0.220M$

31. $43.33\ \cancel{\text{mL}}\ \text{KOH} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times \frac{0.1000\ \text{mol KOH}}{1\ \cancel{\text{L}}\ \text{KOH}}$

$= 4.333 \times 10^{-3}\ \text{mol KOH}$

$4.333 \times 10^{-3}\ \cancel{\text{mol}}\ \text{KOH} \times \frac{1\ \text{mol HNO}_3}{1\ \cancel{\text{mol}}\ \text{KOH}}$

$= 4.333 \times 10^{-3}\ \text{mol HNO}_3$

$M_{\text{HNO}_3} = \frac{4.333 \times 10^{-3}\ \text{mol HNO}_3}{0.02000\ \text{L HNO}_3} = 0.2167M$

32. $49.90\ \cancel{\text{mL}}\ \text{HCl} \times \frac{1\ \cancel{\text{L}}}{1000\ \cancel{\text{mL}}} \times \frac{0.5900\ \text{mol HCl}}{1\ \cancel{\text{L}}\ \text{HCl}}$

$= 2.944 \times 10^{-2}\ \text{mol HCl}$

$2.944 \times 10^{-2}\ \cancel{\text{mol}}\ \text{HCl} \times \frac{1\ \text{mol NH}_3}{1\ \cancel{\text{mol}}\ \text{HCl}}$

$= 2.944 \times 10^{-2}\ \text{mol NH}_3$

$M_{\text{NH3}} = \frac{2.944 \times 10^{-2}\ \text{mol NH}_3}{0.02500\ \text{L NH}_3} = 1.178M$

33. a. $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$
The solution is acidic.

b. $CH_3COO^-(aq) + H_2O(l) \rightleftharpoons$
$CH_3COOH(aq) + OH^-(aq)$
The solution is basic.

c. $SO_4^{2-}(aq) + H_2O(l) \rightleftharpoons HSO_4^-(aq) + OH^-(aq)$
The solution is neutral.

d. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$
The solution is basic.

Chapter 20

1. a. reduction
b. oxidation
c. oxidation
d. reduction

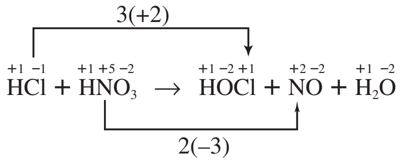
2. a. oxidized: bromide ion
reduced: chlorine
b. oxidized: cerium
reduced: copper(II) ion
c. oxidized: zinc
reduced: oxygen

3. a. oxidizing agent: iodine
reducing agent: magnesium
b. oxidizing agent: hydrogen ion
reducing agent: sodium
c. oxidizing agent: chlorine
reducing agent: hydrogen sulfide

4. a. +7
b. +5
c. +3

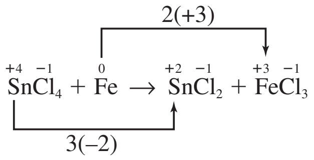
5. a. −3
b. +5
c. +6

12.



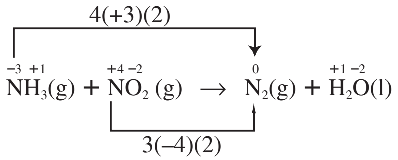
$3HCl + 2HNO_3 \rightarrow 3HOCl + 2NO + H_2O$

13.



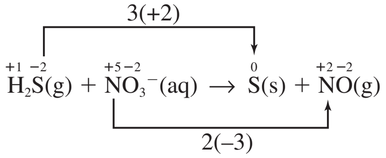
$3SnCl_4 + 2Fe \rightarrow 3SnCl_2 + 2FeCl_3$

14.



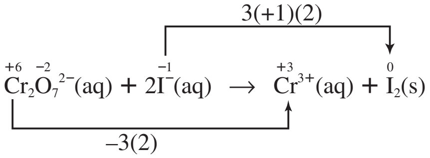
$8NH_3(g) + 6NO_2(g) \rightarrow 7N_2(g) + 12H_2O(l)$

15.



$2H^+(aq) + 3H_2S(g) + 2NO_3^-(aq) \rightarrow$
$3S(s) + 2NO(g) + 4H_2O(l)$

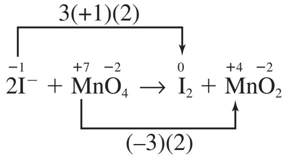
16.



$\overset{+6\ \ -2}{Cr_2O_7^{2-}}(aq) + 2\overset{-1}{I^-}(aq) \longrightarrow \overset{+3}{Cr^{3+}}(aq) + \overset{0}{I_2}(s)$

$14H^+(aq) + Cr_2O_7^{2-}(aq) + 6I^-(aq) \rightarrow$
$2Cr^{3+}(aq) + 3I_2(s) + 7H_2O(l)$

17.



$2\overset{-1}{I^-} + \overset{+7\ \ -2}{MnO_4} \longrightarrow \overset{0}{I_2} + \overset{+4\ \ -2}{MnO_2}$

$6I^-(aq) + 2MnO_4^-(aq) + 4H_2O(l) \rightarrow$
$3I_2(s) + 2MnO_2(s) + 8OH^-(aq)$

24. $2I^-(aq) \rightarrow I_2(s) + 2e^-$ (oxidation)

$14H^+(aq) + 6e^- + Cr_2O7_2^-(aq) \rightarrow$
$2Cr_3^+(aq) + 7H_2O(l)$ (reduction)

Multiply oxidation half-reaction by 3 and add to reduction half-reaction

$14H^+(aq) + 6e^- + Cr_2O_7^{2-}(aq) + 6I^-(aq) \rightarrow$
$3I_2(s) + 2Cr^{3+}(aq) + 7H_2O(l) + 6e^-$

$14H^+(aq) + Cr_2O_7^{2-}(aq) + 6I^-(aq) \rightarrow$
$3I_2(s) + 2Cr^{3+}(aq) + 7H_2O(l)$

25. $Mn^{2+}(aq) + 4H_2O(l) \rightarrow$
$MnO_4^-(aq) + 5e^- + 8H^+(aq)$ (oxidation)

$BiO_3^-(aq) + 3e^- + 6H^+(aq) \rightarrow$
$Bi^{2+}(aq) + 3H_2O(l)$ (reduction)

Multiply oxidation half-reaction. Multiply reduction half-reaction by 5 and add to oxidation half-reaction.

$3Mn^2+(aq) + 12H_2O(l) + 5BiO_3^-(aq) + 15e^- +$
$30H^+(aq) \rightarrow 3MnO_4^-(aq) + 15e^- + 24H^+(aq) +$
$5Bi^{2+}(aq) + 15H_2O(l)$

$3Mn^{2+}(aq) + 5BiO_3^-(aq) + 6H^+(aq) \rightarrow$
$3MnO_4^-(aq) + 5Bi^{2+}(aq) + 3H_2O(l)$

26. $6OH^-(aq) + N_2O(g) \rightarrow 2NO_2^-(aq) + 4e^- + 3H_2O(l)$ (oxidation)

$ClO^-(aq) + 2e^- + H_2O(l) \rightarrow Cl^-(aq) + 2OH^-(aq)$ (reduction)

Multiply reduction half-reaction by 2 and add to oxidation half-reaction.

$6OH^-(aq) + N_2O(g) + 2ClO^-(aq) + 4e^- + 2H_2O(l)$
$\rightarrow 2NO_2^-(aq) + 4e^- + 3H_2O(l) + 2Cl^-(aq) +$
$4OH^-(aq)$

$N_2O(g) + 2ClO^-(aq) + 2OH^-(aq) \rightarrow 2NO_2^-(aq) +$
$2Cl^-(aq) + H_2O(l)$

Chapter 21

1. $Pt^{2+}(aq) + Sn(s) \rightarrow Pt(s) + Sn^{2+}(aq)$
$E^0_{cell} = 1.18\ V - (-0.1375\ V)$
$E^0_{cell} = 1.32\ V$
$Sn|Sn^{2+}||Pt^{2+}|Pt$

2. $3Co^{2+}(aq) + 2Cr(s) \rightarrow 3Co(s) + 2Cr^{3+}(aq)$
$E^0_{cell} = (-0.28\ V) - (-0.744\ V)$
$E^0_{cell} = 0.46\ V$
$Cr|Cr^{3+}||Co^{2+}|Co$

3. $Hg^{2+}(aq) + Cr(s) \rightarrow Hg(l) + Cr^{2+}(aq)$
$E^0_{cell} = 0.851\ V - (-0.913\ V)$
$E^0_{cell} = 1.764\ V$
$Cr|Cr^{2+}||Hg^{2+}|Hg$

4. $E^0_{cell} = (0.521\ V) - (-0.1375\ V)$
$E^0_{cell} = 0.659\ V$
$E^0_{cell} > 0$ spontaneous

5. $E^0_{cell} = (-0.1262\ V) - (-2.372\ V)$
$E^0_{cell} = 2.246\ V$
$E^0_{cell} > 0$ spontaneous

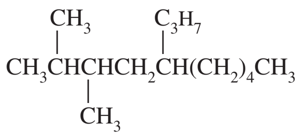
6. $E^0_{cell} =(0.920\ V) - (1.507\ V)$
$E^0_{cell} = –0.587\ V$
$E^0_{cell} < 0$ not spontaneous

7. $E^0_{cell} = (-0.28\ V) - 2.010\ V$
$E^0_{cell} = -2.29\ V$
$E^0_{cell} < 0$ not spontaneous

Chapter 22

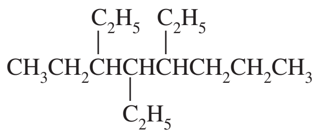
1. a. 2,4-dimethylhexane
   b. 2,4,7-trimethylnonane
   c. 2,2,4-trimethylpentane

2. a.



$$CH_3\overset{CH_3}{\overset{|}{C}}H\underset{\underset{CH_3}{|}}{C}HCH_2\overset{C_3H_7}{\overset{|}{C}}H(CH_2)_4CH_3$$

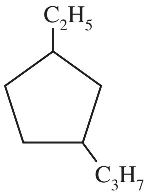
b.



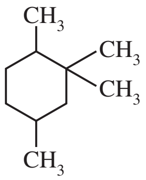
$$CH_3CH_2\overset{C_2H_5}{\overset{|}{C}}H\underset{\underset{C_2H_5}{|}}{C}H\overset{C_2H_5}{\overset{|}{C}}HCH_2CH_2CH_3$$

10. a. methylcyclopentane
   b. 2-ethyl-1,4-dimethylcyclohexane
   c. 1,3-diethylcyclobutane

11. a.



b.



18. a. 4-methyl-2-pentene
   b. 2,2,6-trimethyl-3-octene

19. $CH_2 = CHC = CHCH_3$

Chapter 23

1. 2,3-difluorobutane

2. 1-bromo-5-chloropentane

3. 1,3-dibromo-2-chlorobenzene

Chapter 24

No practice problems

CONTENTS

Chapter 25

6. $^{15}_{8}\mathrm{O} \rightarrow {}^{0}_{1}\beta + {}^{15}_{7}\mathrm{N}$

7. $^{231}_{90}\mathrm{Th} \rightarrow {}^{231}_{91}\mathrm{Pa} + {}^{0}_{-1}\beta$, beta decay

8. $^{97}_{40}\mathrm{Zr} \rightarrow {}^{0}_{-1}\beta + {}^{97}_{41}\mathrm{Nb}$

9. a. $^{142}_{61}\mathrm{Pm} + {}^{0}_{-1}\mathrm{e} \rightarrow {}^{142}_{60}\mathrm{Nd}$

b. $^{218}_{84}\mathrm{Po} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{214}_{82}\mathrm{Pb}$

c. $^{226}_{88}\mathrm{Ra} \rightarrow {}^{222}_{86}\mathrm{Rn} + {}^{4}_{2}\mathrm{He}$

15. $^{27}_{13}\mathrm{Al} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{24}_{11}\mathrm{Na} + {}^{4}_{2}\mathrm{He}$

16. $^{239}_{94}\mathrm{Pu} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{242}_{96}\mathrm{Cm} + {}^{1}_{0}\mathrm{n}$

17. amount remaining $= (10.0 \text{ mg})\left(\frac{1}{2}\right)^{n}$

For $n = 1$, amount remaining $= (10.0 \text{ mg})\left(\frac{1}{2}\right)^{1}$ $= 5.00$ mg

For $n = 2$, amount remaining $= (10.0 \text{ mg})\left(\frac{1}{2}\right)^{2}$ $= 2.50$ mg

For $n = 3$, amount remaining $= (10.0 \text{ mg})\left(\frac{1}{2}\right)^{3}$ $= 1.25$ mg

18. amount remaining $= 25.0$ mg

$= (\text{initial amount})\left(\frac{1}{2}\right)^{5}$

initial amount $= (25.0 \text{ mg})(2)^{5} = 8.00 \times 10^{2}$ mg

19. half-life $= 163.7\ \mu\text{s}$

$n = (818\ \mu\text{s}) \times \frac{1 \text{ half-life}}{163.7\ \mu\text{s}} = 5.00$ half-lives

amount remaining $= (1.0 \text{ g})\left(\frac{1}{2}\right)^{5.00} = 0.031$ g

Chapter 26

No practice problems

CONTENTS

APPENDIX E Try at Home Labs

Try at Home

From your Kitchen, Junk Drawer, or Yard

1 Testing Predictions

Real-World Question How can predictions be tested scientifically?

Possible Materials

- horoscope from previous week
- scissors
- transparent tape
- white paper
- liquid correction fluid

Procedure

1. Obtain a horoscope from last week and cut out the predictions for each sign. Do not cut out the zodiac signs or birth dates accompanying each prediction.
2. As you cut out a horoscope prediction, write the correct zodiac sign on the back of each prediction.
3. Develop a code for the predictions to allow you to identify them. For example, X11 could refer to the Leo prediction. Maintain a list of your codes during the experiment.
4. Scramble your predictions and tape them to a sheet of white paper. Write each prediction's code above it.
5. Ask 10 people to read all the predictions and ask each person to choose the one that best matched his or her life events from the previous week.

Conclude and Apply

1. Calculate the percentage of people who chose the correct sign.
2. Calculate the chances of a person randomly choosing his or her correct sign.
3. Identify the experimental error in your experiment.
4. Research other strictly controlled experiments that have tested the reliability of horoscopes or astrology and write a summary of your findings.

2 SI Measurement Around the Home

Real-World Question What are the SI measurements of common items or dimensions in your home?

Possible Materials

- measuring cup with SI units
- bathroom scale
- meterstick or metric tape measure
- metric ruler
- several empty cans or bottles

Procedure

1. Use a bathroom scale to weigh yourself, your science textbook, and a gallon of milk. Divide your measurements by 2.2 to calculate the mass of each object in kilograms.
2. Collect several empty containers such as bottles and cans. Use a measuring cup with SI units to measure the volume of each container. Accurately measure each container to the nearest milliliter.
3. Use a meterstick to measure the length, width, and height of your room. Accurately measure each dimension to the nearest millimeter and estimate each length to the nearest tenth of a millimeter.

Conclude and Apply

1. Convert your metric mass measurements from kilograms to grams.
2. Identify the number of significant figures for each of your volume measurements.
3. Calculate the area of your room in square meters.
4. Infer why you cannot comment on the accuracy or the precision of your answers.

3 Comparing Frozen Liquids

Real-World Question How do different kitchen liquids react when placed in a freezer?

Possible Materials

- five identical, narrow-necked plastic bottles or photographic film canisters
- large cutting board or cookie sheet
- water
- orange juice
- vinegar
- soft drink
- cooking oil
- freezer

Procedure

1. Obtain permission to use the freezer before beginning this activity.
2. Fill one of the clean, plastic containers with water. The water should come to the top brim of the container.
3. Fill the other four containers in the same way with the other four liquids.
4. Place the cutting board or cookie sheet in a freezer so that it is level and place the five containers on the board.
5. Leave the containers in the freezer overnight and observe the effect of the freezer's temperature on each liquid the following day.

Conclude and Apply

1. Describe the effect of the colder temperature on each liquid.
2. Infer why the water behaved as it did.
3. Infer why some liquids froze but others did not.

4 Comparing Atom Sizes

Real-World Question How do the sizes of different atoms and subatomic particles compare?

Possible Materials

- metric ruler
- meterstick
- white sheet of paper
- fine tipped black marker
- masking tape or transparent tape
- three plastic milk containers

Procedure

1. Using a black marker, draw a 0.1-mm-wide dot on one end of a white sheet of paper. This dot represents the diameter of an electron.
2. Measure a distance of 10 cm from the dot and draw a second dot. The distance between the two dots represents the diameter of a proton or a neutron.
3. Securely tape the paper to the top of a plastic milk container.
4. Measure a distance of 6.2 m from the plastic milk container and place a second plastic milk container. This distance represents the diameter of the smallest atom, a helium atom.
5. Measure a distance of 59.6 m from the first plastic milk container and place a third plastic milk container. This distance represents the diameter of the largest atom, a cesium atom.

Conclude and Apply

1. Research the length of a picometer.
2. Calculate the scale you used for this activity if the diameter of a proton equals one picometer.
3. Compare the size of an electron with a proton.
4. Considering the comparative sizes of protons and neutrons with the sizes of atoms, infer what makes up most of an atom.

CONTENTS

5 Observing Light's Wave Nature

Real-World Question How can you observe light traveling in waves?

Possible Materials

- two pencils
- two pens
- transparent tape
- candle
- candle holder
- matches

Procedure

1. Obtain permission before beginning this activity.
2. Tape two pencils together lengthwise so that only a 1-mm space separates them.
3. Place a candle in a candleholder. Go into a dark room, light the candle, and set it on a flat surface.
4. Hold the pencils about 25 cm from your eyes and look at the candle light through the slit between the pencils. Slowly squeeze the pencils together and apart and observe what the light coming through the slit looks like.
5. Experiment with viewing the candle light through the slits at different distances from your eyes.

Conclude and Apply

1. Describe the appearance of the light when you viewed it through the slit between the pencils.
2. Infer why the light appeared as it did.

6 Turning Up the Heat

Real-World Question What type of metal would be best for making cooking pots?

Possible Materials

- stove top or hotplate
- pan
- water
- 30-cm length of iron wire
- 30-cm length of copper wire
- 30-cm length of aluminum wire
- kitchen knife
- butter
- three small paperclips
- thermometer
- stopwatch or watch with second hand

Procedure

1. Obtain permission to use the stove or hotplate.
2. Create a data table to record your data.
3. Fill a pan with water. Cut three peanut-sized dabs of butter and insert a wire into each dab. Be certain each dab of butter is equal in size.
4. Insert a small paper clip into each dab of butter so that the clip hangs downward.
5. Place the wires in the water so that the paperclips are all hanging over the edge of the pot in the same direction.
6. Slowly heat the water on a stovetop or hotplate bringing it to boil.
7. Record the temperature at which the butter melts and the paperclip falls from each wire. Record the amount of time it takes for each paperclip to fall.

Conclude and Apply

1. Research and define the term "rate of conductivity."
2. Compare the rate of conductivity for the three elements.
3. Infer the relationship between the times you recorded and the rates of conductivity of the elements.
4. Infer which metal would be best suited for making cooking pots.

7 Amazing Aluminum

Real-World Question What properties of aluminum make it a common kitchen element?

Possible Materials

- aluminum foil (several sheets)
- iron nail
- glass
- water
- frying pan
- kitchen knife
- butter
- tablespoon
- oven mitt or hot pad
- hammer
- metric ruler
- stove top or hotplate
- plate

Procedure

1. Obtain permission to use the stove or hotplate before beginning this activity.
2. Roll up a piece of aluminum foil into a tight ball and drop it into a glass of water. Carefully drop an iron nail into the water. After a week, observe and compare any changes in the two metals.
3. Place a 10-cm × 10-cm square of aluminum foil in a frying pan, place the pan on a stove-top burner or hotplate, and turn the burner to a high setting. Drop a tablespoon of butter on the foil. Observe the butter for five minutes. Use an oven mitt to take the aluminum foil out of the pan and place it on a plate. After one minute, quickly touch the foil to test how hot it is.
4. On a workbench or other hard surface, hammer a 2-cm × 2-cm space on the edge of a sheet of wrinkled aluminum foil. Compare how easy it is to rip the hammered foil with a section of foil that was not hammered.

Conclude and Apply

1. Compare the appearance of the iron nail and aluminum foil after each was submerged in water for a week. What do you observe?
2. Infer why the hammered aluminum foil tore easier than the foil that was hammered.
3. Infer what properties make aluminum a desirable element for aluminum foil, pots, and pans.

8 Comparing Sport Drink Electrolytes

Real-World Question Which sport drink has the greatest amounts of electrolytes?

Possible Materials

- several bottles of different brand name sport drinks
- graph paper
- color pencils
- metric ruler

Procedure

1. Research the three major electrolytes needed for good health.
2. Create a data table to record the amount of electrolytes found in several brand name sport drinks.
3. Obtain several bottles of different sport drink brands and read the nutrition facts chart on the back of each bottle.
4. Compare the amounts of the three major electrolytes found in each sport drink brand and record the amounts in your data table. Be certain you compare electrolyte amounts for equal volumes.

Conclude and Apply

1. Create a circle graph or bar graph comparing the amounts of electrolytes found in the sport drinks you compared.
2. Compare the amounts of electrolytes found in the major brands of sport drinks.
3. Infer why a sport drink should not have sodium.

CONTENTS

9 Breaking Covalent Bonds

Real-World Question What liquids will break the covalent bonds of polystyrene?

Possible Materials

- polystyrene packing peanuts or polystyrene cups
- 500-mL container
- acetone or nail polish remover
- shallow dish
- rubbing alcohol
- water
- cooking oil
- measuring cup

Procedure

1. Pour 200 mL of water into a 500-mL container.
2. Drop a polystyrene packing peanut into the water and observe how the polystyrene and water react.
3. Thoroughly wash out the glass and repeat steps 1 and 2 using cooking oil, rubbing alcohol, and acetone or nail polish remover.
4. Drop several packing peanuts into any of the liquids that cause a chemical reaction with the polystyrene peanuts and observe what happens to them.

Conclude and Apply

1. Describe the reaction between the polystyrene peanuts and each of the four liquids.
2. Infer why the polystyrene reacted as it did with each of the liquids.

10 Preventing a Chemical Reaction

Real-World Question How can the chemical reaction that turns apples brown be prevented?

Possible Materials

- seven identical glasses
- measuring cup
- bottled water (large bottle)
- apple
- 100-mg vitamin C tablets
- wax paper
- rolling pin
- paper towels
- kitchen knife
- masking tape
- permanent black marker

Procedure

1. Measure and pour 200 mL of water into each of the glasses.
2. Label glass #1 *no vitamin C,* glass #2 *100 mg,* glass #3 *200 mg,* glass #4 *500 mg,* glass #5 *1 000 mg,* glass #6 *2 000 mg,* and glass #7 *3 000 mg.*
3. Place a 100-mg vitamin C tablet between two sheets of wax paper and use a rolling pin to grind the tablet into powder.
4. Place the powder into glass #2 and stir the mixture vigorously.
5. Repeat steps 3 and 4 for glasses #3, #4, #5, #6, and #7 using the appropriate masses of vitamin C.
6. Cut seven equal-sized wedges of apple and immediately place an apple wedge into each glass. Cut wedges large enough to float with the skin facing upward in the mixture.
7. After 5 minutes, lay the wedges on paper towels in front of the beakers in which they were soaking. Observe the apples every 5 minutes for 45 minutes.

Conclude and Apply

1. Describe the results of your experiment.
2. Research why apple tissues turn brown in the presence of air.
3. Infer why vitamin C prevents apples from turning brown.

CONTENTS

11 Calculating Carbon Percentages

Real-World Question What percentages of common household substances are made of the element carbon?

Possible Materials

- nail polish remover
- vitamin C tablet
- barbeque charcoal
- mothballs
- table sugar
- chemical handbook

Procedure

1. Research the chemical formulas for the following common household items: nail polish remover (acetone), vitamin C (ascorbic acid), barbeque charcoal, mothballs (naphthalene), and table sugar (sucrose).
2. Calculate the percent composition of the element carbon in the molecules of each substance. Use the formula method outlined in the textbook to calculate your answers.

