Answers to Problem-Solving Practice Problems

Chapter 1

1.1 (1) Define the problem: You are asked to find the volume of the sample, and you know the mass.
   (2) Develop a plan: Density relates mass and volume and is the appropriate conversion factor, so look up the density in a table. Volume is proportional to mass, so the mass has to be either multiplied by the density or multiplied by the reciprocal of the density. Use the units to decide which.
   (3) Execute the plan: According to Table 1.1, the density of benzene is 0.880 g/mL. Setting up the calculation so that the unit (grams) cancels gives
   
   \[ 4.33 \text{ g} \times \frac{1 \text{ mL}}{0.880 \text{ g}} = 4.92 \text{ mL} \]

   Notice that the result is expressed to three significant figures, because both the mass and the density had three significant figures.
   (4) Check your answer: Because the density is a little less than 1.00 g/mL, the volume in milliliters should be a little larger than the mass in grams. The calculated answer, 4.92 mL, is a little larger than the mass, 4.33 g.

1.2 Substance A must be a mixture since some of it dissolves and some substance B, does not.

   Substance C is the soluble portion of substance A. Since all of substance C dissolves in water there is no way to determine how many components it has. Additionally, it is not possible to determine whether the one or more components themselves are elements or compounds. Therefore it is not possible to say whether C is an element, a compound, or a mixture.

1.3 Oxygen is \( \text{O}_2 \) ozone is \( \text{O}_3 \). Oxygen is a colorless, odorless gas; ozone is a pale blue gas with a pungent odor.

Chapter 2

2.1 (a) 10 gal = 40 qt. There are 1.0567 quarts per liter, so
   
   \[ 40 \text{ qt} \times \frac{1 \text{ L}}{1.0567 \text{ qt}} = 37.9 \text{ L or 38 L} \]
   
   (b) 100 yds \( \times \frac{3 \text{ ft}}{1 \text{ yd}} \times \frac{12 \text{ in}}{1 \text{ ft}} \times \frac{2.54 \text{ cm}}{1 \text{ in}} \times \frac{1 \text{ m}}{100 \text{ cm}} = 91.46 \text{ m} \]

2.2 (a) 1 lb = 453.59 g, so 5 lb = 2268 g.
   (b) 3 pt \( \times \frac{1 \text{ qt}}{2 \text{ pt}} \times \frac{1 \text{ L}}{1 \text{ qt}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 1420 \text{ mL} \)
   (c) \( \frac{1.420 \text{ L}}{5 \text{ L}} \times 100\% = 28\% \)

2.3 Work with the numerator first: 165 mg is 0.165 g. Work with the denominator next: 1 dL = 0.1 L. Therefore, the concentration is
   
   \[ \frac{0.165 \text{ g}}{0.1 \text{ L}} = 1.65 \text{ g/L} \]

2.4 (a) 0.000602 g 3 sf
   (b) 22.871 mg 5 sf
   (c) 344 °C 3 sf
   (d) 100.0 mL 4 sf
   (e) 0.00042 m 2 sf
   (f) 0.002001 L 4 sf

2.5 (a) 244.2 + 0.1732 = 244.4
   (b) 6.19 × 5.2222 = 32.3
   (c) \( \frac{7.2234}{11.3851} = -0.62 \)

2.6 (a) A phosphorus atom (Z = 15) with 16 neutrons has A = 31.
   (b) A neon-22 atom has A = 22 and Z = 10, so the number of electrons must be 10 and the number of neutrons must be \( A - Z = 22 - 10 = 12 \) neutrons.
   (c) The periodic table shows us that the element with 82 protons is lead. The atomic weight of this isotope of lead is 207 + 125 = 207, so the correct symbol is \( ^{207}\text{Pb} \).

2.7 The magnesium isotope with 12 neutrons has 12 protons, so Z = 12 and the notation is \( ^{24}\text{Mg} \); the isotope with 13 neutrons has Z = 12 and \( ^{25}\text{Mg} \); and the isotope with 14 neutrons has Z = 12 and \( ^{26}\text{Mg} \).

2.8 75 g wire \( \times \) (fraction Ni) = g Ni, so 75 g Ni \( \times \frac{0.80}{60} = 0.60 \text{ g Ni} \). For Cr we have 75 g Cr \( \times \frac{0.20}{15} = 15.0 \text{ g Cr} \). Or, we could have solved for the mass of Cr from 75 g wire = 60 g Ni = 15 g Cr.

2.9 (a) 1 mg Mo = \( 1 \times 10^{-3} \) g Mo
   
   \[ 1 \times 10^{-3} \text{ g Mo} \times \frac{1 \text{ mol Mo}}{95.94 \text{ g Mo}} = 1.04 \times 10^{-3} \text{ mol Mo} \]
   (b) \( 5.00 \times 10^{-3} \) mol Au \( \times \) \( \frac{196.97 \text{ g Au}}{1 \text{ mol Au}} = 0.985 \text{ g Au} \)

Chapter 3

3.1 (a) \( \text{C}_4\text{H}_{11}\text{O}_3\text{N}_3\text{P}_3 \) (b) \( \text{C}_4\text{H}_2\text{O}_2\text{N} \) (c) \( \text{C}_2\text{H}_2\text{O}_4 \)

3.2 (a) Sulfur dioxide
   (b) Boron trifluoride
   (c) Carbon tetrachloride

3.3 Yes, a similar trend would be expected. The absolute values of the boiling points of the chlorine-containing compounds would be different from the alkane parents, but the differences between successive chlorine-containing compounds should follow a similar trend as for the alkane themselves.
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3.11 (a) The molar mass of sucrose, $C_{12}H_{22}O_{11}$, is 342.3 g/mol.