Conclude and Apply

1. List the percentage of carbon that makes up the molecules of each substance.
2. Calculate the mass of carbon in a 200-g sample of table sugar.

12 Baking Soda Stoichiometry

Real-World Question How many moles of baking soda will react with 1 mL of vinegar?

Possible Materials

- vinegar
- sodium bicarbonate (baking soda)
- large bowl
- measuring cup with SI units
- spoon
- kitchen scale

Procedure

1. Measure 100 mL of vinegar and pour it into a bowl.
2. Measure 10 g of sodium bicarbonate.
3. Gradually add sodium bicarbonate to the vinegar and observe the reaction that occurs.
4. Continue adding small amounts of the baking soda to the vinegar until there is no longer a reaction.
5. Calculate the mass of sodium bicarbonate that reacted with the 100 mL of vinegar.

Conclude and Apply

1. Research the chemical formula of sodium bicarbonate (baking soda) and calculate the mass of one mole of the substance.
2. Describe the reaction that occurs when sodium bicarbonate and vinegar are mixed.
3. Calculate the number of moles of sodium bicarbonate that will completely react with 100 mL of vinegar.

CONTENTS

13 Viscosity Race

Real-World Question How do the viscosity of different kitchen liquids compare?

Possible Materials

- stopwatch or watch with second hand
- five identical, tall, clear glasses
- five marbles (identical size)
- water
- maple syrup
- corn syrup
- apple juice
- honey
- measuring cup
- metric ruler

Procedure

1. Fill five identical glasses with equal volumes of the five different liquids.
2. Measure the height of each liquid to the nearest millimeter.
3. Create a data table to record the distance (liquid height), time, and speed for each marble traveling through each liquid.
4. Hold a marble just above the water, drop it so that it falls through the water in the center of the glass, and time how long it takes for the marble to reach the bottom of the glass. You may want to have a friend or family member help with this part.
5. Repeat step 4 for the other four liquids.
6. Record your measurements in your data table and calculate the speed of the marble through each liquid.

Conclude and Apply

1. List the liquids you tested in order of increasing viscosity.
2. Identify possible experimental errors in your experiment.
3. Infer the relationship between marble speed and liquid viscosity.

14 Under Pressure

Real-World Question Why does the compression of gases affect the density of an object filled with air?

Possible Materials

- 2-L clear, plastic bottle with cap (with label removed)
- water
- small dropper (with glass cylinder if possible)

Procedure

1. Perform this activity at the kitchen sink.
2. Remove the label from a 2-L soda bottle and fill the bottle with water to the brim.
3. Carefully place a small dropper into the bottle without spilling any water so that the dropper floats at the top of the bottle.
4. Replace any water that was lost in the bottle.
5. Screw the bottle cap on tightly and squeeze the sides of the bottle.

Conclude and Apply

1. Describe what you observed when you squeezed the sides of the bottle.
2. Identify the law demonstrated by this lab.
3. Infer why the dropper behaved the way it did.

CONTENTS

15 Identifying Colloids

Real-World Question Which household mixtures are solutions and which are colloids?

Possible Materials

- four clear glasses
- flashlight (narrow beam)
- dropper
- spoon
- stirring rod
- iron nail
- bottled water (2 L)
- milk
- cornstarch
- salt

Procedure

1. Fill the first glass with bottled water and place an iron nail in the water. Allow the nail to sit in the water overnight.
2. Fill the other three glasses with bottled water.
3. Add a drop of milk to the second glass and stir it vigorously so that the mixture appears clear.
4. Add a small amount of salt to the third glass and an equal amount of cornstarch to the fourth glass. Stir the mixtures until both appear clear.
5. Darken the room and shine the light beam from a flashlight into each mixture. Be certain not to position the beam so that it reflects into your eyes.

Conclude and Apply

1. Describe the results of your experiment.
2. Identify which mixtures are solutions and which are colloids.

16 Observing Entropy

Real-World Question How quickly do common household liquids enter into a state of entropy?

Possible Materials

- seven identical, clear-glass containers
- stopwatch or watch with second hand
- water
- corn syrup
- rubbing alcohol
- clear soft drink
- vinegar
- cooking oil
- milk
- food coloring
- measuring cup with SI units

Procedure

1. Fill identical glass containers with equal volumes of seven different liquids: water, corn syrup, rubbing alcohol, clear soft drink, vinegar, cooking oil, and milk. Label each container.
2. Create a data table to record your observations and measurements about how quickly food dye will spread throughout each liquid to reach a state of total entropy between the two substances.
3. Place one drop of food coloring into the first container while a friend or family member simultaneously starts a stopwatch.
4. Observe how the food coloring behaves in each liquid. Time how quickly the coloring and each liquid reach total entropy.
5. Record your data in your data table.
6. Repeat with the remaining liquids.

Conclude and Apply

1. List the liquids in order of decreasing rates of entropy. List the liquid that reached a total state of entropy most quickly first and so on.
2. Infer the relationship between the rate at which a liquid and the dye achieved a state of total entropy and the time measurement from your data table.
3. Infer why the entropy rates for the different liquids varied.

17 Surface Area and Cooking Eggs

Real-World Question How does the amount of surface area affect the chemical reaction of an egg cooking?

Possible Materials

- small stainless steel frying pan
- medium stainless steel frying pan
- 1/2-cup stainless steel measuring cup
- two medium eggs (equal size)
- cooking oil
- spatula
- measuring cup
- stove top or hotplate
- oven mitt or pot holder
- metric ruler
- stopwatch or watch with second hand

Procedure

1. Obtain permission to use the stove.
2. Calculate the area of the cooking surface for each of the three different containers.
3. Using a ratio of 1 mL of cooking oil for every 10 cm^2 of cooking surface, measure the appropriate volume of cooking oil for the medium frying pan and pour the oil into the pan.
4. Turn a stove top burner on medium heat and wait 5 minutes.
5. Crack an egg and empty its contents into the center of the frying pan. Use a spatula to break open the yolk of the egg.
6. Measure the amount of time it takes for the egg to cook completely.
7. Turn off the burner and wait 5 minutes.
8. Repeat steps 2–6 using the small frying pan.

Conclude and Apply

1. Identify the variables and controls of your experiment.
2. Identify possible procedural errors that might have occurred in your experiment.
3. Describe the results of your experiment.
4. Infer the relationship between the cooking surface area and the speed of the chemical reaction happening to the egg. Explain why this relationship exists.

18 Cornstarch Solubility

Real-World Question How does heat affect the solubility equilibrium of a water and cornstarch mixture?

Possible Materials

- cornstarch
- water
- pan
- oven mitt or hot pad
- tablespoon
- kitchen scale
- stove top or hotplate

Procedure

1. Obtain permission to use the stove or hotplate.
2. Measure 300 mL of water and pour the water into a pan.
3. Measure 2-3 tablespoons of cornstarch and empty the cornstarch into the pan of water.
4. Stir the cornstarch and water vigorously and observe the reaction that occurs.
5. Place the pan on a heat source and raise the temperature of the mixture until the water starts to boil. Observe what occurs.

Conclude and Apply

1. Describe what occurred when you initially added the cornstarch to the water.
2. Describe what occurred when you raised the temperature of the mixture to the boiling point.
3. Infer the effect of heat on the solubility equilibrium of water and cornstarch.

19 Testing for Ammonia

Real-World Question What substances elevate ammonia levels in natural waterways?

Possible Materials

- four glass jars with lids (spaghetti jars work well)
- measuring cup
- raw chicken (6 ounces)
- water
- ammonia test kit
- scale
- kitchen knife
- masking tape
- black marker

Procedure

1. Use a kitchen scale to measure 28-g (1-ounce), 56-g (2-ounce), and 84-g (3-ounce) pieces of raw chicken.
2. Fill jars with 500 mL of water.
3. Do not put any chicken into the first jar. Place 28 g (1 ounce) of raw chicken into the second jar, 56 g (2 ounces) into the third jar, and 84 g (3 ounces) in the fourth jar.
4. Label your jars.
5. Create a data table to record your data.
6. Measure the amount of ammonia in each water sample every day for five days. Also observe the clarity of each sample.

Conclude and Apply

1. Identify possible procedural errors in your experiment.
2. Summarize your results.
3. Infer the common causes for elevated ammonia levels in natural waterways.

20 Kitchen Oxidation

Real-World Question How do the oxidation rates of a nail in various kitchen liquids compare?

Possible Materials

- seven identical glasses or beakers
- water
- vinegar
- dark soft drink
- orange juice
- milk
- cooking oil
- rubbing alcohol
- seven iron nails
- measuring cup
- large tweezers
- masking tape
- black marker

Procedure

1. Create a data table to record your observations about the oxidation rates of a nail in the seven liquids.
2. Use masking tape and a marker to label the liquids in your seven glasses.
3. Pour 200 mL of water, vinegar, dark soft drink, orange juice, milk, cooking oil, and rubbing alcohol into seven separate glasses.
4. Carefully place an iron nail into each container.
5. Observe the nail and the liquid in each container every day for a week. Record all your observations in your data table.

Conclude and Apply

1. Summarize your observations about the oxidation rates of a nail in the seven different liquids.
2. Infer why the oxidation reactions in water and cooking oil were different.

CONTENTS

21 Old Pennies

Real-World Question How can you make an old penny look like new?

Possible Materials

- 15 dull, dirty pennies
- vinegar
- table salt
- measuring cup with SI units
- teaspoon
- shallow bowl (not metal, plastic, or polystyrene)
- steel nail
- sandpaper
- paper towels

Procedure

1. Measure one teaspoon of salt into 60 mL of vinegar in the bowl. Stir until the salt dissolves.
2. Drop the pennies into the salt solution. Stir and observe.
3. After 5 minutes, remove one penny from the bowl. Rinse it in running water. Place it on the paper towel to dry.
4. Clean the nail with sandpaper. Place it into the salt solution with the pennies. Do not let the nail touch the pennies. What do you observe?
5. After 24–48 hours, remove the nail from the solution. Rinse and observe.

Conclude and Apply

1. Compare and contrast the pennies before and after they were placed in the salt solution. Why did the pennies look dirty? How did the salt solution clean the pennies?
2. Compare and contrast the nail before and after it was placed in the salt solution. Infer what is on the nail.
3. What oxidation-reduction reaction do you think occurred?

22 Comparing Water and a Hydrocarbon

Real-World Question How do the properties of water and a hydrocarbon compare?

Possible Materials

- water
- food coloring
- vegetable oil
- measuring cup
- three glasses
- stopwatch or watch with second hand
- two marbles
- stirring rod
- spoon
- kitchen scale
- metric ruler

Procedure

1. Create a data table for comparing the physical properties of water and cooking oil.
2. Compare the color, feel, and odor of each liquid.
3. Measure the masses of equal volumes of each liquid and calculate the density of water and cooking oil. Mix the water and oil together and observe the behavior of the liquids.
4. Pour 100 mL of water into a glass and 100 mL of cooking oil into a second glass. Measure the time it takes for a marble to pass through each liquid and compare the viscosities of the liquids.
5. Squeeze a drop of food coloring into each glass and observe the behavior of the coloring in the two liquids.

Conclude and Apply

1. Summarize your comparisons of water and the cooking oil.
2. Infer why the food coloring behaved the way it did in each liquid.
3. Infer why water and oil are immiscible.

CONTENTS

23

Modeling Basic Organic Compounds

Real-World Question What do the molecules of different organic compounds and their functional groups look like?

Possible Materials

- toothpicks
- gumdrops (clear, yellow, green, red, orange, blue, and purple in color)
- marshmallows

Procedure

1. Study the basic types of organic compounds in Table 23-1 on page 738 in the textbook.
2. Use the gumdrops, marshmallows, and toothpicks to create molecule models of the general formula for each of the nine basic types of organic compounds. Use marshmallows to represent R groups (carbon chains or rings). Use the green gumdrops to represent fluorine atoms, yellow for chlorine atoms, red for bromine atoms, blue for oxygen atoms, orange for hydrogen atoms, and purple for nitrogen atoms. Clear gumdrops will represent carbon atoms. Use orange gumdrops (hydrogen atoms) in place of the asterisks.
3. Be certain to construct three different halocarbon models.

Conclude and Apply

1. Explain how you represented single and double bonds in your models.
2. Explain the effect of a functional group on a carbon chain or ring.

24

Modeling Sugars

Real-World Question What do sugar molecules look like?

Possible Materials

- gumdrops (three different colors)
- toothpicks

Procedure

1. Using blue gumdrops to represent oxygen atoms, red gumdrops to represent hydrogen atoms, and green gumdrops to represent carbon atoms, construct a model of a glucose molecule from the diagram on page 781. Use toothpicks to represent the bonds between the atoms.
2. Use gumdrops and toothpicks to construct a model of a fructose molecule from the diagram on page 781.
3. Use gumdrops and toothpicks to construct a model of a sucrose molecule from the diagram on page 782.

Conclude and Apply

1. Research common foods containing monosaccrides such as glucose and fructose.
2. Research common foods containing the disaccride sucrose.
3. Infer why it is preferable for an athlete to eat an orange before a game instead of a candy bar.

Try at Home Labs

CONTENTS

25 Modeling Radiation Penetration

Real-World Question How can you model the penetration power of different forms of radiation?

Possible Materials

- cotton swab
- dull pencil
- sheet of tissue paper
- aluminum foil

Procedure

1. Have a friend or family member hold up a sheet of tissue paper by the edges so that the flat side of the paper is facing you.
2. Carefully use a cotton swab to try to puncture a hole in the center of the tissue paper without ripping the sheet in half or pulling it out of the hands of your friend or family member. Next, try using a dull pencil to puncture a hole in the center of the paper.
3. Fold a sheet of aluminum foil in half. The foil sheet should be about the size of a sheet of paper. Have a friend or family member hold up the foil sheet by the edges so that the flat side of the foil is facing you.
4. Using the dull pencil, carefully try to puncture a hole in the center of the foil without ripping the sheet in half or pulling it out of the hands of your friend or family member.

Conclude and Apply

1. Infer what type of radiation the cotton swab and dull pencil modeled.
2. Infer how you could model the penetration power of gamma radiation.
3. Research the human health effects of gamma radiation exposure.

26 Modeling Ozone Depletion

Real-World Question What does the destruction of an ozone molecule look like?

Possible Materials

- toothpicks
- gumdrops (green, yellow, red, and purple)
- three white sheets of paper
- black marker

Procedure

1. Draw a black arrow on each of the sheets of white paper. Arrange the arrows (facing right) one above the other on a flat surface.
2. On page 845, study the three equations that describe the photodissociation of a CFC molecule, destruction of an ozone molecule, and the regeneration of a free chlorine atom.
3. Create models of all the atoms and molecules involved in these three reactions using green gumdrops to represent carbon atoms, yellow gumdrops to represent fluorine atoms, red gumdrops to represent chlorine atoms, and purple gumdrops to represent oxygen atoms.
4. Arrange your models to represent the three reactions involved in ozone depletion.

Conclude and Apply

1. Infer from your models why small amounts of CFCs can deplete large volumes of ozone gas.
2. Infer why the replacement of CFCs with HFCs helps protects the ozone layer.

CONTENTS

Glossary/Glosario

Chemistry Online

A multilingual science glossary at chemistrymc.com includes Arabic, Bengali, Chinese, English, Haitian Creole, Hmong, Korean, Portuguese, Russian, Tagalog, Urdu, and Vietnamese.

A

accuracy (p. 36) Refers to how close a measured value is to an accepted value.	**accuracy/exactitud** (pág. 36) Se refiere a la cercanía con que se encuentra un valor medido de un valor aceptado.
acid-base indicator (p. 619) A chemical dye whose color is affected by acidic and basic solutions.	**acid-base indicator/indicador ácido-base** (pág. 619) Tinta química cuyo color es afectado por soluciones ácidas y básicas.
acid ionization constant (p. 605) The value of the equilibrium constant expression for the ionization of a weak acid.	**acid ionization constant/constante ácida de ionización** (pág. 605) Valor de la expresión de la constante de equilibrio para la ionización de un ácido débil.
actinide series (p. 197) In the periodic table, the f-block elements from period 7 that follow the element actinium.	**actinide series/serie de actínidos** (pág. 197) En la tabla periódica, los elementos del bloque F del período 7 que van después del elemento actinio.
activated complex (p. 532) A short-lived, unstable arrangement of atoms that may break apart and re-form the reactants or may form products; also sometimes referred to as the transition state.	**activated complex/complejo activado** (pág. 532) Un arreglo efímero e inestable de átomos que pueden romper y reagrupar reactantes o puede formar productos; a veces también se le llama estado de transición.
activation energy (p. 533) The minimum amount of energy required by reacting particles in order to form the activated complex and lead to a reaction.	**activation energy/energía de activación** (pág. 533) La cantidad mínima de energía requerida por partículas reaccionantes, para formar el complejo activado y conducir a una reacción.
active site (p. 778) The pocket or crevice to which a substrate binds in an enzyme-catalyzed reaction.	**active site/sitio activo** (pág. 778) Abolsamiento o ranura a la que se une un sustrato en una reacción catalizada por enzimas.
actual yield (p. 370) The amount of product actually produced when a chemical reaction is carried out in an experiment.	**actual yield/rendimiento real** (pág. 370) Cantidad del producto realmente generado cuando se lleva a cabo una reacción química en un experimento.
addition polymerization (p. 762) Occurs when all the atoms present in the monomers are retained in the polymer product.	**addition polymerization/polimerización de adición** (pág. 762) Ocurre cuando todos los átomos presentes en los monómeros son retenidos en el producto polimérico.
addition reaction (p. 755) An organic reaction that occurs when other atoms bond to each of two atoms bonded by double or triple covalent bonds.	**addition reaction/reacción de adición** (pág. 755) Reacción orgánica que ocurre cuando otros átomos se unen a cada uno de los dos átomos unidos por enlaces covalentes dobles o triples.
alcohol (p. 743) An organic compound in which a hydroxyl group replaces a hydrogen atom of a hydrocarbon.	**alcohol/alcohol** (pág. 743) Compuesto orgánico en que un grupo hidroxilo reemplaza un átomo de hidrógeno de un hidrocarburo.
aldehyde (p. 747) An organic compound containing the structure in which a carbonyl group at the end of a carbon chain is bonded to a carbon atom on one side and a hydrogen atom on the other side.	**aldehyde/aldehido** (pág. 747) Compuesto orgánico en el cual un grupo carbonilo al final de una cadena de carbono está unido a un átomo de carbono por un lado y a un átomo de hidrógeno por el otro.
aliphatic compounds (p. 723) Nonaromatic hydrocarbons, such as the alkanes, alkenes, and alkynes.	**aliphatic compounds/compuestos alifáticos** (pág. 723) Hidrocarburos no aromáticos, como los alcanos, los alquenos y los alquinos.
alkali metals (p. 155) Group 1A elements, except for hydrogen, that are on the left side of the modern periodic table.	**alkali metals/metales alcalinos** (pág. 155) Elementos del Grupo 1A, exceptuando el hidrógeno, que se ubican en el lado izquierdo de la tabla periódica moderna.
alkaline earth metals (p. 155) Group 2A elements in the modern periodic table.	**alkaline earth metals/metales alcalinotérreos** (pág. 155) Elementos del Grupo 2A en la tabla periódica moderna.
alkane (p. 699) A saturated hydrocarbon with only single, nonpolar bonds between atoms.	**alkane/alcano** (pág. 699) Hidrocarburo saturado con sólo enlaces sencillos y no polares entre los átomos.
alkene (p. 711) An unsaturated hydrocarbon with one or more double covalent bonds between carbon atoms in a chain.	**alkene/alqueno** (pág. 711) Un hidrocarburo insaturado con uno o más enlaces dobles entre átomos de carbono de una cadena.
alkyl halide (p. 738) An organic compound that contains one or more halogen atoms (F, Cl, Br, or I) covalently bonded to an aliphatic carbon atom.	**alkyl halide/alquilhaluro** (pág. 738) Compuesto orgánico que contiene uno o más átomos de halógeno (F, Cl, Br o I) unidos covalentemente a un átomo de carbono alifático.
alkyne (p. 714) An unsaturated hydrocarbon with one or more triple bonds between carbon atoms in a chain.	**alkyne/alquino** (pág. 714) Hidrocarburo insaturado con uno o más enlaces triples entre átomos de carbono en una cadena.
allotropes (p. 188) Forms of an element with different structures and properties when they are in the same state—solid, liquid, or gas.	**allotropes/alótropos** (pág. 188)) Formas de un elemento con estructuras y propiedades diferentes cuando están en el mismo estado: sólido, líquido o gaseoso.
alloy (p. 230) A mixture of elements that has metallic properties.	**alloy/aleación** (pág. 230) Mezcla de elementos que posee propiedades metálica.

alpha particle (p. 106) A particle with two protons and two neutrons, with a 2+ charge; is equivalent to a helium-4 nucleus, can be represented as α, and is emitted during radioactive decay.

alpha radiation (p. 106) Radiation that is made up of alpha particles; is deflected toward a negatively charged plate when radiation from a radioactive source is directed between two electrically charged plates.

amide (p. 752) An organic compound in which the —OH group of a carboxylic acid is replaced by a nitrogen atom bonded to other atoms.

amines (p. 745) Organic compounds that contain nitrogen atoms bonded to carbon atoms in aliphatic chains or aromatic rings and have the general formula RNH_2.

amino acid (p. 776) An organic molecule that has both an amino group (—NH2) and a carboxyl group (—COOH).

amorphous solid (p. 403) A solid in which particles are not arranged in a regular, repeating pattern that often is formed when molten material cools too quickly to form crystals.

amphoteric (p. 599) Describes water and other substances that can act as both acids and bases.

amplitude (p. 119) The height of a wave from the origin to a crest, or from the origin to a trough.

anabolism (p. 792) Refers to the metabolic reactions through which cells use energy and small building blocks to build large, complex molecules needed to carry out cell functions and for cell structures.

anion (p. 214) An ion that has a negative charge; forms when valence electrons are added to the outer energy level, giving the ion a stable electron configuration.

anode (p. 665) In an electrochemical cell, the electrode where oxidation takes place.

applied research (p. 14) A type of scientific investigation that is undertaken to solve a specific problem.

aqueous solution (p. 292) A solution in which the solvent is water.

aromatic compounds (p. 723) Organic compounds that contain one or more benzene rings as part of their molecular structure.

Arrhenius model (p. 597) A model of acids and bases; states that an acid is a substance that contains hydrogen and ionizes to produce hydrogen ions in aqueous solution and a base is a substance that contains a hydroxide group and dissociates to produce a hydroxide ion in aqueous solution.

aryl halide (p. 739) An organic compound that contains a halogen atom bonded to a benzene ring or another aromatic group.

asymmetric carbon (p. 719) A carbon atom that has four different atoms or groups of atoms attached to it; occurs in chiral compounds.

atmosphere (p. 390) The unit that is often used to report air pressure; (p. 841) the protective, largely gaseous envelope around Earth, hundreds of kilometers thick, that is divided into the troposphere, stratosphere, mesosphere, thermosphere, and exosphere.

atom (p. 90) The smallest particle of an element that retains all the properties of that element; is electrically neutral, spherically shaped, and composed of electrons, protons, and neutrons.

atomic emission spectrum (p. 125) A set of frequencies of electromagnetic waves given off by atoms of an element; consists of a series of fine lines of individual colors.

alpha particle/partícula alfa (pág. 106) Partícula con dos protones y dos neutrones, con una carga de 2+ que equivale a un núcleo de helio 4; se puede representar como α y se emite durante la descomposición radiactiva.

alpha radiation/radiación alfa (pág. 106) Radiación compuesta de partículas alfa; es desviada hacia una placa cargada negativamente cuando la radiación proveniente de una fuente radiactiva se dirige entre dos placas cargadas eléctricamente.

amide/amida (pág. 752) Compuesto orgánico en que el grupo —OH de un ácido carboxílico es reemplazado por un átomo de nitrógeno unido con otros átomos.

amines/aminas (pág. 745) Compuestos orgánicos que contienen átomos de nitrógeno unidos a átomos de carbono en cadenas de alifáticas o anillos aromáticos y su fórmula general es RNH_2.

amino acid/aminoácido (pág. 776) Molécula orgánica que tiene un grupo amino (—NH2) y un grupo carboxilo (—COOH).

amorphous solid/sólido amorfo (pág. 403) Sólido en el cuál las partículas no están ordenadas en un patrón regular repetitivo; a menudo se forma cuando el material fundido se enfría demasiado rápido para formar cristales.

amphoteric/anfotérico (pág. 599) Término que describe al agua y a otras sustancias que pueden actuar como ácidos y como bases.

amplitude/amplitud (pág. 119) Altura de una onda desde el origen hasta una cresta o desde el origen hasta un seno.

anabolism/anabolismo (pág. 792) Se refiere a las reacciones metabólicas a través de las cuales las células usan energía y bloques constitutivos pequeños para construir moléculas grandes y complejas que son necesarias para llevar a cabo las funciones celulares y para construir estructuras celulares.

anion/anión (pág. 214) Ion que tiene una carga negativa; se forma cuando los electrones de valencia se incorporan al nivel de energía externo, dando el ion una configuración electrónica estable.

anode/ánodo (pág. 665) En una celda electroquímica, el electrodo donde se lleva a cabo la oxidación.

applied research/investigación aplicada (pág. 14) Tipo de investigación científica que se lleva a cabo para resolver un problema concreto.

aqueous solution/solución acuosa (pág. 292) Solución en la que el disolvente es agua.

aromatic compounds/compuestos aromáticos (pág. 723) Compuestos orgánicos que contienen uno o más anillos de benceno como parte de su estructura molecular.

Arrhenius model/modelo de Arrhenius (pág. 597) Modelo de ácidos y bases; establece que un ácido es una sustancia que contiene hidrógeno y se ioniza para producir iones hidrógeno en solución acuosa y una base es una sustancia que contiene un grupo hidróxido y se disocia para producir un ion hidróxido en solución acuosa.

aryl halide/haluro de arilo (pág. 739) Compuesto orgánico que contiene un átomo de halógeno unido a un anillo de benceno u otro grupo aromático.

asymmetric carbon/carbono asimétrico (pág. 719) Átomo de carbono que tiene cuatro átomos o grupos de átomos diferentes unidos a él; se encuentra en compuestos quirales.

atmosphere/atmósfera (pág. 390) Unidad que se emplea a menudo para indicar la presión del aire; (pág. 841) la gran cubierta gaseosa protectora que rodea a la Tierra de centenares de kilómetros de ancho y que se divide en troposfera, estratosfera, mesosfera, termosfera y exosfera.

atom/átomo (pág. 90) La partícula más pequeña de un elemento que retiene todas las propiedades de ese elemento; es eléctricamente neutro, de forma esférica y compuesto de electrones, protones y neutrones.

atomic emission spectrum/espectro de emisión atómica (pág. 125) Conjunto de frecuencias de ondas electromagnéticas emitida por los átomos de un elemento; consta de una serie de líneas finas de colores individuales.

atomic mass (p. 102) The weighted average mass of the isotopes of that element.	**atomic mass/masa atómica** (pág. 102) La masa promedio ponderada de los isótopos de ese elemento.
atomic mass unit (amu) (p. 102) One-twelfth the mass of a carbon-12 atom.	**atomic mass unit (amu)/unidad de masa atómica(uma)** (pág. 102)) Un doceavo de la masa de un átomo de carbono 12.
atomic number (p. 98) The number of protons in an atom.	**atomic number/número atómico** (pág. 98) El número de protones en un átomo.
atomic orbital (p. 132) A three-dimensional region around the nucleus of an atom that describes an electron's probable location.	**atomic orbital/orbital atómico** (pág. 132) Región tridimensional alrededor del núcleo de un átomo que describe la ubicación probable del electrón.
ATP (p. 792) Adenosine triphosphate—a nucleotide that functions as the universal energy-storage molecule in living cells.	**ATP/ATP** (pág. 792) Trifosfato de adenosina, un nucleótido que funciona como la molécula universal de almacenamiento de energía en las células vivas.
aufbau principle (p. 135) States that each electron occupies the lowest energy orbital available.	**aufbau principle/principio de Aufbau** (pág. 135) Establece que cada electrón ocupa el orbital de energía más bajo disponible.
Avogadro's number (p. 310) The number 6.022 1367 × 10^{23}, which is the number of representative particles in a mole, and can be rounded to three significant digits: 6.02 × 10^{23}.	**Avogadro's number/número de Avogadro** (pág. 310) El número 6.022 × 10^{23}, que es el número de partículas representativas en un mol, el cual se puede redondear a tres dígitos significativos: 6.02 × 10^{23}.
Avogadro's principle (p. 430) States that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.	**Avogadro's principle/principio de Avogadro** (pág. 430) Establece que volúmenes iguales de gases a la misma temperatura y presión contienen igual número de partículas.

B

band of stability (p. 811) The region on a graph within which all stable nuclei are found when plotting the number of neutrons versus the number of protons for all stable nuclei.	**band of stability/banda de la estabilidad** (pág. 811) Región de la gráfica dentro de la cual se encuentran todos los núcleos estables cuando se grafica el número de neutrones contra el número de protones para todos los núcleos estables.
barometer (p. 389) An instrument that is used to measure atmospheric pressure.	**barometer/barómetro** (pág. 389) Instrumento que se utiliza para medir la presión atmosférica.
base ionization constant (p. 606) The value of the equilibrium constant expression for the ionization of a base.	**base ionization constant/constante de ionización base** (pág. 606) El valor de la expresión de la constante de equilibrio para la ionización de una base.
base unit (p. 26) A defined unit in a system of measurement that is based on an object or event in the physical world and is independent of other units.	**base unit/unidad base** (pág. 26) Unidad definida en un sistema de la medida que se basa en un objeto o el acontecimiento en el mundo físico y es independiente de otras unidades.
battery (p. 672) One or more electrochemical cells in a single package that generates electrical current.	**battery/batería** (pág. 672) Una o más celdas electroquímicas en un solo paquete que genera corriente eléctrica.
beta particle (p. 107) A high-speed electron with a 1− charge that is emitted during radioactive decay.	**beta particle/partícula de beta** (pág. 107) Electrón de alta velocidad con una carga 1− que se emite durante la desintegración radiactiva.
beta radiation (p. 107) Radiation that is made up of beta particles; is deflected toward a positively charged plate when radiation from a radioactive source is directed between two electrically charged plates.	**beta radiation/radiación beta** (pág. 107) Radiación compuesta de partículas beta; es desviada hacia un placa positivamente cargada cuando la radiación de una fuente radiactiva es dirigida entre dos placas cargadas eléctricamente.
boiling point (p. 406) The temperature at which a liquid's vapor pressure is equal to the external or atmospheric pressure.	**boiling point/punto de ebullición** (pág. 406) Temperatura a la cual la presión de vapor de un líquido es igual a la presión externa o atmosférica.
boiling point elevation (p. 472) The temperature difference between a solution's boiling point and a pure solvent's boiling point.	**boiling point elevation/elevación del punto de ebullición** (pág. 472) Diferencia de temperatura entre el punto de ebullición de una solución y el de un disolvente puro.
Boyle's law (p. 421) States that the volume of a given amount of gas held at a constant temperature varies inversely with the pressure.	**Boyle's law/Ley de Boyle** (pág. 421) Establece que el volumen de una cantidad dada de gas a temperatura constante, varía inversamente con la presión.
breeder reactor (p. 825) A nuclear reactor that is able to produce more fuel than it uses.	**breeder reactor/reactor regenerador** (pág. 825) Reactor nuclear que es capaz de producir más combustible de lo que utiliza.
Brønsted-Lowry model (p. 598) A model of acids and bases in which an acid is a hydrogen-ion donor and a base is a hydrogen-ion acceptor.	**Brønsted-Lowry model/modelo de Brønsted-Lowry** (pág. 598) Modelo de ácidos y bases en que un ácido es un donador de ion hidrógeno y una base es un aceptor de ion hidrógeno.
Brownian motion (p. 478) The jerky, random, rapid movements of colloid particles that results from collisions of particles of the dispersion medium with the dispersed particles.	**Brownian motion/movimiento browniano** (pág. 478) Movimientos erráticos, aleatorios y rápidos de las partículas coloidales que resultan de choques de partículas del medio de dispersión con las partículas dispersadas.
buffer (p. 623) A solution that resists changes in pH when limited amounts of acid or base are added.	**buffer/amortiguador** (pág. 623) Solución que resiste los cambios de pH cuando se agregan cantidades moderadas del ácido o la base.

CONTENTS

buffer capacity (p. 623) The amount of acid or base a buffer solution can absorb without a significant change in pH.	**buffer capacity/capacidad amortiguadora** (pág. 623) Cantidad de ácido o base que una solución amortiguadora puede absorber sin un cambio significativo en el pH.

C

calorie (p. 491) The amount of heat required to raise the temperature of one gram of pure water by one degree Celsius.	**calorie/caloría** (pág. 491) Cantidad de calor que se requiere para elevar, por un grado centígrado la temperatura de un gramo de agua pura.
calorimeter (p. 496) An insulated device that is used to measure the amount of heat released or absorbed during a physical or chemical process.	**calorimeter/calorímetro** (pág. 496) Dispositivo aislado que se utiliza para medir la cantidad de calor liberado o absorbido durante un proceso físico o químico.
carbohydrates (p. 781) Compounds that contain multiple hydroxyl groups, plus an aldehyde or a ketone functional group, and function in living things to provide immediate and stored energy.	**carbohydrates/carbohidratos** (pág. 781) Compuestos que contienen múltiples grupos hidroxilo, más un grupo funcional aldehido o cetona y cuya función en los seres vivos es proporcionar energía inmediata y almacenada.
carbonyl group (p. 747) Arrangement in which an oxygen atom is double-bonded to a carbon atom.	**carbonyl group/grupo carbonilo** (pág. 747) Arreglo en el cual un átomo de oxígeno está unido por un doble enlace a un átomo de carbono.
carboxyl group (p. 749) Consists of a carbonyl group bonded to a hydroxyl group.	**carboxyl group/grupo carboxilo** (pág. 749) Consiste en un grupo de carbonilo unido a un grupo hidroxilo.
carboxylic acid (p. 749) An organic compound that contains a carboxyl group and is polar and reactive.	**carboxylic acid/ácido carboxílico** (pág. 749) Compuesto orgánico que contiene un grupo carboxilo y el cual es polar y reactivo.
catabolism (p. 792) Refers to metabolic reactions that cells undergo to extract energy and chemical building blocks from large, complex biological molecules such as proteins, carbohydrates, lipids, and nucleic acids.	**catabolism/catabolismo** (pág. 792) Se refiere a reacciones metabólicas que sufren las células para extraer energía y componentes químicos de moléculas biológicas, complejas y grandes tales como proteínas, carbohidratos, lípidos y ácidos nucleicos.
catalyst (p. 539) A substance that increases the rate of a chemical reaction by lowering activation energies but is not itself consumed in the reaction.	**catalyst/catalizador** (pág. 539) Sustancia que aumenta la velocidad de reacción química disminuyendo las energías de activación pero él mismo no es consumido durante la reacción.
cathode (p. 665) In an electrochemical cell, the electrode where reduction takes place.	**cathode/cátodo** (pág. 665) En una celda de electroquímica, el electrodo donde se lleva a cabo la reducción.
cathode ray (p. 92) A ray of radiation that originates from the cathode and travels to the anode of a cathode ray tube.	**cathode ray/rayo catódico** (pág. 92) Rayo de radiación que se origina en el cátodo y viaja al ánodo de un tubo de rayos catódicos.
cation (p. 212) An ion that has a positive charge; forms when valence electrons are removed, giving the ion a stable electron configuration.	**cation/catión** (pág. 212) Ion que tiene una carga positiva; se forma cuando se descartan los electrones de valencia, dándole al ion una configuración electrónica estable.
cellular respiration (p. 794) The process in which glucose is broken down in the presence of oxygen gas to produce carbon dioxide, water, and large amounts of energy.	**cellular respiration/respiración celular** (pág. 794) El proceso en cual la glucosa se rompe en presencia de oxígeno para producir dióxido de carbono, agua y grandes cantidades de energía.
Charles's law (p. 424) States that the volume of a given mass of gas is directly proportional to its kelvin temperature at constant pressure.	**Charles's law/Ley de Charles** (pág. 424) Establece que el volumen de una masa dada de gas es directamente proporcional a su temperatura Kelvin a presión constante.
chemical bond (p. 211) The force that holds two atoms together; may form by the attraction of a positive ion for a negative ion or by the attraction of a positive nucleus for negative electrons.	**chemical bond/enlace químico** (pág. 211) La fuerza que mantiene juntos a dos átomos; puede formarse por la atracción de un ion positivo por un ion negativo o por la atracción de un núcleo positivo hacia los electrones negativos.
chemical change (p. 62) A process involving one or more substances changing into new substances; also called a chemical reaction.	**chemical change/cambio químico** (pág. 62) Proceso que involucra una o más sustancias que se transforman en sustancias nuevas; también llamado reacción química.
chemical equation (p. 280) A statement using chemical formulas to describe the identities and relative amounts of the reactants and products involved in the chemical reaction.	**chemical equation/ecuación química** (pág. 280) Expresión que utiliza fórmulas químicas para describir las identidades y cantidades relativas de los reactantes y productos presentes en la reacción química.
chemical equilibrium (p. 561) The state in which forward and reverse reactions balance each other because they occur at equal rates.	**chemical equilibrium/equilibrio químico** (pág. 561) El estado en que las reacciones directa e inversa se equilibran mutuamente debido a que ocurren a velocidades iguales.
chemical potential energy (p. 490) The energy stored in a substance because of its composition; is released or absorbed as heat during chemical reactions or processes.	**chemical potential energy/energía potencial química** (pág. 490) La energía almacenada en una sustancia debido a su composición; se libera o se absorbe como calor durante reacciones o procesos químicos.
chemical property (p. 57) The ability or inability of a substance to combine with or change into one or more new substances.	**chemical property/propiedad química** (pág. 57) La capacidad o incapacidad de una sustancia para combinarse o transformarse en uno o más sustancias nuevas.

chemical reaction (p. 277) The process by which the atoms of one or more substances are rearranged to form different substances; occurrence can be indicated by changes in temperature, color, odor, and physical state.

chemistry (p. 7) The study of matter and the changes that it undergoes.

chirality (p. 719) A property of a compound to exist in both left (*l*−) and right (*d*−) forms; occurs whenever a compound contains an asymmetric carbon.

chromatography (p. 69) A technique that is used to separate the components of a mixture based on the tendency of each component to travel or be drawn across the surface of another material.

coefficient (p. 280) In a chemical equation, the number written in front of a reactant or product; tells the smallest number of particles of the substance involved in the reaction.

colligative property (p. 471) A physical property of a solution that depends on the number, but not the identity, of the dissolved solute particles; example properties include vapor pressure lowering, boiling point elevation, osmotic pressure, and freezing point depression.

collision theory (p. 532) States that atoms, ions, and molecules must collide in order to react.

colloids (p. 477) Heterogeneous mixtures containing particles larger than solution particles but smaller than suspension particles that are categorized according to the phases of their dispersed particles and dispersing mediums.

combined gas law (p. 428) A single law combining Boyle's, Charles's, and Gay-Lussac's laws that states the relationship among pressure, volume, and temperature of a fixed amount of gas.

combustion reaction (p. 285) A chemical reaction that occurs when a substance reacts with oxygen, releasing energy in the form of heat and light.

common ion (p. 584) An ion that is common to two or more ionic compounds.

common ion effect (p. 584) The lowering of the solubility of a substance by the presence of a common ion.

complete ionic equation (p. 293) An ionic equation that shows all the particles in a solution as they realistically exist.

complex reaction (p. 548) A chemical reaction that consists of two or more elementary steps.

compound (p. 71) A chemical combination of two or more different elements; can be broken down into simpler substances by chemical means and has properties different from those of its component elements.

concentration (p. 462) A quantitative measure of the amount of solute in a given amount of solvent or solution.

conclusion (p. 12) A judgment based on the information obtained.

condensation (p. 407) The energy-releasing process by which a gas or vapor becomes a liquid.

condensation polymerization (p. 764) Occurs when monomers having at least two functional groups combine with the loss of a small by-product, usually water.

condensation reaction (p. 753) Occurs when two smaller organic molecules combine to form a more complex molecule, accompanied by the loss of a small molecule such as water.

chemical reaction/reacción química (pág. 277) El proceso por el cual los átomos de una o más sustancias se reordenan para formar sustancias diferentes; su ocurrencia puede identificarse por cambios en temperatura, color, olor y producción de un gas.

chemistry/química (pág. 7) El estudio de la materia y los cambios que experimenta.

chirality/quiralidad (pág. 719) Propiedad de un compuesto para existir en ambas formas: izquierda (*i*−) y derecha (*d*−); ocurre siempre que un compuesto contiene un carbono asimétrico.

chromatography/cromatografía (pág. 69) Técnica usada para separar los componentes de una mezcla basada en la tendencia de cada componente para moverse o ser absorbido a través de la superficie de otra materia.

coefficient/coeficiente (pág. 280) En una ecuación química, el número escrito delante de un reactante o producto; indica el número más pequeño de partículas de la sustancia involucrada en la reacción.

colligative property/propiedad coligativa (pág. 471) Propiedad física de una solución que depende del número, pero no de la identidad, de las partículas solubles disueltas; ejemplos de propiedades incluyen disminución de la presión de vapor, elevación del punto de ebullición, la presión osmótica y la depresión del punto de congelación.

collision theory/teoría de colisión (pág. 532) Establece que los átomos, iones y moléculas deben chocar para reaccionar.

colloids/coloides (pág. 477) Mezclas heterogéneas que contienen partículas más grandes que las partículas de una solución pero más pequeñas que las partículas de una suspensión; se clasifican según las fases de sus partículas dispersadas y los medios dispersantes.

combined gas law/ley combinada de los gases (pág. 428) Una sola ley que combina las leyes de Boyle, Charles y de Gay-Lussac, que indica la relación entre la presión, el volumen y la temperatura de una cantidad fija de gas.

combustion reaction/reacción de combustión (pág. 285) Reacción química que ocurre cuando una sustancia reacciona con oxígeno, liberando energía en forma de calor y luz.

common ion/ion común (pág. 584) Un ion que es común a dos o más compuestos iónicos.

common ion effect/efecto de ion común (pág. 584) Disminución de la solubilidad de una sustancia por la presencia de un ion común.

complete ionic equation/ecuación iónica completa (pág. 293) Una ecuación iónica que muestra como existen en realidad todas las partículas en una solución.

complex reaction/reacción compleja (pág. 548) Reacción química que consiste en dos o más pasos elementales.

compound/compuesto (pág. 71) Combinación química de dos o más elementos diferentes; puede separarse en sustancias más sencillas por medios químicos y exhibe propiedades diferentes de aquellas de sus elementos constituyentes.

concentration/concentración (pág. 462) Medida cuantitativa de la cantidad de soluto en una cantidad dada de disolvente o solución.

conclusion/conclusión (pág. 12)) Juicio basado en la información obtenida.

condensation/condensación (pág. 407) El proceso de liberación de energía mediante el cual un gas o vapor se convierte en un líquido.

condensation polymerization/polimerización de condensación (pág. 764) Ocurre cuando se combinan monómeros que tienen por lo menos dos grupos funcionales, con la pérdida de un producto secundario pequeño, generalmente agua.

condensation reaction/reacción de condensación (pág. 753) Ocurre cuando dos moléculas orgánicas más pequeñas se combinan para formar una molécula más compleja, lo cual va acompañado de la pérdida de una molécula pequeña como el agua.

CONTENTS

conjugate acid (p. 598) The species produced when a base accepts a hydrogen ion from an acid.	**conjugate acid/ácido conjugado** (pág. 598) Especie producida cuando una base acepta un ion hidrógeno de un ácido.
conjugate acid-base pair (p. 598) Consists of two substances related to each other by the donating and accepting of a single hydrogen ion.	**conjugate acid-base pair/par ácido-base conjugado** (pág. 598) Consiste en dos sustancias relacionadas una con otra por la donación y aceptación de un solo ion hidrógeno.
conjugate base (p. 598) The species produced when an acid donates a hydrogen ion to a base.	**conjugate base/base conjugada** (pág. 598) Especie producida cuando un ácido dona un ion hidrógeno a una base.
control (p. 12) In an experiment, the standard that is used for comparison.	**control/control** (pág. 12) Estándar de comparación en un experimento.
conversion factor (p. 34) A ratio of equivalent values used to express the same quantity in different units; is always equal to 1 and changes the units of a quantity without changing its value.	**conversion factor/factor de conversión** (pág. 34) Proporción de valores equivalentes utilizados para expresar la misma cantidad en unidades diferentes; siempre es igual a 1 y cambia las unidades de una cantidad sin cambiar su valor.
coordinate covalent bond (p. 257) Forms when one atom donates a pair of electrons to be shared with an atom or ion that needs two electrons to become stable.	**coordinate covalent bond/enlace covalente coordinado** (pág. 257) Se forma cuando un átomo dona un par de electrones para ser compartidos con un átomo o ion que requiere dos electrones para volverse estable.
corrosion (p. 679) The loss of metal that results from an oxidation-reduction reaction of the metal with substances in the environment.	**corrosion/corrosión** (pág. 679) Pérdida de metal que resulta de una reacción de óxido-reducción del metal con sustancias en el ambiente.
covalent bond (p. 242) A chemical bond that results from the sharing of valence electrons.	**covalent bond/enlace covalente** (pág. 242) Enlace químico que resulta al compartir electrones de valencia.
cracking (p. 726) The process by which heavier fractions of petroleum are converted to gasoline by breaking their large molecules into smaller molecules.	**cracking/cracking** (pág. 726) El proceso por el cual las fracciones más pesadas de petróleo se convierten en gasolina, rompiendo sus moléculas grandes en moléculas más pequeñas.
critical mass (p. 823) The minimum mass of a sample of fissionable material necessary to sustain a nuclear chain reaction.	**critical mass/masa crítica** (pág. 823) La masa mínima de una muestra de material fisionable necesario para sostener una reacción nuclear en cadena.
crystalline solid (p. 400) A solid whose atoms, ions, or molecules are arranged in an orderly, geometric, three-dimensional structure; can be classified by shape and by composition.	**crystalline solid/sólido cristalino** (pág. 400) Sólido cuyos átomos, iones o moléculas se arreglan en una estructura tridimensional, ordenada y geométrica; puede clasificarse por forma y por composición.
crystallization (p. 69) A separation technique that produces pure solid particles of a substance from a solution that contains the dissolved substance.	**crystallization/cristalización** (pág. 69) Técnica de separación que produce partículas sólidas puras de una sustancia a partir de una solución que contiene la sustancia disuelta.
cyclic hydrocarbon (p. 706) An organic compound that contains a hydrocarbon ring.	**cyclic hydrocarbon/hidrocarburo cíclico** (pág. 706) Compuesto orgánico que contiene un hidrocarburo aromático (con un anillo).
cycloalkane (p. 706) A saturated hydrocarbon that can have rings with three, four, five, six, or more carbon atoms.	**cycloalkane/cicloalcano** (pág. 706) Hidrocarburo saturado que puede tener anillos con tres, cuatro, cinco, seis o más átomos de carbono.

D

Dalton's atomic theory (p. 89) A theory proposed by John Dalton in 1808, based on numerous scientific experiments, that marked the beginning of the development of modern atomic theory.	**Dalton's atomic theory/teoría atómica de Dalton** (pág. 89) Teoría propuesta por John Dalton en 1808, basada en numerosos experimentos científicos, que marcó el principio del desarrollo de la teoría atómica moderna.
Dalton's law of partial pressures (p. 391) States that the total pressure of a mixture of gases is equal to the sum of the pressures of all the gases in the mixture.	**Dalton's law of partial pressures/ley de presiones parciales de Dalton** (pág. 391) Establece que la presión total de una mezcla de gases es igual a la suma de las presiones de todos los gases en la mezcla.
de Broglie equation (p. 130) Predicts that all moving particles have wave characteristics and relates each particle's wavelength to its frequency, its mass, and Planck's constant.	**de Broglie equation/ecuación de deBroglie** (pág. 130) Predice que todas las partículas móviles tienen características de onda y relaciona la longitud de onda de cada partícula con su frecuencia, su masa y la constante de Planck.
decomposition reaction (p. 286) A chemical reaction that occurs when a single compound breaks down into two or more elements or new compounds.	**decomposition reaction/reacción de descomposición** (pág. 286) Reacción química que ocurre cuando un solo compuesto se divide en dos o más elementos o compuestos nuevos.
dehydration reaction (p. 755) An organic elimination reaction in which the atoms removed form water.	**dehydration reaction/reacción de deshidratación** (pág. 755) Una reacción de eliminación orgánica en la que los átomos eliminados forman agua.
dehydrogenation reaction (p. 754) Organic reaction that eliminates two hydrogen atoms, which form a hydrogen molecule.	**dehydrogenation reaction/reacción de deshidrogenación** (pág. 754) Reacción orgánica que elimina dos átomos de hidrógeno, los cuales forman una molécula de hidrógeno.

CONTENTS

delocalized electrons (p. 228) The electrons involved in metallic bonding that are free to move easily from one atom to the next throughout the metal and are not attached to a particular atom.	**delocalized electrons/electrones deslocalizados** (pág. 228)Los electrones implicados en el enlace metálico que están libres para moverse fácilmente de un átomo al próximo a través del metal y no están relacionados con cierto átomo en particular.
denaturation (p. 778) The process in which a protein's natural, intricate three-dimensional structure is disrupted.	**denaturation/desnaturalización** (pág. 778) Proceso en que se interrumpe la estructura tridimensional, intrincada y natural de una proteína.
denatured alcohol (p. 744) Ethanol to which noxious substances have been added in order to make it unfit to drink.	**denatured alcohol/alcohol desnaturalizado** (pág. 744) Etanol al cual se le añadieron sustancias nocivas a fin de inhabilitarlo para beber.
density (p. 27) A ratio that compares the mass of an object to its volume.	**density/densidad** (pág. 27) Proporción que compara la masa de un objeto con su volumen.
dependent variable (p. 12) In an experiment, the variable whose value depends on the independent variable.	**dependent variable/variable dependiente** (pág. 12) En un experimento, la variable cuyo valor depende de la variable independientele.
deposition (p. 408) The energy-releasing process by which a substance changes from a gas or vapor to a solid without first becoming a liquid.	**deposition/depositación** (pág. 408) Proceso de liberación de energía por el cual una sustancia cambia de un gas o vapor a un sólido sin convertirse antes en un líquido.
derived unit (p. 27) A unit defined by a combination of base units.	**derived unit/unidad derivada** (pág. 27) Unidad definida por una combinación de unidades base.
desalination (p. 851) The removal of salts from seawater by processes such as reverse osmosis or distillation in order to make it fit for use by living things.	**desalination/desalinación** (pág. 851) Eliminación de las sales del agua marina por procesos como la ósmosis inversa o la destilación para que puedan usarla los seres vivos.
diagonal relationships (p. 180) The close relationships between elements in neighboring groups of the periodic table.	**diagonal relationships/relaciones diagonales** (pág. 180) Relaciones estrechas entre elementos en grupos vecinos de la tabla periódica.
diffusion (p. 387) The movement of one material through another from an area of higher concentration to an area of lower concentration.	**diffusion/difusión** (pág. 387) El movimiento de un material a través de otro, de un área de mayor concentración a un área de menor concentración.
dimensional analysis (p. 34) A problem-solving method that focuses on the units that are used to describe matter.	**dimensional analysis/análisis dimensional** (pág. 34) Método de resolución de problemas enfocado en las unidades que se utilizan para describir la materia.
dipole–dipole forces (p. 394) The attractions between oppositely charged regions of polar molecules.	**dipole–dipole forces/fuerzas dipolo-dipolo** (pág. 394) Las atracciones entre regiones opuestamente cargadas de moléculas polares.
disaccharide (p. 782) Forms when two monosaccharides bond together.	**disaccharide/disacárido** (pág. 782) Se forma de la unión de dos monosacáridos.
dispersion forces (p. 393) The weak forces resulting from temporary shifts in the density of electrons in electron clouds.	**dispersion forces/fuerzas de dispersión** (pág. 393) Fuerzas débiles resultantes de los cambios temporales en la densidad de electrones en la nube electrónica.
distillation (p. 69) A technique that can be used to physically separate most homogeneous mixtures based on the differences in the boiling points of the substances involved.	**distillation/destilación** (pág. 69) Técnica que se puede emplear para separar físicamente la mayoría de las mezclas homogéneas, basándose en las diferencias en los puntos de ebullición de las sustancias implicadas.
double-replacement reaction (p. 290) A chemical reaction that involves the exchange of positive ions between two compounds and produces either a precipitate, a gas, or water.	**double-replacement reaction/reacción de doble desplazamiento** (pág. 290) Reacción química que involucra el cambio de iones positivos entre dos compuestos y produce un precipitado o un gas o agua.
dry cell (p. 673) An electrochemical cell that contains a moist electrolytic paste inside a zinc shell.	**dry cell/celda seca** (pág. 673) Una celda electroquímica que contiene una pasta electrolítica húmeda dentro de un armazón de zinc.

E

elastic collision (p. 386) Describes a collision in which kinetic energy may be transferred between the colliding particles but the total kinetic energy of the two particles remains the same.	**elastic collision/choque elástico** (pág. 386) Describe una colisión en la cual energía cinética se puede transferir entre las partículas que chocan pero la energía cinética total de las dos partículas permanece igual.
electrochemical cell (p. 665) An apparatus that uses a redox reaction to produce electrical energy or uses electrical energy to cause a chemical reaction.	**electrochemical cell/celda electroquímica** (pág. 665) Aparato que usa una reacción redox para producir energía eléctrica o utiliza energía eléctrica para causar una reacción química.
electrolysis (p. 683) The process that uses electrical energy to bring about a chemical reaction.	**electrolysis/electrólisis** (pág. 683)) Proceso que emplea energía eléctrica para producir una reacción química.
electrolyte (p. 218) An ionic compound whose aqueous solution conducts an electric current.	**electrolyte/electrolito** (pág. 218) Compuesto iónico cuya solución acuosa conduce una corriente eléctrica.

◀ CONTENTS ▶

electrolytic cell (p. 683) An electrochemical cell in which electrolysis occurs.	**electrolytic cell/celda electrolítica** (pág. 683) Celda electroquímica en la cual se lleva a cabo la electrólisis.
electromagnetic radiation (p. 118) A form of energy exhibiting wavelike behavior as it travels through space; can be described by wavelength, frequency, amplitude, and speed and includes visible light, microwaves, X rays, and radio waves.	**electromagnetic radiation/radiación electromagnética** (pág. 118) Forma de energía que exhibe un comportamiento parecido al de una onda al viajar por el espacio; puede describirse por su longitud de onda, frecuencia, amplitud y velocidad e incluye a la luz visible, las microondas, los rayos X y las ondas radiales.
electromagnetic spectrum (p. 120) Includes all forms of electromagnetic radiation, with the only differences in the types of radiation being their frequencies and wavelengths.	**electromagnetic spectrum/espectro electromagnético** (pág. 120) Incluye toda forma de radiación electromagnética, en el cual las frecuencias y longitudes de onda son las únicas diferencias entre los tipos de radiación.
electron (p. 93) A negatively charged, fast-moving particle with an extremely small mass that is found in all forms of matter and moves through the empty space surrounding an atom's nucleus.	**electron/electrón** (pág. 93) Partícula móvil rápida, cargada negativamente y con una masa muy pequeña, que se encuentra en todas las formas de materia y se mueve a través del espacio vacío que rodea el núcleo de un átomo.
electron capture (p. 812) A radioactive decay process that occurs when an atom's nucleus draws in a surrounding electron, which combines with a proton to form a neutron, resulting in an X-ray photon being emitted.	**electron capture/captura del electrón** (pág. 812) Proceso de desintegración radiactiva que ocurre cuando el núcleo de un átomo atrae un electrón circundante, que se combina con un protón para formar un neutrón, lo cual resulta en la emisión de un fotón de rayos X.
electron configuration (p. 135) The arrangement of electrons in an atom, which is prescribed by three rules—the aufbau principle, the Pauli exclusion principle, and Hund's rule.	**electron configuration/configuración del electrón** (pág. 135)) El arreglo de electrones en un átomo, que está establecido por tres reglas: el principio de Aufbau, el principio de la exclusión de Pauli y la regla de Hund.
electron-dot structure (p. 140) Consists of an element's symbol, representing the atomic nucleus and inner-level electrons, that is surrounded by dots, representing the atom's valence electrons.	**electron-dot structure/estructura punto electrón** (pág. 140) Consiste en el símbolo de un elemento, que representa el núcleo atómico y los electrones de los niveles interiores, rodeado por puntos que representan los electrones de valencia del átomo.
electron sea model (p. 228) Proposes that all metal atoms in a metallic solid contribute their valence electrons to form a “sea” of electrons, and can explain properties of metallic solids such as malleability, conduction, and ductility.	**electron sea model/modelo del mar de electrones** (pág. 228) Propone que todos los átomos de metal en un sólido metálico contribuyen con sus electrones de valencia para formar un "mar" de electrones y esto puede explicar propiedades de sólidos metálicos como maleabilidad, conducción y ductilidad.
electronegativity (p. 168) Indicates the relative ability of an element's atoms to attract electrons in a chemical bond.	**electronegativity/electronegatividad** (pág. 168) Indica la capacidad relativa de los átomos de un elemento para atraer electrones en un enlace químico.
element (p. 70) A pure substance that cannot be broken down into simpler substances by physical or chemical means.	**element/elemento** (pág. 70) Sustancia pura que no se puede separar en sustancias más sencillas por medios físicos ni químicos.
elimination reaction (p. 754) A reaction of organic compounds that occurs when a combination of atoms is removed from two adjacent carbon atoms forming an additional bond between the atoms.	**elimination reaction/reacción de eliminación** (pág. 754) Reacción de compuestos orgánicos que ocurre cuando una combinación de átomos se elimina de dos átomos adyacentes del carbono, formando un enlace adicional entre los átomos.
empirical formula (p. 331) A formula that shows the smallest whole-number mole ratio of the elements of a compound, and may or may not be the same as the actual molecular formula.	**empirical formula/fórmula empírica** (pág. 331) Fórmula que muestra la proporción molar más pequeña en números enteros de los elementos de un compuesto y puede o no puede ser igual que la fórmula molecular real.
endothermic (p. 247) A chemical reaction in which a greater amount of energy is required to break the existing bonds in the reactants than is released when the new bonds form in the product molecules.	**endothermic/endotérmica** (pág. 247) Reacción química en la cual se requiere una mayor cantidad de energía para romper los enlaces existentes en los reactantes que aquella que se libera cuando se forman los enlaces nuevos en las moléculas del producto.
end point (p. 619) The point at which the indicator that is used in a titration changes color.	**end point/punto final** (pág. 619) Punto en el cual el indicador que se utiliza en la titulación cambia de color.
energy (p. 489) The capacity to do work or produce heat; exists as potential energy, which is stored in an object due to its composition or position, and kinetic energy, which is the energy of motion.	**energy/energía** (pág. 489) Capacidad de hacer trabajo o producir calor; existe como energía potencial, que se almacena en un objeto debido a su composición o posición y como energía cinética, que es la energía del movimiento.
energy sublevels (p. 133) The energy levels contained within a principal energy level.	**energy sublevels/subniveles de energía** (pág. 133) Los niveles de energía dentro de un nivel principal de energía.
enthalpy (p. 499) The heat content of a system at constant pressure.	**enthalpy/entalpía** (pág. 499) El contenido de calor en un sistema a presión constante.
enthalpy (heat) of combustion (p. 501) The enthalpy change for the complete burning of one mole of a given substance.	**enthalpy (heat) of combustion/entalpía (calor) de combustión** (pág. 501) El cambio de entalpía para la combustión completa de un mol de una sustancia dada.
enthalpy (heat) of reaction (p. 499) The change in enthalpy for a reaction—the difference between the enthalpy of the sub-	**enthalpy (heat) of reaction/entalpía (calor) de la reacción** (pág. 499) El cambio en la entalpía para una reacción, es decir, la

CONTENTS

stances that exist at the end of the reaction and the enthalpy of the substances present at the start.	diferencia entre la entalpía de las sustancias que existen al final de la reacción y la entalpía de las sustancias presentes al comienzo de la misma.
entropy (p. 514) A measure of the disorder or randomness of the particles of a system.	**entropy/entropía** (pág. 514) Medida del desorden o la aleatoriedad de las partículas de un sistema.
enzyme (p. 778) A highly specific, powerful biological catalyst.	**enzyme/enzima** (pág. 778) Catalizador biológico, poderoso y sumamente específico.
equilibrium constant (p. 563) K_{eq}, which describes the ratio of product concentrations to reactant concentrations, with each raised to the power corresponding to its coefficient in the balanced equation.	**equilibrium constant/constante de equilibrio** (pág. 563) K_{eq}, la cual describe la proporción de concentraciones de producto a concentraciones de reactante, con cada uno elevado a la potencia correspondiente a su coeficiente en la ecuación equilibrada.
equivalence point (p. 618) The stoichiometric point of a titration.	**equivalence point/punto de equivalencia** (pág. 618) Punto estequiométrico de una titulación.
ester (p. 750) An organic compound with a carboxyl group in which the hydrogen of the hydroxyl group is replaced by an alkyl group; may be volatile and sweet-smelling and is polar.	**ester/éster** (pág. 750) Compuesto orgánico con un grupo carboxilo en que el hidrógeno del grupo de hidroxilo es reemplazado por un grupo alquilo; puede ser volátil y de olor dulce y es polar.
ether (p. 745) An organic compound that contains an oxygen atom bonded to two carbon atoms.	**ether/éter** (pág. 745) Compuesto orgánico que contiene un átomo de oxígeno unido a dos átomos del carbono.
evaporation (p. 405) The process in which vaporization occurs only at the surface of a liquid.	**evaporation/evaporación** (pág. 405)) Proceso en el cual la vaporización ocurre sólo en la superficie de un líquido.
excess reactant (p. 364) A reactant that remains after a chemical reaction stops.	**excess reactant/reactante en exceso** (pág. 364) Reactante que queda después de que se detiene una reacción química.
exothermic (p. 247) A chemical reaction in which more energy is released than is required to break bonds in the initial reaction.	**exothermic/exotérmica** (pág. 247) Reacción química en que se libera más energía que aquella requerida para romper los enlaces en la reacción inicial.
experiment (p. 11) A set of controlled observations that test the hypothesis.	**experiment/experimento** (pág. 11) Conjunto de las observaciones controladas para comprobar la hipótesis.
extensive property (p. 56) A physical property, such as mass, length, and volume, that is dependent upon the amount of substance present.	**extensive property/propiedad extensiva** (pág. 56) Propiedad física, como masa, longitud y volumen, dependiente de la cantidad de sustancia presente.

F

fatty acid (p. 784) A long-chain carboxylic acid that usually has between 12 and 24 carbon atoms and can be saturated (no double bonds), or unsaturated (one or more double bonds).	**fatty acid/ácido graso** (pág. 784) Ácido carboxílico de cadena larga que tiene generalmente entre 12 y 24 átomos de carbono y puede ser saturado (sin enlaces dobles) o insaturado (uno ó más enlaces dobles).
fermentation (p. 794) The process in which glucose is broken down in the absence of oxygen, producing either ethanol, carbon dioxide, and energy (alcoholic fermentation) or lactic acid and energy (lactic acid fermentation).	**fermentation/fermentación** (pág. 794) Proceso en el que la glucosa se rompe en ausencia de oxígeno, produciendo ya sea etanol, dióxido de carbono y energía (fermentación alcohólica) o ácido láctico y energía (fermentación ácido láctica).
ferromagnetism (p. 199) The strong attraction of a substance to a magnetic field.	**ferromagnetism/ferromagnetismo** (pág. 199) Atracción fuerte de una sustancia a un campo magnético.
filtration (p. 68) A technique that uses a porous barrier to separate a solid from a liquid.	**filtration/filtración** (pág. 68) Técnica que utiliza una barrera porosa para separar un sólido de un líquido.
formula unit (p. 221) The simplest ratio of ions represented in an ionic compound.	**formula unit/fórmula unitaria** (pág. 221) La proporción más sencilla de iones representados en un compuesto iónico.
fractional distillation (p. 725) The process by which petroleum can be separated into simpler components, called fractions, as they condense at different temperatures.	**fractional distillation/destilación fraccionaria** (pág. 725) Proceso mediante el cual el petróleo se puede separar en componentes más simples, llamados fracciones, dado que se condensan a temperaturas diferentes.
free energy (p. 517) The energy that is available to do work—the difference between the change in enthalpy and the product of the entropy change and the absolute temperature.	**free energy/energía libre** (pág. 517) Energía disponible para hacer trabajo: la diferencia entre el cambio en la entalpía y el producto del cambio de entropía y la temperatura absoluta.
freezing point (p. 408) The temperature at which a liquid is converted into a crystalline solid.	**freezing point/punto de congelación** (pág. 408)) La temperatura a la cual un líquido se convierte en un sólido cristalino.
freezing point depression (p. 473) The difference in temperature between a solution's freezing point and the freezing point of its pure solvent.	**freezing point depression/disminución del punto de congelación** (pág. 473) Diferencia de temperatura entre el punto de congelación de una solución y el punto de congelación de su disolvente puro.
frequency (p. 118) The number of waves that pass a given point per second.	**frequency/frecuencia** (pág. 118) Número de ondas que pasan por un punto dado en un segundo.
fuel cell (p. 677) A voltaic cell in which the oxidation of a fuel, such as hydrogen gas, is used to produce electric energy.	**fuel cell/celda de combustible** (pág. 677) Celda voltaica en la cual la oxidación de un combustible, como el gas hidrógeno, se utiliza para producir energía eléctrica.

functional group (p. 737) An atom or group of atoms that always react in a certain way in an organic molecule.	**functional group/grupo funcional** (pág. 737) Átomo o grupo de átomos que siempre reaccionan de cierta manera en una molécula orgánica.

G

galvanizing (p. 681) The process in which an iron object is dipped into molten zinc or electroplated with zinc to make the iron more resistant to corrosion.	**galvanizing/galvanizado** (pág. 681) Proceso en que un objeto de hierro se sumerge en zinc fundido o se electroemplaca con zinc para hacer el hierro más resistente a la corrosión.
gamma rays (p. 107) High-energy radiation that has no electrical charge and no mass, is not deflected by electric or magnetic fields, usually accompanies alpha and beta radiation, and accounts for most of the energy lost during radioactive decay.	**gamma rays/rayos gamma** (pág. 107) Radiación de alta energía que no tiene ni carga eléctrica ni masa, no es desviada por campos eléctricos ni magnéticos, acompaña generalmente a la radiación alfa y beta y representan la mayor parte de la energía perdida durante la desintegración radiactiva.
gas (p. 59) A form of matter that flows to conform to the shape of its container, fills the container's entire volume, and is easily compressed.	**gas/gas** (pág. 59) Forma de la materia que fluye para adaptarse a la forma de su contenedor, llena el volumen entero del recipiente y se comprime fácilmente.
Gay-Lussac's law (p. 426) States that the pressure of a given mass of gas varies directly with the kelvin temperature when the volume remains constant.	**Gay-Lussac's law/ley de Gay- Lussac** (pág. 426) Establece que la presión de una masa dada de gas varía directamente con la temperatura en Kelvin cuando el volumen permanece constante.
geometric isomers (p. 718) A category of stereoisomers that results from different arrangements of groups around a double bond.	**geometric isomers/isómeros geométricos** (pág. 718) Categoría de estereoisómeros que es una consecuencia de arreglos diferentes de grupos alrededor de un enlace doble.
global warming (p. 859) The rise in global temperatures, which may be due to increases in greenhouse gases, such as CO_2.	**global warming/calentamiento global** (pág. 859) Incremento en temperaturas globales, que puede deberse a aumentos en gases invernadero, como el CO_2.
Graham's law of effusion (p. 387) States that the rate of effusion for a gas is inversely proportional to the square root of its molar mass.	**Graham's law of effusion/ley de efusión de Graham** (pág. 387) Establece que la velocidad de efusión de un gas es proporcional al inverso de la raíz cuadrada de su masa molar.
graph (p. 43) A visual representation of information, such as a circle graph, line graph, or bar graph, that can reveal patterns in data.	**graph/gráfica** (pág. 43) Representación visual de información, como por ejemplo, las gráficas circulares, las gráficas lineales y las gráficas de barras, que pueden revelar patrones en los datos.
greenhouse effect (p. 859) The natural warming of Earth's surface due to certain atmospheric gases that absorb solar energy, which is converted to heat; prevents Earth from becoming too cold to support life.	**greenhouse effect/efecto de invernadero** (pág. 859) El calentamiento natural de la superficie de la Tierra debido a ciertos gases atmosféricos que absorben energía solar, que es convertida a calor; previene que la Tierra llegue a ser demasiado fría para sostener la vida.
ground state (p. 127) The lowest allowable energy state of an atom.	**ground state/estado base** (pág. 127) Estado de energía más bajo admisible de un átomo.
group (p. 154) A vertical column of elements in the periodic table; also called a family.	**group/grupo** (pág. 154) Columna vertical de elementos en la tabla periódica; llamado también familia.

H

half-cells (p. 665) The two parts of an electrochemical cell in which the separate oxidation and reduction reactions occur.	**half-cells/celdas medias** (pág. 665) Las dos partes de una celda electroquímica en que se llevan a cabo las reacciones separadas de la oxidación y la reducción.
half-life (p. 817) The time required for one-half of a radioisotope's nuclei to decay into its products.	**half-life/media vida** (pág. 817) Tiempo requerido para que la mitad de los núcleos de un radioisótopo se desintegren en sus productos.
half-reaction (p. 651) One of two parts of a redox reaction—the oxidation half, which shows the number of electrons lost when a species is oxidized, or the reduction half, which shows the number of electrons gained when a species is reduced.	**half-reaction/reacción media** (pág. 651) Una de dos partes de una reacción redox: la parte de la oxidación, la cual muestra el número de electrones perdidos cuando una especie se oxida o la parte de la reducción, que muestra el número de electrones ganados cuando una especie se reduce.
halocarbon (p. 738) Any organic compound containing a halogen substituent.	**halocarbon/halocarbono** (pág. 738) Cualquier compuesto orgánico que contiene un sustituyente de halógeno.
halogen (p. 158) A highly reactive group 7A element.	**halogen/halógeno** (pág. 158) Elemento del grupo 7A, sumamente reactivo.
halogenation (p. 741) A process by which hydrogen atoms may be replaced by halogen atoms (typically Cl or Br).	**halogenation/halogenación** (pág. 741) Proceso mediante el cual átomos de hidrógeno pueden ser reemplazados por átomos de halógeno (típicamente Cl o Br).

CONTENTS

heat (p. 491) A form of energy that flows from a warmer object to a cooler object.	**heat/calor** (pág. 491)Forma de energía que fluye de un cuerpo más caliente a uno más frío.
heat of solution (p. 457) The overall energy change that occurs during the solution formation process.	**heat of solution/calor de solución** (pág. 457) El cambio global de energía que ocurre durante el proceso de formación de la solución.
Heisenberg uncertainty principle (p. 131) States that it is not possible to know precisely both the velocity and the position of a particle at the same time.	**Heisenberg uncertainty principle/principio de incertidumbre de Heisenberg** (pág. 131) Establece que no es posible saber precisamente la velocidad y la posición de una partícula al mismo tiempo.
Henry's law (p. 460) States that at a given temperature, the solubility of a gas in a liquid is directly proportional to the pressure of the gas above the liquid.	**Henry's law/ley de Henry** (pág. 460) Establece que a una temperatura dada, la solubilidad de un gas en un líquido es directamente proporcional a la presión del gas por encima del líquido.
Hess's law (p. 506) States that if two or more thermochemical equations can be added to produce a final equation for a reaction, then the sum of the enthalpy changes for the individual reactions is the enthalpy change for the final reaction.	**Hess's law/ley de Hess** (pág. 506) Establece que si dos o más ecuaciones termoquímicas se pueden sumar para producir una ecuación final para una reacción, entonces la suma de los cambios de entalpía para las reacciones individuales es igual al cambio de entalpía para la reacción final.
heterogeneous catalyst (p. 541) A catalyst that exists in a different physical state than the reaction it catalyzes.	**heterogeneous catalyst/catalizador heterogéneo** (pág. 541) Catalizador que existe en un estado físico diferente al de la reacción que cataliza.
heterogeneous equilibrium (p. 565) A state of equilibrium that occurs when the reactants and products of a reaction are present in more than one physical state.	**heterogeneous equilibrium/equilibrio heterogéneo** (pág. 565) Estado de equilibrio que ocurre cuando los reactantes y los productos de una reacción están presentes en más de un estado físico.
heterogeneous mixture (p. 67) One that does not have a uniform composition and in which the individual substances remain distinct.	**heterogeneous mixture/mezcla heterogénea** (pág. 67) Aquélla que no tiene una composición uniforme y en la que las sustancias individuales permanecen separadas.
homogeneous catalyst (p. 541) A catalyst that exists in the same physical state as the reaction it catalyzes.	**homogeneous catalyst/catalizador homogéneo** (pág. 541) Catalizador que existe en el mismo estado físico de la reacción que cataliza.
homogeneous equilibrium (p. 564) A state of equilibrium that occurs when all the reactants and products of a reaction are in the same physical state.	**homogeneous equilibrium/equilibrio homogéneo** (pág. 564) estado de equilibrio que ocurre cuando todos los reactantes y productos de una reacción están en el mismo estado físico.
homogeneous mixture (p. 67) One that has a uniform composition throughout and always has a single phase; also called a solution.	**homogeneous mixture/mezcla homogénea** (pág. 67) Aquélla que tiene una composición uniforme a lo largo de todo su sistema y siempre tiene una sola fase; también llamada solución.
homologous series (p. 701) Describes a series of compounds that differ from one another by a repeating unit.	**homologous series/serie homóloga** (pág. 701) Describe una serie de compuestos que difieren uno del otro por una unidad repetitiva.
Hund's rule (p. 136) States that single electrons with the same spin must occupy each equal-energy orbital before additional electrons with opposite spins can occupy the same orbitals.	**Hund's rule/regla de Hund** (pág. 136) Establece que electrones individuales con igual rotación deben ocupar cada orbital de igual energía antes de que electrones adicionales con rotaciones opuestas puedan ocupar los mismos orbitales.
hybridization (p. 261) The process by which the valence electrons of an atom are rearranged to form four new, identical hybrid orbitals.	**hybridization/hibridación** (pág. 261) El proceso mediante el cual los electrones de valencia de un átomo se reordenan para formar cuatro orbitales híbridos nuevos e idénticos.
hydrate (p. 338) A compound that has a specific number of water molecules bound to its atoms.	**hydrate/hidrato** (pág. 338) Compuesto que tiene un número específico de moléculas de agua asociadas a sus átomos.
hydration reaction (p. 756) An addition reaction in which a hydrogen atom and a hydroxyl group from a water molecule add to a double or triple bond.	**hydration reaction/reacción de hidratació** (pág. 756) Reacción de adición en que un átomo de hidrógeno y un grupo hidroxilo de una molécula de agua se añaden a un enlace doble o triple.
hydrocarbon (p. 698) Simplest organic compound composed only of the elements carbon and hydrogen.	**hydrocarbon/hidrocarburo** (pág. 698) Compuesto orgánico más simple compuesto sólo de los elementos carbono e hidrógeno.
hydrogenation reaction (p. 756) An addition reaction in which hydrogen is added to atoms in a double or triple bond; usually requires a catalyst and is often used to convert liquid unsaturated fats into saturated fats that are solid at room temperature.	**hydrogenation reaction/reacción de hidrogenación** (pág. 756) Reacción de adición en la que hidrógeno se agrega a átomos en un enlace doble o triple; requiere generalmente un catalizador y a menudo se emplea para convertir grasas insaturadas líquidas en grasas saturadas que son sólidas a temperatura ambiente.
hydrogen bond (p. 395) A strong dipole-dipole attraction between molecules that contain a hydrogen atom bonded to a small, highly electronegative atom with at least one lone electron pair.	**hydrogen bond/puente de hidrógeno** (pág. 395) Fuerte atracción bipolo- bipolo entre moléculas que contienen un átomo de hidrógeno unido a un átomo pequeño, sumamente electronegativo con por lo menos un par de electrones no combinados.
hydrosphere (p. 850) All the water in and on Earth's surface, more than 97% of which is found in the oceans.	**hydrosphere/hidrosfera** (pág. 850) Toda el agua dentro y sobre la superficie de la Tierra, más del 97% de la cual se encuentra en los océanos.

CONTENTS

hydroxyl group (p. 743) An oxygen-hydrogen group covalently bonded to a carbon atom.	**hydroxyl group/grupo hidroxilo** (pág. 743) Un grupo hidrógeno-oxígeno unido covalentemente a un átomo de carbono.
hypothesis (p. 11) A tentative, testable statement or prediction about what has been observed.	**hypothesis/hipótesis** (pág. 11) Enunciado tentativo y sujeto a comprobación o predicción acerca de lo que se ha observado.

I

ideal gas constant (R) (p. 434) An experimentally determined constant whose value in the ideal gas equation depends on the units that are used for pressure.	**ideal gas constant** (R)**/constante de los gases ideales** (R)/ (pág. 434) Constante experimentalmente determinada cuyo valor en la ecuación ideal de gas depende de las unidades que se utilizan para la presión.
ideal gas law (p. 434) Describes the physical behavior of an ideal gas in terms of the temperature, volume, and pressure, and number of moles of a gas that are present.	**ideal gas law/ley del gas ideal** (pág. 434) Describe el comportamiento físico de un gas ideal en términos de temperatura, volumen y presión y del número de moles de un gas que están presentes.
immiscible (p. 454) Describes two liquids that can be mixed together but separate shortly after you cease mixing them.	**immiscible/inmiscible** (pág. 454) Describe dos líquidos que se pueden mezclar juntos pero que se separan poco después de que se cesa de mezclarlos.
independent variable (p. 12) In an experiment, the variable that the experimenter plans to change.	**independent variable/variable independiente** (pág. 12) En un experimento, la variable que el experimentador piensa cambiar.
induced transmutation (p. 815) The process in which nuclei are bombarded with high-velocity charged particles in order to create new elements.	**induced transmutation/trasmutación inducida** (pág. 815) Proceso en cual núcleos se bombardean con partículas cargadas de alta velocidad para crear elementos nuevos.
inhibitor (p. 540) A substance that slows down the reaction rate of a chemical reaction or prevents a reaction from happening.	**inhibitor/inhibidor** (pág. 540) Sustancia que decelera la velocidad de reacción de una reacción química o previene que ésta suceda.
inner transition metal (p. 158) A type of group B element that is contained in the f-block of the periodic table and is characterized by a filled outermost s orbital, and filled or partially filled 4f and 5f orbitals.	**inner transition metal/metal de transición interna** (pág. 158) Tipo de elemento del grupo B que está situado en el bloque F de la tabla periódica y se caracteriza por tener el orbital más externo lleno y los orbitales 4f y 5f parcialmente llenos.
insoluble (p. 454) Describes a substance that cannot be dissolved in a given solvent.	**insoluble/insoluble** (pág. 454) Describe una sustancia que no se puede disolver en un disolvente dado.
instantaneous rate (p. 546) The rate of decomposition at a specific time, calculated from the rate law, the specific rate constant, and the concentrations of all the reactants.	**instantaneous rate/velocidad instantánea** (pág. 546) Velocidad de descomposición a un tiempo específico, calculada a través de la ley de velocidad, la constante específica de velocidad y las concentraciones de todos los reactantes.
intensive property (p. 56) A physical property that remains the same no matter how much of a substance is present.	**intensive property/propiedad intensiva** (pág. 56) Propiedad física que permanece igual sea cual sea la cantidad de sustancia presente.
intermediate (p. 548) A substance produced in one elementary step of a complex reaction and consumed in a subsequent elementary step.	**intermediate/intermediario** (pág. 548) Sustancia producida en un paso elemental de una reacción compleja y consumida en un paso elemental subsecuente.
ion (p. 165) An atom or bonded group of atoms with a positive or negative charge.	**ion/ion** (pág. 165) Átomo o grupo de átomos unidos con carga positiva o negativa.
ionic bond (p. 215) The electrostatic force that holds oppositely charged particles together in an ionic compound.	**ionic bond/enlace iónico** (pág. 215)Fuerza electrostática que mantiene unidas las partículas opuestamente cargadas en un compuesto iónico.
ionization energy (p. 167) The energy required to remove an electron from a gaseous atom; generally increases in moving from left-to-right across a period and decreases in moving down a group.	**ionization energy/energía de ionización** (pág. 167) Energía que se requiere para quitar un electrón de un átomo gaseoso; generalmente aumenta al moverse de izquierda a derecha a través de un período y disminuye al moverse un grupo hacia abajo.
ionizing radiation (p. 827) Radiation that is energetic enough to ionize matter it collides with.	**ionizing radiation/radiación ionizante** (pág. 827) Radiación que es suficientemente energética para ionizar la materia con la que choca.
ion product constant for water (p. 608) The value of the equilibrium constant expression for the self-ionization of water.	**ion product constant for water/constante del producto ion para el agua** (pág. 608) Valor de la expresión de la constante de equilibrio para la autoionización del agua.
isomers (p. 717) Two or more compounds that have the same molecular formula but have different molecular structures.	**isomers/isómeros** (pág. 717) Dos o más compuestos que tienen la misma fórmula molecular pero poseen estructuras moleculares diferentes.
isotopes (p. 100) Atoms of the same element with the same number of protons but different numbers of neutrons.	**isotopes/isótopos** (pág. 100) Átomos del mismo elemento con el mismo número de protones, pero números diferentes de neutrones.

CONTENTS

J

joule (p. 491) The SI unit of heat and energy.	**joule/julio** (pág. 491) La unidad SI del calor y la energía.

K

kelvin (p. 30) The SI base unit of temperature.	**kelvin/kelvin** (pág. 30) La unidad base de temperatura del SI.
ketone (p. 748) An organic compound in which the carbon of the carbonyl group is bonded to two other carbon atoms.	**ketone/cetona** (pág. 748) Compuesto orgánico en que el carbono del grupo carbonilo está unido a otros dos átomos de carbono.
kilogram (p. 27) The SI base unit for mass; about 2.2 pounds.	**kilogram/kilogramo** (pág. 27) Unidad base del SI para la masa; aproximadamente equivale a 2.2 libras.
kinetic-molecular theory (p. 385) Explains the properties of gases in terms of the energy, size, and motion of their particles.	**kinetic-molecular theory/teoría cinético-molecular** (pág. 385) Explica las propiedades de gases en términos de energía, tamaño y movimiento de sus partículas.

L

lanthanide series (p. 197) In the periodic table, the f-block elements from period 6 that follow the element lanthanum.	**lanthanide series/serie de lantánidos** (pág. 197) En la tabla periódica, los elementos del bloque F del período 6 que siguen después del elemento lantano.
lattice energy (p. 219) The energy required to separate one mole of the ions of an ionic compound, which is directly related to the size of the ions bonded and is also affected by the charge of the ions.	**lattice energy/energía de rejilla** (pág. 219) Energía requerida para separar un mol de iones de un compuesto iónico, lo cual está directamente relacionado con el tamaño de los iones unidos y es afectado también por la carga de los iones.
law of chemical equilibrium (p. 563) States that at a given temperature, a chemical system may reach a state in which a particular ratio of reactant and product concentrations has a constant value.	**law of chemical equilibrium/ley del equilibrio químico** (pág. 563) Establece que a una temperatura dada, un sistema químico puede alcanzar un estado en que cierta proporción de concentraciones de reactante y producto tiene un valor constante.
law of conservation of energy (p. 490) States that in any chemical or physical process, energy may change from one form to another but it is neither created nor destroyed.	**law of conservation of energy/ley de la conservación de energía** (pág. 490) Establece que en un proceso químico o físico, la energía puede cambiar de una forma a otra pero ni se crea ni se destruye.
law of conservation of mass (p. 63) States that mass is neither created nor destroyed during a chemical reaction but is conserved.	**law of conservation of mass/ley de la conservación de masa** (pág. 63) Establece que la masa ni se crea ni se destruye durante una reacción química sino que se conserva.
law of definite proportions (p. 75) States that, regardless of the amount, a compound is always composed of the same elements in the same proportion by mass.	**law of definite proportions/ley de proporciones definidas** (pág. 75) Indica que, a pesar de la cantidad, un compuesto siempre está constituido por los mismos elementos en la misma proporción másica.
law of disorder (p. 514) States that entropy of the universe must increase as a result of a spontaneous reaction or process.	**law of disorder/ley del desorden** (pág. 514) Indica que la entropía del universo debe aumentar como resultado de una reacción o proceso espontáneo.
law of multiple proportions (p. 76) States that when different compounds are formed by the combination of the same elements, different masses of one element combine with the same mass of the other element in a ratio of small whole numbers.	**law of multiple proportions/ley de proporciones múltiples** (pág. 76) Establece que cuando compuestos diferentes están formados por la combinación de los mismos elementos, masas diferentes de un elemento se combinan con la misma masa del otro elemento en una proporción de números enteros pequeños.
Le Châtelier's principle (p. 569) States that if a stress is applied to a system at equilibrium, the system shifts in the direction that relieves the stress.	**Le Châtelier's principle/Principio de Le Châtelier** (pág. 569) Establece que si se aplica un estrés a un sistema en el equilibrio, el sistema cambia en la dirección en que se disminuye el estrés.
Lewis structure (p. 243) A model that uses electron-dot structures to show how electrons are arranged in molecules. Pairs of dots or lines represent bonding pairs.	**Lewis structure/estructura de Lewis** (pág. 243) Modelo que utiliza las estructuras punto electrón para mostrar como están distribuidos los electrones en las moléculas. Los pares de puntos o líneas representan pares de unión.
limiting reactant (p. 364) A reactant that is totally consumed during a chemical reaction, limits the extent of the reaction, and determines the amount of product.	**limiting reactant/reactante limitante** (pág. 364) Reactante que se consume completamente durante una reacción química, limita el alcance de la reacción y determina la cantidad de producto.

CONTENTS

lipids (p. 784) Large, nonpolar biological molecules that vary in structure, store energy in living organisms, and make up most of the structure of cell membranes.	**lipids/lípidos** (pág. 784) Moléculas biológicas no polares de gran tamaño que varían en estructura, guardan energía en organismos vivos y representan la mayor parte de la estructura de membranas de célula.
liquid (p. 58) A form of matter that flows, has constant volume, and takes the shape of its container.	**liquid/líquido** (pág. 58) Forma de materia que fluye, tiene volumen constante y toma la forma de su envase.
liter (p. 27) The metric unit for volume equal to one cubic decimeter.	**liter/litro** (pág. 27) Unidad métrica para el volumen igual a un decímetro cúbico.
lithosphere (p. 855) The solid part of Earth's crust and upper mantle, which contains a large variety of elements including oxygen, silicon, aluminum, and iron.	**lithosphere/litosfera** (pág. 855) La parte sólida de la corteza y el manto superior de la Tierra, que contiene una gran variedad de elementos, incluyendo oxígeno, silicio, aluminio y hierro.

M

mass (p. 8) A measure of the amount of matter.	**mass/masa** (pág. 8) Medida de la cantidad de materia.
mass defect (p. 822) The difference in mass between a nucleus and its component nucleons.	**mass defect/defecto másico** (pág. 822) La diferencia de masa entre un núcleo y sus nucleones componentes.
mass number (p. 100) The number after an element's name, representing the sum of its protons and neutrons.	**mass number/número de masa** (pág. 100) El número después del nombre de un elemento, la cual representa la suma de sus protones y neutrones.
matter (p. 8) Anything that has mass and takes up space.	**matter/materia** (pág. 8) Cualquier cosa que tiene masa y ocupa espacio.
melting point (p. 405) For a crystalline solid, the temperature at which the forces holding a crystal lattice together are broken and it becomes a liquid.	**melting point/punto de fusión** (pág. 405) Para un sólido cristalino, la temperatura en que se rompen las fuerzas que mantienen la matriz cristalina estable y éste se convierte en un líquido.
metabolism (p. 792) The sum of the many chemical reactions that occur in living cells.	**metabolism/matabolismo** (pág. 792) La suma de las numerosas reacciones químicas que ocurren en células vivas.
metal (p. 155) An element that is solid at room temperature, a good conductor of heat and electricity, and generally is shiny; most metals are ductile and malleable.	**metal/metal** (pág. 155) Elemento sólido a temperatura ambiente que es buen conductor de calor y electricidad y generalmente es brillante; la mayoría de los metales son dúctiles y maleables.
metallic bond (p. 228) The attraction of a metallic cation for delocalized electrons.	**metallic bond/enlace metálico** (pág. 228) Atracción de un catión metálico hacia electrones deslocalizados.
metalloid (p. 158) An element, such as silicon or germanium, that has physical and chemical properties of both metals and nonmetals.	**metalloid/metaloide** (pág. 158) Elemento, como el silicio o el germanio, que tiene las propiedades físicas y químicas tanto de metales como de no metales.
metallurgy (p. 199) The branch of applied science that studies and designs methods for extracting metals and their compounds from ores.	**metallurgy/metalurgia** (pág. 199) Rama de la ciencia aplicada que estudia y diseña los métodos para extraer de menas a metales y sus compuestos.
meter (p. 26) The SI base unit for length.	**meter/metro** (pág. 26) Unidad base para longitud del SI.
method of initial rates (p. 544) Determines the reaction order by comparing the initial rates of a reaction carried out with varying reactant concentrations.	**method of initial rates/método de velocidades iniciales** (pág. 544) Determina el orden de la reacción comparando las velocidades iniciales de una reacción llevada a cabo con diversas concentraciones de reactante.
mineral (p. 187) An element or inorganic compound that occurs in nature as solid crystals and usually is found mixed with other materials in ores.	**mineral/mineral** (pág. 187) Elemento o compuesto inorgánico que está presente en la naturaleza como cristales sólidos y se encuentra generalmente mezclado con otros materiales en menas.
miscible (p. 454) Describes two liquids that are soluble in each other.	**miscible/miscible** (pág. 454) Describe dos líquidos que son solubles uno en el otro.
mixture (p. 66) A physical blend of two or more pure substances in any proportion in which each substance retains its individual properties; can be separated by physical means.	**mixture/mezcla** (pág. 66) Combinación física de dos o más sustancias puras en cualquier proporción, en la cual cada sustancia retiene sus propiedades individuales; puede ser separada por medios físicos.
model (p. 13) A visual, verbal, and/or mathematical explanation of data collected from many experiments.	**model/modelo** (pág. 13) Explicación matemática, verbal y/o visual de datos recolectados de muchos experimentos.
molality (p. 469) The ratio of the number of moles of solute dissolved in one kilogram of solvent; also known as molal concentration.	**molality/molalidad** (pág. 469) Proporción del número de moles de soluto disueltos en un kilogramo de disolvente; también conocida como concentración molal.
molar enthalpy (heat) of fusion (p. 502) The amount of heat required to melt one mole of a solid substance.	**molar enthalpy (heat) of fusion/entalpía (calor) molar de fusión** (pág. 502) Cantidad requerida de calor para fundir un mol de una sustancia sólida.
molar enthalpy (heat) of vaporization (p. 502) The amount of heat required to evaporate one mole of a liquid.	**molar enthalpy (heat) of vaporization/entalpía (calor) molar de vaporización** (pág. 502) Cantidad requerida de calor para evaporar un mol de un líquido.

CONTENTS

molarity (p. 464) The number of moles of solute dissolved per liter of solution; also known as molar concentration.	**molarity/molaridad** (pág. 464) Número de moles de soluto disueltos por litro de solución; también conocida como concentración molar.
molar mass (p. 313) The mass in grams of one mole of any pure substance.	**molar mass/masa molar** (pág. 313) Masa en gramos de un mol de cierta sustancia pura.
molar volume (p. 431) For a gas, the volume that one mole occupies at 0.00°C and 1.00 atm pressure.	**molar volume/volumen molar** (pág. 431) Para un gas, el volumen que ocupa un mol a 0.00°C y 1.00 atm de presión.
mole (p. 310) The SI base unit used to measure the amount of a substance, abbreviated mol; one mole is the amount of a pure substance that contains 6.02×10^{23} representative particles.	**mole/mol** (pág. 310) Unidad base del SI utilizada para medir la cantidad de una sustancia, abreviada mol; un mol es la cantidad de sustancia pura que contienen 6.02×10^{23} partículas representativas.
molecular formula (p. 333) A formula that specifies the actual number of atoms of each element in one molecule or formula unit of the substance.	**molecular formula/fórmula molecular** (pág. 333) Fórmula que especifica el número real de átomos de cada elemento en una molécula o unidad de fórmula de la sustancia.
molecule (p. 242) Forms when two or more atoms covalently bond and is lower in potential energy than its constituent atoms.	**molecule/molécula** (pág. 242) Se forma cuando dos o más átomos se unen covalentemente y la cual tiene menor energía potencial que sus átomos constituyentes.
mole fraction (p. 470) The ratio of the number of moles of solute in solution to the total number of moles of solute and solvent.	**mole fraction/fracción mol** (pág. 470) Proporción del número de moles de soluto en solución entre el número total de moles de soluto y disolvente.
mole ratio (p. 356) In a balanced equation, the ratio between the numbers of moles of any two substances.	**mole ratio/proporción molar** (pág. 356) En una ecuación equilibrada, la proporción entre los números de moles de dos sustancias cualesquiera.
monatomic ion (p. 221) An ion formed from only one atom.	**monatomic ion/monómero** (pág. 221) Ion formado a partir de un sólo átomo.
monomer (p. 762) A molecule from which a polymer is made.	**monomer/** (pág. 762) Molécula a partir de la cual se forma un polímero.
monosaccharides (p. 781) The simplest carbohydrates, which are aldehydes or ketones that also have multiple hydroxyl groups; also called simple sugars.	**monosaccharides/monosacáridos** (pág. 781) Los carbohidratos más simples, los cuales son aldehidos o cetonas que tienen también múltiples grupos hidroxilo; llamados también azúcares simples.

N

net ionic equation (p. 293) An ionic equation that includes only the particles that participate in the reaction.	**net ionic equation/ecuación iónica neta** (pág. 293) Ecuación iónica que incluye sólo las partículas que participan en la reacción.
neutralization reaction (p. 617) A reaction in which an acid and a base react in aqueous solution to produce a salt and water.	**neutralization reaction/reacción de neutralización** (pág. 617) Reacción en que un ácido y una base reaccionan en una solución acuosa para producir una sal y agua.
neutron (p. 96) A neutral subatomic particle in an atom's nucleus that has a mass nearly equal to that of a proton.	**neutron/neutrón** (pág. 96) Partícula subatómica neutral en el núcleo de un átomo que tiene una masa casi igual a la de un protón.
nitrogen fixation (p. 860) The process that converts nitrogen gas into biologically useful nitrates.	**nitrogen fixation/fijación de nitrógeno** (pág. 860) Proceso que convierte gas nitrógeno en nitratos biológicamente útiles.
noble gas (p. 158) An extremely unreactive group 8A element.	**noble gas/gas noble** (pág. 158) Elemento extremadamente poco reactivo del grupo 8A.
nonmetals (p. 158) Elements that are generally gases or dull, brittle solids that are poor conductors of heat and electricity.	**nonmetals/no metales** (pág. 158) Elementos que generalmente son gases o sólidos quebradizos sin brillo y malos conductores de calor y electricidad.
nuclear equation (p. 106) A type of equation that shows the atomic number and mass number of the particles involved.	**nuclear equation/ecuación nuclear** (pág. 106) Tipo de ecuación que muestra el número atómico y el número másico de las partículas involucradas.
nuclear fission (p. 822) The splitting of a nucleus into smaller, more stable fragments, accompanied by a large release of energy.	**nuclear fission/fisión nuclear** (pág. 822) Ruptura de un núcleo en fragmentos más pequeños y más estables, acompañado de una gran liberación de energía.
nuclear fusion (p. 826) The process of binding smaller atomic nuclei into a single larger and more stable nucleus.	**nuclear fusion/fusión nuclear** (pág. 826) El proceso de unión de núcleos atómicos más pequeños en un sólo núcleo más grande y más estable.
nuclear reaction (p. 105) A reaction that involves a change in the nucleus of an atom.	**nuclear reaction/reacción nuclear** (pág. 105) Reacción que implica un cambio en el núcleo de un átomo.
nucleic acid (p. 788) A nitrogen-containing biological polymer that is involved in the storage and transmission of genetic information.	**nucleic acid/ácido nucleico** (pág. 788) Polímero biológico que contiene nitrógeno y que está involucrado en el almacenamiento y transmisión de información genética.
nucleons (p. 810) The positively charged protons and neutral neutrons contained in an atom's densely packed nucleus.	**nucleons/nucleones** (pág. 810) Protones positivamente cargados y neutrones neutros en el núcleo densamente poblado de un átomo.

CONTENTS

nucleotide (p. 788) The monomer that makes up a nucleic acid; consists of a nitrogen base, an inorganic phosphate group, and a five-carbon monosaccharide sugar.

nucleus (p. 95) The extremely small, positively charged, dense center of an atom that contains positively charged protons, neutral neutrons, and is surrounded by empty space through which one or more negatively charged electrons move.

nucleotide/nucleótido (pág. 788) Monómero que constituye un ácido nucleico; consiste en una base nitrogenada, un grupo fosfato inorgánico y un azúcar monosacárido de cinco carbonos.

nucleus/núcleo (pág. 95) El diminuto centro de un átomo, denso y positivamente cargado, que contiene protones positivamente cargados, neutrones neutrales y está rodeado de un espacio vacío a través del cual se mueven uno o más electrones cargados negativamente.

O

octet rule (p. 168) States that atoms lose, gain, or share electrons in order to acquire a full set of eight valence electrons (the stable electron configuration of a noble gas).

optical isomers (p. 720) A class of chiral stereoisomers that results from two possible arrangements of four different atoms or groups of atoms bonded to the same carbon atom.

optical rotation (p. 721) An effect that occurs when polarized light passes through a solution containing an optical isomer and the plane of polarization is rotated to the right by a *d*-isomer or to the left by an *l*-isomer.

ore (p. 187) A material from which a mineral can be extracted at a reasonable cost.

organic compounds (p. 698) All compounds that contain carbon with the primary exceptions of carbon oxides, carbides, and carbonates, all of which are considered inorganic.

osmosis (p. 475) The diffusion of solvent particles across a semipermeable membrane from an area of higher solvent concentration to an area of lower solvent concentration.

osmotic pressure (p. 475) The additional pressure needed to reverse osmosis.

oxidation (p. 637) The loss of electrons from the atoms of a substance; increases an atom's oxidation number.

oxidation number (p. 222) The positive or negative charge of a monatomic ion.

oxidation-number method (p. 644) The technique that can be used to balance more difficult redox reactions, based on the fact that the number of electrons transferred from atoms must equal the number of electrons accepted by other atoms.

oxidation-reduction reaction (p. 636) Any chemical reaction in which electrons are transferred from one atom to another; also called a redox reaction.

oxidizing agent (p. 638) The substance that oxidizes another substance by accepting its electrons.

oxyacid (p. 250) Any acid that contains hydrogen and an oxyanion.

oxyanion (p. 225) A polyatomic ion composed of an element, usually a nonmetal, bonded to one or more oxygen atoms.

octet rule/regla del octeto (pág. 168) Establece que átomos pierden, ganan o comparten electrones para adquirir un conjunto completo de ocho electrones de valencia (la configuración electrónica estable de un gas noble).

optical isomers/isómeros ópticos (pág. 720) Clase de estereoisómeros quirales que resulta de dos posibles arreglos de cuatro átomos o grupos de átomos diferentes unidos al mismo átomo de carbono.

optical rotation/rotación óptica (pág. 721) Efecto que ocurre cuando la luz polarizada pasa a través de una solución que contiene un isómero óptico y el plano de polarización es rotado a la derecha por un isómero *d* o a la izquierda por un isómero *l*

ore/mena (pág. 187) Material del cual puede extraerse un mineral a un costo razonable.

organic compounds/compuestos orgánicos (pág. 698) Todo compuesto que contiene carbono, con las excepciones primarias de óxidos de carbono, carburos y carbonatos, todos los cuales se consideran inorgánicos.

osmosis/ósmosis (pág. 475) Difusión de partículas de disolvente a través de una membrana semipermeable de un área de mayor concentración de disolvente a un área de menor concentración.

osmotic pressure/presión osmótica (pág. 475) Presión adicional necesaria para invertir la ósmosis.

oxidation/oxidación (pág. 637) Pérdida de electrones de los átomos de una sustancia; incrementa el número de oxidación de un átomo.

oxidation number/número de oxidación (pág. 222) La carga positiva o negativa de un ion monoatómico.

oxidation-number method/método del número de oxidación (pág. 644)) Técnica que puede utilizarse para equilibrar las reacciones redox más difíciles, en base al hecho de que el número de electrones transferidos de ciertos átomos debe igualar el número de electrones aceptados por otros átomos.

oxidation-reduction reaction/reacción de óxido-reducción (pág. 636) Cualquier reacción química en la cual se transfieren electrones de un átomo a otro; también llamada reacción redox.

oxidizing agent/agente oxidante (pág. 638) Sustancia que oxida otra sustancia aceptando sus electrones.

oxyacid/oxiácido (pág. 250) Cualquier ácido que contiene hidrógeno y un oxianión.

oxyanion/oxianión (pág. 225) Ion poliatómico compuesto de un elemento, generalmente un no metal, unido a uno o a más átomos de oxígeno.

P

parent chain (p. 701) The longest continuous chain of carbon atoms in a branched-chain alkane, alkene, or alkyne.

pascal (p. 390) The SI unit of pressure; one pascal (Pa) is equal to a force of one newton per square meter.

parent chain/cadena principal (pág. 701) Cadena continua más larga de átomos de carbono en un alcano, alqueno o alquino ramificado.

pascal/pascal (pág. 390) La unidad SI de presión; un pascal (Pa) es igual a una fuerza de un newton por metro cuadrado.

Pauli exclusion principle (p. 136) States that a maximum of two electrons may occupy a single atomic orbital, but only if the electrons have opposite spins.	**Pauli exclusion principle/principio de exclusión de Pauli** (pág. 136) Establece que un máximo de dos electrones pueden ocupar un solo orbital atómico, pero sólo si los electrones tienen giros opuestos.
peptide (p. 777) A chain of two or more amino acids linked by peptide bonds.	**peptide/péptido** (pág. 777) Cadena de dos o más aminoácidos unidos por enlaces peptídicos.
peptide bond (p. 777) The amide bond that joins two amino acids.	**peptide bond/enlace peptídico** (pág. 777) Enlace amida que une dos aminoácidos.
percent by mass (p. 75) A percentage determined by the ratio of the mass of each element to the total mass of the compound.	**percent by mass/por ciento masa** (pág. 75) Porcentaje determinado por la proporción de la masa de cada elemento en relación con la masa total del compuesto.
percent composition (p. 328) The percent by mass of each element in a compound.	**percent composition/composición porcentual** (pág. 328) Por ciento de masa de cada elemento en un compuesto.
percent error (p. 37) The ratio of an error to an accepted value.	**percent error/porcentaje de error** (pág. 37) Proporción de un error en relación con un valor aceptado.
percent yield (p. 370) The ratio of actual yield (from an experiment) to theoretical yield (from stoichiometric calculations) expressed as a percent.	**percent yield/porcentaje de rendimiento** (pág. 370) Razón del rendimiento real (de un experimento) al rendimiento teórico (de cálculos estequiométricos) expresado como un por ciento.
period (p. 154) A horizontal row of elements in the modern periodic table.	**period/período** (pág. 154) Fila horizontal de elementos en la tabla periódica moderna.
periodic law (p. 153) States that when the elements are arranged by increasing atomic number, there is a periodic repetition of their chemical and physical properties.	**periodic law/ley periódica** (pág. 153) Establece que cuando los elementos se ordenan por número atómico ascendente, existe una repetición periódica de sus propiedades físicas y químicas.
periodic table (p. 70) A chart that organizes all known elements into a grid of horizontal rows (periods) and vertical columns (groups or families) arranged by increasing atomic number.	**periodic table/tabla periódica** (pág. 70) Gráfica que organiza todos los elementos conocidos en una cuadrícula de filas horizontales (períodos) y columnas verticales (grupos o familias) ordenados según el aumento del número atómico.
pH (p. 610) The negative logarithm of the hydrogen ion concentration of a solution; acidic solutions have pH values between 0 and 7, basic solutions have values between 7 and 14, and a solution with a pH of 7.0 is neutral.	**pH/pH** (pág. 610) El logaritmo negativo de la concentración de ion hidrógeno de una solución; las soluciones ácidas poseen valores de pH entre 0 y 7, las soluciones básicas tienen valores entre 7 y 14 y una solución con un pH de 7.0 es neutra.
phase diagram (p. 408) A graph of pressure versus temperature that shows which phase a substance exists in under different conditions of temperature and pressure.	**phase diagram/diagrama de fase** (pág. 408) Gráfica de presión contra temperatura que muestra en qué fase se encuentra una sustancia bajo condiciones diferentes de temperatura y presión.
phospholipid (p. 786) A triglyceride in which one of the fatty acids is replaced by a polar phosphate group.	**phospholipid/fosfolípido** (pág. 786) Triglicérido en el cual un grupo fosfato polar reemplaza uno de los ácidos grasos.
photoelectric effect (p. 123) A phenomenon in which photoelectrons are emitted from a metal's surface when light of a certain frequency shines on the surface.	**photoelectric effect/efecto fotoeléctrico** (pág. 123) Fenómeno en el cual se emiten fotoelectrones de la superficie de un metal cuando brilla en la superficie luz de cierta frecuencia.
photon (p. 123) A particle of electromagnetic radiation with no mass that carries a quantum of energy.	**photon/fotón** (pág. 123) Partícula de radiación electromagnética sin masa que lleva un cuanto de energía.
photosynthesis (p. 793) The complex process that converts energy from sunlight to chemical energy in the bonds of carbohydrates.	**photosynthesis/fotosíntesis** (pág. 793) Proceso complejo que convierte la energía de la luz solar en energía química en los enlaces de carbohidratos.
physical change (p. 61) A type of change that alters the physical properties of a substance but does not change its composition.	**physical change/cambio físico** (pág. 61) Tipo del cambio que altera las propiedades físicas de una sustancia pero no cambia su composición.
physical property (p. 56) A characteristic of matter that can be observed or measured without changing the sample's composition—for example, density, color, taste, hardness, and melting point.	**physical property/propiedad física** (pág. 56) Característica de la materia que se puede observar o medir sin cambiar la composición de la muestra; por ejemplo, la densidad, el color, el sabor, la dureza y el punto de fusión.
pi bond (p. 246) A bond that is formed when parallel orbitals overlap to share electrons.	**pi bond/enlace pi** (pág. 246) Enlace que se forma cuando losorbitales paralelos se superponen para compartir electrones.
Planck's constant (p. 123) *h*, which has a value of 6.626×10^{-34} J•s, where J is the symbol for the joule.	**Planck's constant/constante de Planck** (pág. 123) *h*, que tiene un valor de 6.626×10^{-34} J•s, donde J es el símbolo del julio.
plastic (p. 764) A polymer that can be heated and molded while relatively soft.	**plastic/plástico** (pág. 764) Polímero que puede calentarse y moldearse mientras está relativamente suave.
pOH (p. 611) The negative logarithm of the hydroxide ion concentration of a solution; a solution with a pOH above 7.0 is acidic, a solution with a pOH below 7.0 is basic, and a solution with a pOH of 7.0 is neutral.	**pOH/pOH** (pág. 611) El logaritmo negativo de la concentración de ion hidróxido de una solución; una solución con un pOH mayor que 7.0 es ácida, una solución con un pOH menor que 7.0 es básica y una solución con un pOH de 7.0 es neutra.
polar covalent (p. 264) A type of bond that forms when electrons are not shared equally.	**polar covalent/covalente polar** (pág. 264) Tipo de enlace que se forma cuando los electrones no se comparten igualmente.
polarized light (p. 720) Light that can be filtered and reflected so that the resulting waves all lie in the same plane.	**polarized light/luz polarizada** (pág. 720) Luz que puede filtrarse y reflejarse para que todas las ondas resultantes se encuentren en el mismo plano.
polyatomic ion (p. 224) An ion made up of two or more atoms bonded together that acts as a single unit with a net charge.	**polyatomic ion/ion poliatómico** (pág. 224) Ion compuesto de dos o más átomos unidos que actúan como una sola unidad con una carga neta.

CONTENTS

polymerization reaction (p. 762) A reaction in which monomer units are bonded together to form a polymer.	**polymerization reaction/reacción de polimerización** (pág. 762) Reacción en la cual las unidades monoméricas se unen para formar un polímero.
polymers (p. 761) Large molecules formed by combining many repeating structural units (monomers); are synthesized through addition or condensation reactions and include polyethylene, polyurethane, and nylon.	**polymers/polímeros** (pág. 761) Moléculas grandes formadas de la combinación de muchas unidades estructurales repetidas (monómeros); se sintetizan a través de reacciones de adición o de condensación e incluyen el polietileno, el poliuretano y el nilón.
polysaccharide (p. 782) A complex carbohydrate, which is a polymer of simple sugars that contains 12 or more monomer units.	**polysaccharide/polisacárido** (pág. 782) Carbohidrato complejo, que es un polímero de azúcares simples que contiene 12 o más unidades monoméricas.
positron (p. 812) A particle that has the same mass as an electron but an opposite charge.	**positron/positrón** (pág. 812)) Partícula que tiene la misma masa que un electrón pero una carga opuesta.
positron emission (p. 812) A radioactive decay process in which a proton in the nucleus is converted into a neutron and a positron and then the positron is emitted from the nucleus.	**positron emission/emisión del positrón** (pág. 812)) Proceso de desintegración radiactiva en que un protón en el núcleo se convierte en un neutrón y un positrón y entonces el positrón se emite del núcleo.
precipitate (p. 290) A solid produced during a chemical reaction in a solution.	**precipitate/precipitado** (pág. 290) Sólido que se produce durante una reacción química en una solución.
precision (p. 36) Refers to how close a series of measurements are to one another; precise measurements show little variation over a series of trials but may not be accurate.	**precision/precisión** (pág. 36) Se refiere al grado de cercanía en que una serie de medidas están de unas de otras; las medidas precisas muestran poca variación durante una serie de pruebas, pero quizazás no sean exactas.
pressure (p. 388) Force applied per unit area.	**pressure/presión** (pág. 388) Fuerza aplicada por unidad de área.
primary battery (p. 675) A type of battery that produces electric energy by redox reactions that are not easily reversed, delivers current until the reactants are gone, and then is discarded.	**primary battery/batería primaria** (pág. 675) Tipo de batería que produce energía eléctrica por reacciones redox que no son fácilmente reversibles, produce corriente hasta agotar los reactantes y entonces se desecha.
principal energy levels (p. 133) The major energy levels of an atom.	**principal energy levels/niveles de energía principal** (pág. 133) Los niveles más importantes de energía de un átomo.
principal quantum numbers (p. 132) *n*, which the quantum mechanical model assigns to indicate the relative sizes and energies of atomic orbitals.	**principal quantum numbers/números cuánticos principales** (pág. 132) *n*, el cual asigna el modelo mecánico-cuántico para indicar tamaños y energías relativas de orbitales atómicos.
product (p. 278) A substance formed during a chemical reaction.	**product/producto** (pág. 278) Sustancia formada durante una reacción química.
protein (p. 775) An organic polymer made up of animo acids linked together by peptide bonds that can function as an enzyme, transport important chemical substances, or provide structure in organisms.	**protein/proteína** (pág. 775) Polímero orgánico compuesto de aminoácidos unidos por enlaces peptídicos que puede funcionar como una enzima, transportar sustancias químicas importantes o proporcionar estructura en los organismos.
proton (p. 96) A subatomic particle in an atom's nucleus that has a positive charge of 1+.	**proton/protón** (pág. 96) Partícula subatómica en el núcleo de un átomo que tiene una carga positiva de 1+.
pure research (p. 14) A type of scientific investigation that seeks to gain knowledge for the sake of knowledge itself.	**pure research/investigación pura** (pág. 14) Tipo de investigación científica que busca obtener conocimiento en nombre del conocimiento mismo.

Q

qualitative data (p. 10) Information describing color, odor, shape, or some other physical characteristic.	**qualitative data/datos cualitativos** (pág. 10) Información que describe el color, el olor, la forma o alguna otra característica física.
quantitative data (p. 11) Numerical information describing how much, how little, how big, how tall, how fast, etc.	**quantitative data/datos cuantitativos** (pág. 11) Información numérica que describe cantidad (grande o pequeña), dimensión, altura, rapidez, etc.
quantum (p. 122) The minimum amount of energy that can be gained or lost by an atom.	**quantum/cuanto** (pág. 122) La cantidad mínima de energía que puede ganar o perder un átomo.
quantum mechanical model of the atom (p. 131) An atomic model in which electrons are treated as waves; also called the wave mechanical model of the atom.	**quantum mechanical model of the atom/modelo mecánico cuántico del átomo** (pág. 131) Modelo atómico en el cual los electrones se tratan como si fueran ondas; también llamado modelo mecánico de ondas del átomo.

CONTENTS

R

radiation (p. 105) The rays and particles—alpha and beta particles and gamma rays—that are emitted by radioactive materials.

radioactive decay (p. 106) A spontaneous process in which unstable nuclei lose energy by emitting radiation.

radioactive decay series (p. 814) A series of nuclear reactions that starts with an unstable nucleus and results in the formation of a stable nucleus.

radioactivity (p. 105) The process in which some substances spontaneously emit radiation.

radiochemical dating (p. 819) The process that is used to determine the age of an object by measuring the amount of a certain radioisotope remaining in that object.

radioisotopes (p. 807) Isotopes of atoms that have unstable nuclei and emit radiation to attain more stable atomic configurations.

radiotracer (p. 828) An isotope that emits nonionizing radiation and is used to signal the presence of an element or specific substance; can be used to analyze complex chemical reactions mechanisms and to diagnose disease.

rate-determining step (p. 549) The slowest elementary step in a complex reaction; limits the instantaneous rate of the overall reaction.

rate law (p. 542) The mathematical relationship between the rate of a chemical reaction at a given temperature and the concentrations of reactants.

reactant (p. 278) The starting substance in a chemical reaction.

reaction mechanism (p. 548) The complete sequence of elementary steps that make up a complex reaction.

reaction order (p. 543) For a reactant, describes how the rate is affected by the concentration of that reactant.

reaction rate (p. 530) The change in concentration of a reactant or product per unit time, generally calculated and expressed in moles per liter per second.

redox reaction (p. 636) An oxidation-reduction reaction.

reducing agent (p. 638) The substance that reduces another substance by losing electrons.

reduction (p. 637) The gain of electrons by the atoms of a substance; decreases an atom's oxidation number.

reduction potential (p. 666) The tendency of an ion to gain electrons.

representative elements (p. 154) Groups of elements in the modern periodic table that are designated with an A (1A through 8A) and possess a wide range of chemical and physical properties.

resonance (p. 256) Condition that occurs when more than one valid Lewis structure exists for the same molecule.

reversible reaction (p. 560) A reaction that can take place in both the forward and reverse directions; leads to an equilibrium state where the forward and reverse reactions occur at equal rates and the concentrations of reactants and products remain constant.

radiation/radiación (pág. 105) Los rayos y partículas (partículas alfa y beta y rayos gamma) que emiten los materiales radiactivos.

radioactive decay/desintegración radiactiva (pág. 106) Proceso espontáneo en el cual los núcleos inestables pierden energía emitiendo radiación.

radioactive decay series/serie de desintegración radiactiva (pág. 814) Serie de reacciones nucleares que empieza con un núcleo inestable y tiene como resultado la formación de un núcleo fijo.

radioactivity/radiactividad (pág. 105)) El proceso en que algunas sustancias emiten radiación espontáneamente.

radiochemical dating/datación radioquímica (pág. 819) Proceso que se utiliza para determinar la edad de un objeto midiendo la cantidad de cierto radioisótopo remanente en ese objeto.

radioisotopes/radioisótopos (pág. 807) Isótopos de átomos que tienen los núcleos inestables y emiten radiación para alcanzar configuraciones atómicas más estables.

radiotracer/radiolocalizador (pág. 828) Isótopo que emite radiación no ionizante y que se utiliza para señalar la presencia de un elemento o sustancia específica; puede usarse para analizar mecanismos de reacciones químicas complejas y para diagnosticar enfermedades.

rate-determining step/paso de determinación de velocidad (pág. 549) Paso elemental más lento en una reacción compleja; limita la velocidad instantánea de la reacción global.

rate law/ley de velocidad (pág. 542) Relación matemática entre la velocidad de una reacción química a una temperatura dada y las concentraciones de reactantes.

reactant/reactante (pág. 278) Sustancia inicial en una reacción química.

reaction mechanism/mecanismo de reacción (pág. 548) Sucesión completa de pasos elementales que componen una reacción compleja.

reaction order/orden de reacción (pág. 543) Para un reactante, describe cómo la velocidad se ve afectada por la concentración del reactante.

reaction rate/velocidad de reacción (pág. 530) Cambio en la concentración de reactante o producto por unidad de tiempo, generalmente se calcula y expresa en moles por litro por segundo.

redox reaction/reacción redox (pág. 636) Una reacción de óxido–reducción.

reducing agent/agente reductor (pág. 638) Sustancia que reduce otra sustancia perdiendo electrones.

reduction/reducción (pág. 637) Ganancia de electrones de átomos de una sustancia; disminuye el número de oxidación de un átomo.

reduction potential/potencial de reducción (pág. 666) Tendencia de un ion a ganar electrones.

representative elements/elementos representativos (pág. 154) Grupos de elementos en la tabla periódica moderna que se designan con una A (1A hasta 8A) y poseen una gran variedad de propiedades físicas y químicas.

resonance/resonancia (pág. 256) Condición que ocurre cuando existe más de una estructura válida de Lewis para la misma molécula.

reversible reaction/reacción reversible (pág. 560) Reacción que puede ocurrir en dirección normal e inversa; conduce a un estado de equilibrio donde las reacciones normales e inversas ocurren a velocidades iguales y las concentraciones de reactantes y productos permanecen constantes.

CONTENTS

S

salinity (p. 851) A measure of the mass of salts dissolved in seawater, which is 35 g per kg, on average.	**salinity/salinidad** (pág. 851) Medida de la masa de sales disueltas en el agua de mar, que en promedio es de 35 g por kg.
salt (p. 617) An ionic compound made up of a cation from a base and an anion from an acid.	**salt/sal** (pág. 617) Compuesto iónico constituido por un catión de una base y un anión de un ácido.
salt bridge (p. 664) A pathway constructed to allow positive and negative ions to move from one solution to another.	**salt bridge/puente salino** (pág. 664) Vía construida para permitir que los iones positivos y negativos se muevan de una solución a otra.
salt hydrolysis (p. 621) The process in which anions of the dissociated salt accept hydrogen ions from water or the cations of the dissociated salt donate hydrogen ions to water.	**salt hydrolysis/hidrólisis de sal** (pág. 621) Proceso en el cual los aniones de la sal disociada aceptan iones hidrógeno del agua o los cationes de la sal disociada donan iones hidrógeno al agua.
saponification (p. 785) The hydrolysis of the ester bonds of a triglyceride using an aqueous solution of a strong base to form carboxylate salts and glycerol; is used to make soaps.	**saponification/saponificación** (pág. 785) Hidrólisis de los enlaces éster de un triglicérido usando una solución acuosa de una base fuerte para formar sales de carboxilato y glicerol; se usa en la elaboración de jabones.
saturated hydrocarbon (p. 710) A hydrocarbon that contains only single bonds.	**saturated hydrocarbon/hidrocarburo saturado** (pág. 710) Hidrocarburo que contiene únicamente enlaces sencillos.
saturated solution (p. 458) Contains the maximum amount of dissolved solute for a given amount of solvent at a specific temperature and pressure.	**saturated solution/solución saturada** (pág. 458) La que contiene la cantidad máxima de soluto disuelto para una cantidad dada de disolvente a una temperatura y presión específicas.
scientific law (p. 13) Describes a relationship in nature that is supported by many experiments.	**scientific law/ley científica** (pág. 13) Describe una relación en la naturaleza que es avalada por muchos experimentos.
scientific method (p. 10) A systematic approach used in scientific study that typically includes observation, a hypothesis, experiments, data analysis, and a conclusion.	**scientific method/método científico** (pág. 10) Enfoque sistemático utilizado en el estudio científico que incluye típicamente la observación, una hipótesis, los experimentos, los análisis de datos y una conclusión.
scientific notation (p. 31) Expresses numbers as a multiple of two factors—a number between 1 and 10, and 10 raised to a power, or exponent; makes it easier to handle extremely large or small measurements.	**scientific notation/notación científica** (pág. 31) Expresa los números como un múltiplo de dos factores: un número entre 1 y 10 y 10 elevado a una potencia o exponente; facilita el manejo de medidas extremadamente grandes o pequeñas.
second (p. 26) The SI base unit for time.	**second/segundo** (pág. 26) La unidad base del SI para el tiempo.
secondary battery (p. 675) A rechargeable battery that depends on reversible redox reactions and powers such devices as laptop computers and cordless drills.	**secondary battery/batería secundaria** (pág. 675) Batería recargable que depende de reacciones redox reversibles y provee energía a dispositivos como computadoras portátiles y taladros inalámbricos.
sigma bond (p. 245) A single covalent bond that is formed when an electron pair is shared by the direct overlap of bonding orbitals.	**sigma bond/enlace sigma** (pág. 245) Enlace covalente sencillo que se forma cuando un par de electrón es compartido por la superposición directa de orbitales de unión.
significant figures (p. 38) The number of all known digits reported in measurements plus one estimated digit.	**significant figures/cifras significativas** (pág. 38) El número de dígitos conocidos reportados en medidas, más un dígito estimado.
single-replacement reaction (p. 287) A chemical reaction that occurs when the atoms of one element replace the atoms of another element in a compound.	**single-replacement reaction/reacción de reemplazo simple** (pág. 287) Reacción química que ocurre cuando los átomos de un elemento reemplazan los átomos de otro elemento en un compuesto.
solid (p. 58) A form of matter that has its own definite shape and volume, is incompressible, and expands only slightly when heated.	**solid/sólido** (pág. 58) Forma de materia que tiene su propia forma y volumen, es incompresible y sólo se expande levemente cuando se calienta.
solubility (p. 457) The maximum amount of solute that will dissolve in a given amount of solvent at a specific temperature and pressure.	**solubility/solubilidad** (pág. 457) Cantidad máxima de soluto que se disolverá en una cantidad dada de disolvente a una temperatura y presión específicas.
solubility product constant (p. 578) K_{sp}, which is an equilibrium constant for the dissolving of a sparingly soluble ionic compound in water.	**solubility product constant/constante del producto de solubilidad** (pág. 578) K_{sp}, que es una constante de equilibrio para la disolución de un compuesto iónico moderadamente soluble en agua.
soluble (p. 454) Describes a substance that can be dissolved in a given solvent.	**soluble/soluble** (pág. 454) Describe una sustancia que se puede disolver en un disolvente dado.
solute (p. 292) A substance dissolved in a solution.	**solute/soluto** (pág. 292) Sustancia disuelta en una solución.
solution (p. 67) A uniform mixture that may contain solids, liquids, or gases; also called a homogeneous mixture.	**solution/solución** (pág. 67) Mezcla uniforme que puede contener sólidos, líquidos o gases; llamada también mezcla homogénea.
solvation (p. 455) The process of surrounding solute particles with solvent particles to form a solution; occurs only where and when the solute and solvent particles come in contact with each other.	**solvation/solvatación** (pág. 455) Proceso de rodear partículas de soluto con partículas de disolvente para formar una solución; ocurre sólo en lugares donde y cuando las partículas de soluto y disolvente entran en contacto.

CONTENTS

solvent (p. 292) The substance that dissolves a solute to form a solution.	**solvent/disolvente** (pág. 292) Sustancia que disuelve un soluto para formar una solución.
species (p. 650) Any kind of chemical unit involved in a process.	**species/especie** (pág. 650) Cualquier clase de unidad química implicada en un proceso.
specific heat (p. 492) The amount of heat required to raise the temperature of one gram of a given substance by one degree Celsius.	**specific heat/calor específico** (pág. 492) Cantidad de calor requerida para elevar la temperatura de un gramo de una sustancia dada en un grado centígrado.
specific rate constant (p. 542) A numerical value that relates reaction rate and concentration of reactant at a specific temperature.	**specific rate constant/constante de velocidad específica** (pág. 542) Valor numérico que relaciona la velocidad de reacción y la concentración de reactante a una temperatura específica.
spectator ion (p. 293) An ion that does not participate in a reaction and usually is not shown in an ionic equation.	**spectator ion/ion espectador** (pág. 293) Ion que no participa en una reacción y generalmente no se muestra en una ecuación iónica.
spontaneous process (p. 513) A physical or chemical change that occurs without outside intervention and may require energy to be supplied to begin the process.	**spontaneous process/proceso espontáneo** (pág. 513) Cambio físico o químico que ocurre sin intervención exterior y puede requerir de un suministro de energía para empezar el proceso.
standard enthalpy (heat) of formation (p. 509) The change in enthalpy that accompanies the formation of one mole of a compound in its standard state from its constituent elements in their standard states.	**standard enthalpy (heat) of formation/entalpía (calor) estándar de formación** (pág. 509) Cambio en la entalpía que acompaña la formación de un mol de un compuesto en su estado estándar a partir de sus elementos constituyentes en sus estados estándares.
standard hydrogen electrode (p. 666) The standard electrode against which the reduction potential of all electrodes can be measured.	**standard hydrogen electrode/electrodo estándar de hidrógeno** (pág. 666) Electrodo estándar contra el cual se puede medir el potencial de reducción de todos los electrodos.
states of matter (p. 58) The physical forms in which all matter naturally exists on Earth—most commonly as a solid, a liquid, or a gas.	**states of matter/estados de la materia** (pág. 58) Las formas físicas en que toda materia existe naturalmente en la Tierra, más comúnmente como un sólido, un líquido o un gas.
stereoisomers (p. 718) A class of isomers whose atoms are bonded in the same order but are arranged differently in space.	**stereoisomers/estereoisómeros** (pág. 718) Clase de isómeros cuyos átomos están unidos en el mismo orden pero se arreglan de manera diferente en el espacio.
steroids (p. 787) Lipids that have multiple cyclic rings in their structures.	**steroids/esteroides** (pág. 787) Lípidos que tienen múltiples anillos cíclicos en sus estructuras.
stoichiometry (p. 354) The study of quantitative relationships between the amounts of reactants used and products formed by a chemical reaction; is based on the law of conservation of mass.	**stoichiometry/estequiometría** (pág. 354) El estudio de las relaciones cuantitativas entre las cantidades de reactantes utilizados y los productos formados por una reacción química; se basa en la ley de la conservación de masa.
stratosphere (p. 842) The atmospheric layer above the troposphere and below the mesosphere; contains an ozone layer, which forms a protective layer against ultraviolet radiation, and has temperatures that increase with increasing altitude.	**stratosphere/estratosfera** (pág. 842) Capa atmosférica encima de la troposfera y debajo de la mesosfera; contiene una capa de ozono, que forma una capa protectora contra la radiación ultravioleta y tiene temperaturas que aumentan al incrementar la altitud.
strong acid (p. 602) An acid that ionizes completely in aqueous solution.	**strong acid/ácido fuerte** (pág. 602) Ácido que se ioniza completamente en solución acuosa.
strong base (p. 606) A base that dissociates entirely into metal ions and hydroxide ions in aqueous solution.	**strong base/base fuerte** (pág. 606) Base que disocia enteramente en iones metálicos e iones hidróxido en solución acuosa.
strong nuclear force (p. 810) A force that acts only on subatomic particles that are extremely close together and overcomes the electrostatic repulsion between protons.	**strong nuclear force/fuerza nuclear fuerte** (pág. 810) Fuerza que actúa sólo en las partículas subatómicas que están extremadamente cercanas y vence la repulsión electrostática entre protones.
structural formula (p. 252) A molecular model that uses symbols and bonds to show relative positions of atoms; can be predicted for many molecules by drawing the Lewis structure.	**structural formula/fórmula estructural** (pág. 252) Modelo molecular que usa símbolos y enlaces para mostrar las posiciones relativas de los átomos; para muchas moléculas puede predecirse dibujando la estructura de Lewis.
structural isomers (p. 717) A class of isomers whose atoms are bonded in different orders with the result that they have different chemical and physical properties despite having the same formula.	**structural isomers/isómeros estructurales** (pág. 717) Clase de isómeros cuyos átomos están unidos en diferente orden y como resultado tienen propiedades químicas y físicas diferentes, a pesar de tener la misma fórmula.
sublimation (p. 407) The energy-requiring process by which a solid changes directly to a gas without first becoming a liquid.	**sublimation/sublimación** (pág. 407) Proceso demandante de energía por el que un sólido cambia directamente a un gas sin llegar a ser primero un líquido.
substance (p. 55) A form of matter that has a uniform and unchanging composition; also known as a pure substance.	**substance/sustancia** (pág. 55) Forma de la materia que tiene una composición uniforme e inmutable; también conocida como sustancia pura.
substituent groups (p. 701) The side branches that extend from the parent chain because they appear to substitute for a hydrogen atom in the straight chain.	**substituent groups/grupo sustituyente** (pág. 701) Cadenas ramificadas que se extiende a partir de la cadena principal porque aparentemente sustituyen a un átomo de hidrógeno en la cadena recta.

CONTENTS

substitution reaction (p. 741) A reaction of organic compounds in which one atom or group of atoms in a molecule is replaced by an atom or group of atoms.	**substitution reaction/reacción de la sustitución** (pág. 741) Reacción de compuestos orgánicos en la cual un átomo o grupo de átomos en una molécula son reemplazados por un átomo o grupo de átomos.
substrate (p. 778) A reactant in an enzyme-catalyzed reaction that binds to specific sites on enzyme molecules.	**substrate/sustrato** (pág. 778) Reactante en una reacción catalizada por enzimas que se une a sitios específicos en moléculas de enzima.
supersaturated solution (p. 459) Contains more dissolved solute than a saturated solution at the same temperature.	**supersaturated solution/solución sobresaturada** (pág. 459) La que contiene más soluto disuelto que una solución saturada a la misma temperatura.
surface tension (p. 398) The energy required to increase the surface area of a liquid by a given amount; results from an uneven distribution of attractive forces.	**surface tension/tensión superficial** (pág. 398) Energía requerida para aumentar el área superficial de un líquido en una cantidad dada; se produce por una distribución desigual de fuerzas atractivas.
surfactant (p. 398) A compound, such as soap, that lowers the surface tension of water by disrupting hydrogen bonds between water molecules; also called a surface active agent.	**surfactant/surfactante** (pág. 398) Compuesto, como el jabón, que disminuye la tensión superficial del agua interrumpiendo los puentes de hidrógeno entre moléculas de agua; llamado también agente activo de superficie.
surroundings (p. 498) In thermochemistry, includes everything in the universe except the system.	**surroundings/alrededores** (pág. 498) En termoquímica, incluye el todo en el universo menos el sistema.
suspension (p. 476) A type of heterogeneous mixture whose particles settle out over time and can be separated from the mixture by filtration.	**suspension/suspensión** (pág. 476) Tipo de mezcla heterogénea cuyas partículas se asientan con el tiempo y pueden ser separadas de la mezcla por filtración.
synthesis reaction (p. 284) A chemical reaction in which two or more substances react to yield a single product.	**synthesis reaction/reacción de la síntesis** (pág. 284) Reacción química en que dos o más sustancias reaccionan para generar un solo producto.
system (p. 498) In thermochemistry, the specific part of the universe containing the reaction or process being studied.	**system/sistema** (pág. 498) En termoquímica, la parte específica del universo que contiene la reacción o el proceso que se está estudiado.

T

technology (p. 17) The practical use of scientific information.	**technology/tecnología** (pág. 17) Uso práctico de información científica.
temperature (p. 386) A measure of the average kinetic energy of the particles in a sample of matter.	**temperature/temperatura** (pág. 386) Medida de la energía cinética promedio de las partículas en una muestra de materia.
theoretical yield (p. 370) In a chemical reaction, the maximum amount of product that can be produced from a given amount of reactant.	**theoretical yield/rendimiento teórico** (pág. 370) En una reacción química, la cantidad máxima del producto que se puede producir a partir de una cantidad dada de reactante.
theory (p. 13) An explanation supported by many experiments; is still subject to new experimental data, can be modified, and is considered successful it if can be used to make predictions that are true.	**theory/teoría** (pág. 13) Explicación respaldada por muchos experimentos; está todavía sujeta a datos experimentales nuevos, puede modificarse y es considerada exitosa si se puede utilizar para hacer predicciones verdaderas.
thermochemical equation (p. 501) A balanced chemical equation that includes the physical states of all the reactants and products and specifies the change in enthalpy.	**thermochemical equation/ecuación termoquímica** (pág. 501) Ecuación química equilibrada que incluye los estados físicos de todos los reactantes y productos y especifica el cambio en entalpía.
thermochemistry (p. 498) The study of heat changes that accompany chemical reactions and phase changes.	**thermochemistry/termoquímica** (pág. 498) El estudio de los cambios caloríficos que acompañan las reacciones químicas y los cambios de fase.
thermonuclear reaction (p. 826) A nuclear fusion reaction.	**thermonuclear reaction/reacción termonuclear** (pág. 826) Reacción de fusión nuclear.
thermoplastic (p. 764) A type of polymer that can be melted and molded repeatedly into shapes that are retained when it is cooled.	**thermoplastic/termoplástico** (pág. 764) Tipo de polímero que puede fundirse y moldearse repetidas veces en formas que se retienen cuando se enfría.
thermosetting (p. 764) A type of polymer that can be molded when it is first prepared but when cool cannot be remelted.	**thermosetting/fraguado** (pág. 764) Tipo de polímero que se puede moldear mientras se está preparando pero cuando se enfría no puede fundirse de nuevo.
titration (p. 618) The process in which an acid-base neutralization reaction is used to determine the concentration of a solution of unknown concentration.	**titration/titulación** (pág. 618) Proceso en que una reacción de neutralización ácido- base se utiliza para determinar la concentración de una solución de concentración desconocida.
transition elements (p. 154) Groups of elements in the modern periodic table that are designated with a B (1B through 8B) and are further divided into transition metals and inner transition metals.	**transition elements/elementos de transición** (pág. 154) Grupos de elementos en la tabla periódica moderna que se designan con una B (1B a 8B) y son divididos adicionalmente en metales de transición y metales de transición interna.

CONTENTS

transition metal (p. 158) A type of group B element that is contained in the d-block of the periodic table and, with some exceptions, is characterized by a filled outermost s orbital of energy level n, and filled or partially filled d orbitals of energy level $n - 1$.

transition state (p. 532) Term used to describe an activated complex because the activated complex is as likely to form reactants as it is to form products.

transmutation (p. 815) The conversion of an atom of one element to an atom of another element.

transuranium element (p. 815) An element with an atomic number of 93 or greater in the periodic table that is produced in the laboratory by induced transmutation.

triglyceride (p. 785) Forms when three fatty acids are bonded to a glycerol backbone through ester bonds; can be either solid or liquid at room temperature.

triple point (p. 409) The point on a phase diagram representing the temperature and pressure at which the three phases of a substance (solid, liquid, and gas) can coexist.

troposphere (p. 842) The lowest layer of Earth's atmosphere where weather occurs and in which we live; has temperatures that generally decrease with increasing altitude.

Tyndall effect (p. 479) The scattering of light by colloidal particles.

transition metal/metal de transición (pág. 158) Tipo de elemento del grupo B contenido en el bloque D de la tabla periódica y que, con algunas excepciones, se caracteriza por un orbital exterior lleno con nivel de energía n, y orbitales d llenos o parcialmente llenos con niveles de energía $n - 1$.

transition state/estado de transición (pág. 532) Término que se usa para describir un complejo activado dado que el complejo activado es igualmente probable que forme reactantes a que forme productos.

transmutation/trasmutación (pág. 815) Conversión de un átomo de un elemento a un átomo de otro elemento.

transuranium element/elemento transuránico (pág. 815) Un elemento en la tabla periódica con un número atómico de 93 ó mayor que es producido en el laboratorio por trasmutación inducida.

triglyceride/triglicérido (pág. 785) Se forma cuando tres ácidos grasos son unidos a un cadena principal de glicerol por enlaces éster; puede ser sólido o líquido a temperatura ambiente.

triple point/punto triple (pág. 409) El punto en un diagrama de fase que representa la temperatura y la presión en que las tres fases de una sustancia (sólido, líquido y gas) pueden coexistir.

troposphere/troposfera (pág. 842) La capa más baja de la atmósfera terrestre donde se presenta el clima y en la que vivimos; las temperaturas disminuyen generalmente conforme aumenta la altitud.

Tyndall effect/efecto de Tyndall (pág. 479) Dispersión de la luz por partículas coloidales.

U

unit cell (p. 400) The smallest arrangement of connected points that can be repeated in three directions to form a crystal lattice.

universe (p. 498) In thermochemistry, is the system plus the surroundings.

unsaturated hydrocarbon (p. 710) A hydrocarbon that contains at least one double or triple bond between carbon atoms.

unsaturated solution (p. 458) Contains less dissolved solute for a given temperature and pressure than a saturated solution; has further capacity to hold more solute.

unit cell/celda unitaria (pág. 400) El arreglo más pequeño de puntos conectados que se puede repetir en tres direcciones para formar una red cristalina.

universe/universo (pág. 498) En termoquímica, es el sistema más los alrededores.

unsaturated hydrocarbon/hidrocarburo insaturad (pág. 710) Hidrocarburo que contiene por lo menos uno enlace doble o triple entre átomos de carbono.

unsaturated solution/solución insaturada (pág. 458) La que contiene menos soluto disuelto a una temperatura y presión dadas que una solución saturada; tiene capacidad para contener soluto adicional.

V

valence electrons (p. 140) The electrons in an atom's outermost orbitals; determine the chemical properties of an element.

vapor (p. 59) Gaseous state of a substance that is a liquid or a solid at room temperature.

vaporization (p. 405) The energy-requiring process by which a liquid changes to a gas or vapor.

vapor pressure (p. 406) The pressure exerted by a vapor over a liquid.

vapor pressure lowering (p. 472) The lowering of vapor pressure of a solvent by the addition of a nonvolatile solute to the solvent.

viscosity (p. 397) A measure of the resistance of a liquid to flow, which is affected by the size and shape of particles, and generally increases as the temperature decreases and as intermolecular forces increase.

valence electrons/electrones de valencia (pág. 140) Los electrones en el orbital más externo de un átomo; determinan las propiedades químicas de un elemento.

vapor/vapor (pág. 59) Estado gaseoso de una sustancia que es líquida o sólida a temperatura ambiente.

vaporization/vaporización (pág. 405) Proceso demandante de energía por el que un líquido cambia a gas o vapor.

vapor pressure/presión del vapor (pág. 406) Presión ejercida por un vapor sobre un líquido.

vapor pressure lowering/disminución de la presión del vapor (pág. 472) Disminución de la presión de vapor de un disolvente por la adición de un soluto no volátil al disolvente.

viscosity/viscosidad (pág. 397) Medida de la resistencia de un líquido para fluir, que se ve afectada por el tamaño y la forma de las partículas y aumenta generalmente cuando la temperatura disminuye y cuando se incrementan las fuerzas intermoleculares.

CONTENTS

voltaic cell (p. 665) A type of electrochemical cell that converts chemical energy into electrical energy.

VSEPR model (p. 259) **V**alence **S**hell **E**lectron **P**air **R**epulsion model, which is based on an arrangement that minimizes the repulsion of shared and unshared pairs of electrons around the central atom.

voltaic cell/celda voltaica (pág. 665) Tipo de la celda electroquímica que convierte energía química en energía eléctrica.

VSEPR model/modelo RPCEV (pág. 259) Modelo de **R**epulsión de los **P**ares **E**lectrónicos de la **C**apa de **V**alencia, que se basa en un arreglo que minimiza la repulsión de los pares de electrones compartidos y no compartidos alrededor del átomo central.

W

wavelength (p. 118) The shortest distance between equivalent points on a continuous wave; is usually expressed in meters, centimeters, or nanometers.

wax (p. 787) A type of lipid that is formed by combining a fatty acid with a long-chain alcohol; is made by both plants and animals.

weak acid (p. 603) An acid that ionizes only partially in dilute aqueous solution.

weak base (p. 606) A base that ionizes only partially in dilute aqueous solution to form the conjugate acid of the base and hydroxide ion.

weight (p. 8) A measure of an amount of matter and also the effect of Earth's gravitational pull on that matter.

wavelength/longitud de onda (pág. 118) La distancia más corta entre puntos equivalentes en una onda continua; se expresa generalmente en metros, en centímetros o en nanómetros.

wax/cera (pág. 787) Tipo de lípido que se forma combinando un ácido graso con un alcohol de cadena larga; es elaborada por plantas y animales.

weak acid/ácido débil (pág. 603) Ácido que se ioniza sólo parcialmente en solución acuosa diluida.

weak base/base débil (pág. 606) Base que se ioniza sólo parcialmente en solución acuosa diluida para formar el ácido conjugado de la base y el ion hidróxido.

weight/peso (pág. 8) Medida de la cantidad de materia y también del efecto de la fuerza gravitatoria de la Tierra sobre esa materia.

X

X ray (p. 809) A form of high-energy, penetrating electromagnetic radiation emitted from some materials that are in an excited electron state.

X ray/rayo X (pág. 809) Forma de radiación electromagnética penetrante de alta energía emitida por algunas materias en un estado electrónico excitado.

Index

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

CONTENTS

Photo Credits

Cover (drop)John Harwood/Science Photo Library/Photo Researchers, (glacier)Tom Bean/Stone, (molecules)Ken Edward/Photo Researchers, (snowflake)Scott Camazine/Photo Researchers; **v** (t)VCG/FPG, (b)Roberto De Gugliemo/Science Photo Library/Photo Researchers; **vi** (t)Mark A. Schneider/Visuals Unlimited, (b)Richard Megna/Fundamental Photographs; **vii** Ellis Herwig/Stock Boston; **viii** Stephen Frisch/Stock Boston; **ix** (t)Millard H. Sharp/Photo Researchers, (b)PhotoDisc; **x** Dan Hamm/Stone; **xi xii** Matt Meadows; **xiii** Doug Martin; **xiv** (t)Matt Meadows, (b)Bob Daemmrich/Stock Boston; **xvi** NASA/Roger Ressmeyer/Corbis; **1** Bernhard Edmaeir/Science Photo Library/Photo Researchers; **2** Royal Observatory, Edinburgh/AAO/Science Photo Library/Photo Researchers; **3** Barry Runk from Grant Heilman; **4** Charles O'Rear/CORBIS; **5** (l)Doug Martin, (r)NASA/Science Photo Library/Photo Researchers; **7** (t)Doug Mills/AP/Wide World Photos, (bl)Andy Sacks/Stone, (br)Richard Clintsman/Stone; **8** David Young-Wolff/Stone; **10** Bob Daemmrich/Stock Boston; **11** Lynn M. Stone; **12** (b)Matt Meadows; **12** (t)Matt Meadows; **14** Andrew McClenaghan/Science Photo Library/Photo Researchers; **15** Chip Clark; **16** Matt Meadows; **17** (l)E. Nagel/FPG, (c)Oaktree Automation Inc., (r)Chris Bjornberg/Photo Researchers; **19** Matt Meadows; **20** (l)U.S. DOE Human Genome Program, (r)PhotoDisc; **24** CORBIS; **25** (t)Matt Meadows, (b)Tony Freeman/PhotoEdit; **26** Tim Brown/Stone; **27** National Bureau of Weights and Measures; **28** Matt Meadows; **31** Rich Frishman/Stone; **32** Pictor-Uniphoto; **34** Rod Joslin; **37** Henry Horenstein/Stock Boston; **40** Geoff Butler; **47** Matt Meadows; **48** (t)Telegraph Colour Library/FPG, (c)Watson Photography/Medichrome, (bl)Anatomyworks Inc./Medichrome; **54** Jeff Hunter/The Image Bank; **55** Matt Meadows; **56** David Cavagnaro/Visuals Unlimited; **57** (tl)John Cancalosi/Stock Boston, (tr)Ken Lucas/Visuals Unlimited, (c)Erich Schrempp/Photo Researcher, (b)Dennis Hallinan/FPG; **58** (l)Simon Wilkinson/The Image Bank, (r)Travelpix/FPG; **59** (tl)Aaron Haupt, (tr)Jacques Jangoux/Photo Researchers, (b)Ellis Herwig/Stock Boston; **60** Mary Kate Denny/PhotoEdit; **61** StudiOhio; **62** Matt Meadows; **62** (l)John Eastcott & Yva Momatiuk/Photo Researchers, (r)Erich Schrempp/Photo Researchers; **63** (l)Clyde H. Smith/FPG, (r)Greig Cranna/Stock Boston; **64** (tl tr)Stephan Frisch/Stock Boston, (b)file photo; **65** Michael Holford; **66 67 68 69** Matt Meadows; **70** Stamp from the collection of Prof. C.M. Lang, photograph by Gary Shulfer, University of WI at Stevens Point; **72-73** from The Periodic Systems of the Elements, author P. Menzel. (c)Ernst Klett Schulbuch Verlag GmbH, Stuttgart, Germany. Charts available from Science Import, Quebec, Canada.; **74** (t)Charles D. Winters/Photo Researchers, (b)Stephen Frisch/Stock Boston; **75** file photo; **77** Matt Meadows; **80** Chip Clark; **82** (t)Geoff Butler, (b)Larry Hamill; **86** Courtesy IBM Corporation, Research Division, Almaden Research Center; **87** Matt Meadows; **88** (air)William D. Popejoy, (water)Rudi Von Briel , (earth)file photo, (fire)Doug Martin, (b)Nimatallah/Art Resource, NY; **89** (t)Scala/Art Resource, NY, (b)Bettmann/CORBIS; **90** Kean Collection/Archive Photos; **91** (l)David Parker/Science Photo Library/Photo Researchers, (r)Philippe Plailly/Science Photo Library/Photo Researchers; **96** (t)OMICRON Vakuumphysik GmbH, (b)courtesy IBM Corporation, Research Division, Almaden Research Center; **100** Lew Lause/Pictor; **102 109** Matt Meadows; **110** Dustin W. Carr & Harold G. Craighead/Physics New Graphics/American Institute of Physics; **114** H.R. Bramaz/Peter Arnold, Inc.; **116** Steve Allen/The Image Bank; **117** Matt Meadows; **118** (l)Fundamental Photographs, (c)Michael Neveux/CORBIS, (r)Richard Megna/Fundamental Photographs; **119** StudiOhio; **120** David Parker/Science Photo Library/Photo Researchers; **121** David R. Frazier; **122** (l)Ray Ellis/Photo Researchers, (c)Werner H. Muller/Peter Arnold, Inc., (r)Russ Lappa, **123** Mark Burnett, **124** Michael Martin/Science Photo Library/Photo Researchers; **129** Paul Silverman/Fundamental Photographs; **131** Pekka Parviainen/Science Photo Library/Photo Researchers; **132** Nicolas Sapieha, Kea Publishing Services Ltd./CORBIS; **139** Phil A. Harrington/Peter Arnold, Inc.; **141** Ron Sherman/Pictor; **143** (t)Ted Rice, (b)Matt Meadows; **144** Runk/Schoenberger from Grant Heilman; **150** Bill Ross/CORBIS; **151** Matt Meadows; **152** K. Urban/CORBIS; **153** (t) Edgar Fahs Smith Collection, University of PA Library, (bl)Archive Photos, (br)Steve Raymer/CORBIS; **155** (l)Robert Mayer, (r)file photo; **158** (l)Keren Su/Stock Boston, (tr)Victoria & Albert Museum, London/Art Resource, NY, (br)(c)**2002** Kay Chernush; **162** Doug Martin/Photo Researchers; **171** Matt Meadows; **172** Hazel Hankin/Stock Boston; **178** Scala/Art Resource, NY; **179** Paul Brown; **180** Bettmann/CORBIS; **181** (l)Charles D. Winters/Photo Researchers, (r)Richard Megna/Fundamental Photography; **182** (l)Owen Franken/Stock Boston, (r)Richard Gaul/FPG; **183** Mark A. Schneider/Visuals Unlimited; **184** E.O. Hoppe/CORBIS; **185** (l)Cliff Leight, (r)Aaron Haupt; **186** (l)Ed Eckstein/CORBIS, (r)Matt Meadows; **187** Mary Kay Denny/PhotoEdit; **188** (tl)Adam Woolfitt/CORBIS, (tr)Zigy Kaluzny/Stone, (bl)Barry Runk from Grant Heilman, (bc)Runk/Schoenberger from Grant Heilman, (br)Charles D. Winters/Photo Researchers; **189** (l)A. Ramey/PhotoEdit, (r)Dave G. Houser/CORBIS; **190** (l)Bettmann/CORBIS, (r)Stephen Frisch/Stock Boston; **191** (l)Colonial Williamsburg Foundation, (r)Dick Luria/FPG; **192** (l)Hal Beral/Visuals Unlimited, (r)Comar/Gerard; **193** (b)Woods Hole Oceanographic Institution, (others)Richard Megna/Fundamental Photography; **194** (t)Grant Heilman Photography, (b)Richard Megna/Fundamental Photographs; **195** (l)Morton & White, (r)Michael Newman/PhotoEdit; **198** (t)Stephen Frisch/Stock Boston, (b)Richard Megna/Fundamental Photographs; **199** Michael S. Yamashita/CORBIS; **201** (l)Nik Wheeler/CORBIS, (r)Stephen Marks/The Image Bank; **203** Matt Meadows; **204** Pictor; **206** PhotoTake/PictureQuest; **207** Lester V. Bergman/CORBIS; **210** Cliff Leight; **211** Matt Meadows; **213** Lawrence Migdale/Science Source/Photo Researchers; **215** (l)Yoav Levy/Phototake/QictureQuest, (r)Paul Silverman/Fundamental Photographs; **218** (l c)Paul Silverman/Fundamental Photographs, (r)Roberto De Gugliemo/Photo Researchers; **226** Doug Martin; **230 233** Matt Meadows; **234** Doug Martin; **240** Tracy J. Borland; **241** Matt Meadows; **244** Amanita Pictures; **247** Barry Runk from Grant Heilman; **249** Richard Megna/Fundamental photographs; **253** Amanita Pictures; **254** Simon Bruty/Stone; **255** Doug Martin; **258** Argonne National Laboratories; **259** Matt Meadows; **262** Holt Studios Int./Photo Researchers; **264** Hulton Getty/Archive Photos; **265** StudiOhio; **266** Matt Meadows; **267** Bud Roberts/Visuals Unlimited; **269** Matt Meadows; **270** Bill Horsman/Stock Boston/PictureQuest; **276** Keith Kent/Science Photo Library/Photo Researchers; **277** Matt Meadows; **278** (tl)Sara Gray/Stone, (tr)Matt Meadows, (bl)Robert Mathena/Fundamental Photographs, (br)B. D'Ohgee/Liaison Agency; **279** Charles D. Winters; **280** Geoff Butler; **282** Michelle Bridewell/PhotoEdit; **284** Bob Daemmrich/Stock Boston; **285** CORBIS; **286** Didier Charre/The Image Bank; **287** (l)Charles D. Winters/Photo Researchers, (r)Tim Courlas; **289** Geoff Butler; **292** Matt Meadows; **294** Telegraph Colour Library/FPG; **295** Matt Meadows; **296** Bob Daemmrich/Stock Boston; **297** Matt Meadows; **298** Mark Steinmetz; **299** National Bureau of Standards; **301 302** Matt Meadows; **308** Aaron Haupt; **309 310** Matt Meadows; **312** Grant Le Duc/Stock Boston; **313 314** Matt Meadows; **315** Ray Massey/Stone; **317** British Museum, London UK/Bridgeman Art Library; **318** Skip Comer; **321** Underwood & Underwood/CORBIS; **322** Matt Meadows; **323** John Neubaur/PhotoEdit; **328** (l)Kenji Kerins, (r)James Holmes, Oxford Centre for Molecular Sciences/Science Photo Library/Photo Researchers; **330** Aaron Haupt; **333** Liane Enkelis/Stock Boston/PictureQuest; **334** L. West/Photo Researchers; **336** George Hall/CORBIS; **338** (l)Patrick Ward/Stock Boston, (r)Peter Menzel/Stock Boston; **339 340 341 342** Matt Meadows; **344** Romilly Lockyer/The Image Bank; **344** Steve Chenn/CORBIS; **352** Thomas Del Brase/Stone; **353** Matt Meadows; **354** L.S. Stepanowicz/Visuals Unlimited; **355** Ronnie Kaufman/The Stock Market; **356** Chip Clark; **358** Richard Megna/Fundamental Photographs; **360** Doug Martin; **361** Charles D. Winters; **364** Aaron Haupt; **366** Andrew Syred/Science Photo Library/Photo Researchers; **367** Richard Megna/Fundamental Photographs; **369** Matt Meadows; **371** Richard Megna/Fundamental Photographs; **372** Matt Meadows; **373** David Nunuk/Science Photo Library/Photo Researchers; **375** Matt Meadows; **384** Ron Scherl Photography; **385** Amanita Pictures; **386** CORBIS; **388** Charles D. Winters/Photo Researchers; **389** Mark Turner-FDB/Liaison Agency; **392** KS Studio; **396** Morrison Photography; **397** Glencoe photo; **398** Rozlyn R. Masley/Photo OP; **399** (t)L.S. Stepanowicz, (b)Chip Clark; **400** John Noble/CORBIS; **401** (l to r)Mark A. Schneider/Visuals Unlimited, Runk/Schoenberger from Grant Heilman, Mark A. Schneider/Visuals Unlimited, Mark A. Schneider/Visuals Unlimited, Runk/Schoenberger from Grant Heilman, Mark A. Schneider/Visuals Unlimited, Ken Lucas/Visuals Unlimited; **402** Roberto De Gugliemo/Science Photo Library/Photo Researchers; **403** (l)Andrew J.G. Bell/CORBIS, (r)Ric Ergenbright/CORBIS; **407** (l)Liane Enkelis/Stock Boston/PictureQuest, (r)NASA/Roger Ressmeyer/CORBIS; **408** (l)Aaron Haupt, (r)Runk/Schoenberger from Grant Heilman; **411** Matt Meadows; **412** Tom Pantages; **418** Peter Skinner/Photo Researchers; **419 420** Matt Meadows; **426** Tony Freeman/PhotoEdit; **428** Dan Hamm/Stone; **430** Matt Meadows; **432** Jeffrey Muir Hamilton/Stock Boston; **433** David Parker/Science Photo Library/Photo Researchers; **434** Vanessa Vick/Photo Researchers; **435** (l)James Holmes/Celltech/Science Photo Library/Photo Researchers, (r)Matt

CONTENTS

Meadows; **436** (l)Larry Hamill, (r)Matt Meadows; **438** Richard Megna/Fundamental Photographs; **439** Matt Meadows; **441** Jim Sugar Photography/CORBIS; **442** Thomas Hovland from Grant Heilman; **445** Matt Meadows; **450** David & Doris Krumholz/Fundamental Photographs; **452** Jeff Lepore/Photo Researchers; **453** Matt Meadows; **454** (l)Paul Conklin/PhotoEdit, (c)Dr. Tony Brain/Science Photo Library/Photo Researchers, (r)David Young-Wolff/PhotoEdit; **456** (t)Richard Megna/Fundamental Photographs, (b)Andy Levin/Photo Researchers; **457** Kirtley-Perkins/Visuals Unlimited; **458** Matt Meadows; **459** (bl)Aaron Haupt, (br)Tony Craddock/Science Photo Library/Photo Researchers, (others)Richard Megna/Fundamental Photographs; **460** Runk/Schoenberger from Grant Heilman; **462** Mark Steinmetz; **463** Andrea Pistolesi/The Image Bank; **464** Aaron Haupt; **465** Richard T. Nowitz/CORBIS; **466 467 468** Matt Meadows; **469** Geoff Butler; **471** Stephen Frisch/Stock Boston; **476** Matt Meadows; **477** (l)Stan Skaggs/Visuals Unlimited, (c)Skip Comer, (r)Matt Meadows; **478** Clint Farlinger/Visuals Unlimited; **479** (l)Richard Hamilton Smith/CORBIS, (r)Kip & Pat Peticolas/Fundamental Photographs; **482** Dr. Gopal Murti/Science Photo Library/Photo Researchers; **488** AFP/CORBIS; **489** Matt Meadows; **490** (l)Davis Barber/PhotoEdit, (r)L.S. Stepanowicz; **491** Doug Martin; **492** Michael Pole/CORBIS; **493** Ted Rice; **494** William Stranton from Rainbow/PictureQuest; **495** NASA/Liaison Agency; **497** Matt Meadows; **498** Michael Newman/PhotoEdit; **499** Mark Burnett; **501** Lawrence Migdale/Photo Researchers; **503** Jim Strawser from Grant Heilman; **507** InterNetwork Media/Photodisc; **508** Dean Conger/CORBIS; **510** Hank de Lespinasse/The Image Bank; **511** CORBIS; **513** Steve Kaufman/Peter Arnold, Inc.; **514** Matt Meadows; **515** Mark Steinmetz; **516** Matt Meadows; **517** Bernhard Edmaier/Science Photo Library/Photo Researchers; **521** Matt Meadows; **528** NASA/Science Photo Library/Photo Researchers; **529** Matt Meadows; **530** (t)Greg Vaughn/Tom Stack & Associates, (b)Brian Bailey/Stone; **532** Mary Messenger/Stock Boston; **535 536** Richard Megna/Fundamental Photographs; **537** (l)Michael Dalton/Fundamental Photographs, (r)Richard Megna/Fundamental Photographs; **538** Matt Meadows; **539** Leonard Lessin/Peter Arnold, Inc.; **540** Art Wolfe/Stone; **541** Matt Meadows; **542 543** Stephen Frisch; **548** Ray Juno/The Stock Market; **551** Matt Meadows; **552** (l)AC Rochester Division of General Motors, (r)Aaron Haupt; **558** Grant Heilman Photography; **559** Geoff Butler; **562** Jan Halaska/Photo Researchers; **563** Robbie Jack/CORBIS; **564** Jeffrey Muir Hamilton/Stock Boston; **566** Matt Meadows; **570** Tim Courlas; **572** Matt Meadows; **574** Davis Barber/PhotoEdit; **575** Barry Runk from Grant Heilman; **577** Doug Martin; **578** CNRI/Science Photo Library/Photo Researchers; **579** Peter Essick/Aurora/PictureQuest; **580** Matt Meadows; **582** (t)Matt Meadows, (b)Hank Erdmann/Visuals Unlimited; **583** David Simson/Stock Boston/PictureQuest; **584 587** Matt Meadows; **588** PhotoDisc; **594** Ian Harwood; Ecoscene/CORBIS; **595** Geoff Butler; **596** Matt Meadows; **597** Aaron Haupt; **598** Doug Menuez/PhotoDisc; **600** Millard H. Sharp/Photo Researchers; **602** Matt Meadows; **609** Mitch Hrdlicka/PhotoDisc; **612** Geoff Butler; **613** David York/Medichrome; **614** Matt Meadows; **615** Jon Bertsch/Visuals Unlimited; **616 618 620 621** Matt Meadows; **622** Mike Buxton/CORBIS; **625** Tim David/Photo Researchers; **627** Matt Meadows; **628** (t)Mark Steinmetz, (b)PhotoDisc; **634** Thomas Eisner & D. Anashansly/Visuals Unlimited; **635** Mike & Carol Werner/Stock Boston; **636** (t) Doug Martin, (b)Bob Rogers; **637** Runk/Schoenberger from Grant Heilman; **638** Barry Runk from Grant Heilman; **639** (tl)Geoff Butler, (bl)Michael Newman/PhotoEdit, (r)David Young-Wolff/PhotoEdit; **641** Matt Meadows; **642** CORBIS; **644** Richard Megna/Fundamental Photographs; **645** Geoff Butler; **647** NASA; **651** Richard Megna/Fundamental Photographs; **652** Wolfgang Kaehler/CORBIS; **655** Matt Meadows; **656** (t to b)Dennie Cody/FPG, Dennie Cody/FPG, Richard Pasley/Stock Boston, Gunter Marx/CORBIS, Gunter Marx/CORBIS; **662** Ron Chapple/FPG; **663** Matt Meadows; **665** Bettmann/CORBIS; **674** Matt Meadows; **674** Lester V. Bergman/CORBIS; **675** Novastock/Tom Stack & Associates; **676** Aaron Haupt; **677** Michael W. Thomas/Pictor; **680** (t)Greig Cranna/Stock Boston, (c)Robert Fried/Stock Boston, (b)Visuals Unlimited; **681** Geoff Butler; **682** Marty Pardo; **684** Capital Features/The Image Works; **685** (t)Grant Heilman Photography, (b)Doug Martin; **686** (t)Charles E. Rotkin/CORBIS, (b)Stephen Frisch/Stock Boston/PictureQuest; **687** ALCOA; **690** Eric Sander/Liaison Agency; **696** Paul Souders/Liaison Agency; **697** Matt Meadows; **700** James Marshall/CORBIS; **703** Peter Menzel/Stock Boston/PictureQuest; **707** Tony Freeman/PhotoEdit; **709** (l)Peter Marbach from Grant Heilman, (c)George N. Matchneer, (r)Geoff Butler; **714** Bob Krist/CORBIS; **716** (l)Larry Hamill, (r)Archive Photos; **719** Aaron Haupt; **723** (l)Mark Steinmetz, (c)Rudi Von Briel, (r)Mark Steinmetz; **724** Bonnie Kamin/PhotoEdit; **726** Bob Daemmrich/Stock Boston/PictureQuest; **727** Myrleen Cate/PhotoEdit; **729** Matt Meadows; **730** David M. Dennis; **736** Roger Tully/Stone; **737** Matt Meadows; **741** Kevin C. Rose/The Image Bank; **742** Nancy Sheehan/PhotoEdit; **743** Steven Peters/Stone; **744** (t)Tony Freeman/PhotoEdit, (b)Jeff Greenberg/Visuals Unlimited **745** Bettmann/CORBIS; **746** (t)Doug Martin, (b) Dean Siracusa/FPG; **748** (l)B. Borrell Casals, Frank Lane Picture Agency/CORBIS, (r)Deborah Denker/Liaison Agency; **749** (l)Doug Martin, (r)Telegraph Colour Library/FPG; **750** (t)Ralph A. Clevenger/CORBIS, (b)Geoff Butler; **751** (l r)Larry Hamill, (c)Matt Meadows, **752** Charles Michael Murray/CORBIS; **754** Matt Meadows; **758** David Toase/PhotoDisc; **761** (l)Jim McGuire/Index Stock, (r)Mark Steinmetz; **762** (t)Aaron Haupt, (b)Geoff Butler; **764** (t)David Brooks/The Stock Market, (b)CORBIS; **765 767** Matt Meadows; **768** Ales Fevzer/CORBIS; **774** David Ulmer/Stock Boston; **775** Richard Megna/Fundamental Photographs; **779** Peter Cade/Stone; **780** Quest/Science Photo Library/Photo Researchers; **782** (l)Aaron Haupt, **782** (r)Jeff Smith/Fotosmith, (l)Aaron Haupt; **783** Aaron Haupt; **784** (l)PhotoDisc, (r)Digital Stock; **785** Mike Hopiak for the Cornell Laboratory of Ornithology; **787** (t)Lynn M. Stone, (b)William J. Weber; **793** Gregory Ochocki/Photo Researchers; **794** Lori Adamski Peek/Stone; **795** Aaron Haupt; **797** Matt Meadows; **798** Spencer Grant/PhotoEdit; **804** CORBIS; **806** (t)Paul Silverman/Fundamental Photographs, (b)Bettmann/CORBIS; **809** (l)Richard T. Nowitz/Photo Researchers, (r)James King-Holmes/Science Photo Library/Photo Researchers; **815** Fermi Lab/Photo Researchers; **818** Vince Michaels/Stone; **820** (t)Sygma/CORBIS, (b)Kenneth Garrett/National Geographic Image Collection; **824** (t)Wolfgang Kaehler/CORBIS, (b)Reuters/Str/Archive Photos; **825** (l)Tim Wright/CORBIS, (r)Alex Bartel/Science Photo Library/Photo Researchers; **826** U.S. DOE/Science Photo Library/Photo Researchers; **827** Michael Collier/Stock Boston; **828** (l)Klaus Guldbrandsen/Science Photo Library/Photo Researchers, (r)Aaron Haupt; **829** (t)JISAS/Lockheed/Science Photo Library/Photo Researchers, (b)Mark Harmel/Stone; **833** Matt Meadows; **840** VCG/FPG; **841** Telegraph Colour Library/FPG; **843** Edna Douthat; **846** (t)NASA, (b)EPA Documerica; **847** Telegraph Colour Library/FPG; **848** (l)Richard A. Cooke/CORBIS, (r)Ray Pfortner/Peter Arnold, Inc.; **852** Nubar Alexanian/CORBIS; **853** Tom McGuire; **855** NASA; **857** (tl)Mark A. Schneider/Photo Researchers, (tcl)John Greim/Medichrome, (tcr)George Whitely/Photo Researchers, (tr)Cobalt, (bl)Doug Martin, (bc)PhotoDisc, (br)Will & Deni McIntyre/Photo Researchers; **863** Matt Meadows; **864** Spencer Grant/Stock Boston/PictureQuest; **888** Larry B. Jennings/Photo Researchers; **888** Matt Meadows; **889** (l)NIBSC/Science Photo Library/Photo Researchers, (r)Edna Douthat; **890** (t)PhotoDisc, (b)Dustin W. Carr & Harold G. Craighead/Physics New Graphics/American Institute of Physics; **891** CNRI/Science Photo Library/Photo Researchers; **895** Matt Meadows; **896** Brian Heston; **897** George Hall/Corbis; **898** Brent Turner; **900** Phyllis Picardi/Stock Boston; **902** Matt Meadows; **903** Kenji Kerins; **908** Matt Meadows; **909** Alexander Lowry/Photo Researchers; **910** Michael Collier/Stock Boston; **911** Geoff Butler.