(b) $Cr^{2+}$ is possible because chromium is a transition metal that forms $2^+\text{ and } 3^+\text{ ions.}$

(c) Strontium is a Group 2A metal and forms $2^+\text{ ions;}$ thus, a $Sr^{2+}\text{ ion is highly unlikely.}$

3.12 (a) The molar mass of cholesterol is 386.7 g/mol.

(b) $Mn_2(SO_4)_3$ is manganese(III) sulfate.

3.13 (a) The molar mass of $Si$ in 1 mol $SiO_2$ is 28.0855 g. The mass of $O$ in 1 mol $SiO_2$ is 31.9988 g.

\[
% \text{Si in } SiO_2 = \frac{28.0855 \text{ g}}{60.08 \text{ g}} \times 100\% = 46.7\% \text{ Si}
\]

\[
% \text{O in } SiO_2 = \frac{31.9988 \text{ g}}{60.08 \text{ g}} \times 100\% = 53.3\% \text{ O}
\]

3.14 The molar mass of hydrated nickel chloride is

\[
58.69 \text{ g/mol} + 2(35.45 \text{ g/mol})
\]

\[
= 12(1.008 \text{ g/mol}) + 6(16.00 \text{ g/mol}) = 237.69 \text{ g/mol}
\]

The percentages by weight for each element are found from the mass of each element in 1 mole of hydrated nickel chloride to the molar mass of hydrated nickel chloride:

\[
\frac{58.69 \text{ g Ni}}{237.69 \text{ g hydrated nickel chloride}} \times 100\% = 24.7\% \text{ Ni}
\]

\[
\frac{70.90 \text{ g Cl}}{237.69 \text{ g hydrated nickel chloride}} \times 100\% = 29.8\% \text{ Cl}
\]

\[
\frac{12.096 \text{ g H}}{237.69 \text{ g hydrated nickel chloride}} \times 100\% = 5.09\% \text{ H}
\]

\[
\frac{96.00 \text{ g O}}{237.69 \text{ g hydrated nickel chloride}} \times 100\% = 40.4\% \text{ O}
\]

3.15 A 100 g sample of the phosphorus oxide contains 43.64 g P and 56.36 g O.

\[
43.64 \text{ g P} \times \frac{1 \text{ mol P}}{30.9738 \text{ g P}} = 1.41 \text{ mol P}
\]

\[
56.36 \text{ g O} \times \frac{1 \text{ mol O}}{15.9994 \text{ g O}} = 3.52 \text{ mol O}
\]

The mole ratio is

\[
\frac{3.52 \text{ mol O}}{1.41 \text{ mol P}} = \frac{2.50 \text{ mol O}}{1.00 \text{ mol P}}
\]

There are 2.5 oxygen atoms for every phosphorus atom. Thus, the empirical formula is $P_2O_5$. The molar mass corresponding to this empirical formula is

\[
2 \text{ mol P} \times \frac{30.9738 \text{ g P}}{1 \text{ mol P}} + \frac{5 \text{ mol O} \times 15.9994 \text{ g O}}{1 \text{ mol O}} = 141.9 \text{ g/mol}
\]

The known molar mass is 283.89 g/mol. The molar mass is twice as large as the empirical formula mass, so the molecular formula of the oxide is $P_2O_5$.

3.16 Find the number of moles of each element in 100.0 g of vitamin C.

\[
40.9 \text{ g C} \times \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 3.405 \text{ mol C}
\]

\[
4.58 \text{ g H} \times \frac{1 \text{ mol H}}{1.0079 \text{ g H}} = 4.544 \text{ mol H}
\]

\[
54.5 \text{ g O} \times \frac{1 \text{ mol O}}{15.9994 \text{ g O}} = 3.406 \text{ mol O}
\]

Find the mole ratios.
4.1 (a) Decomposition reaction:

4.2 (a) Decomposition reaction:

2 Al(OH)₃(s) → Al₂O₃(s) + 3 H₂O(g)

(b) Combination reaction:

Na₂O(s) + H₂O(l) → 2 NaOH(aq)

(c) Combination reaction:

N₂(g) + 2 O₂(g) → 2 NO₂(g)

(d) Exchange reaction:

3 NaOH(aq) + H₃PO₄(aq) → Na₃PO₄(aq) + 3 H₂O(l)

(e) Displacement:

3 C(s) + Fe₂O₃(s) → 3 CO(g) + 2 Fe(s)

4.3 (a) 2 Cr(s) + 3 Cl₂(g) → 2 CrCl₃(s)

(b) Combination reaction:

As₂O₃(s) + 3 H₂(g) → 2 As(s) + 3 H₂O(l)

(c) Combination reaction:

C₆H₈O₆(s) + 3 O₂(g) → 2 CO₂(g) + 3 H₂O(l)

(d) Exchange reaction:

3 NaOH(aq) + H₃PO₄(aq) → Na₃PO₄(aq) + 3 H₂O(l)

4.4 (a) C₂H₆O₂ + 3 O₂ → 2 CO₂ + 3 H₂O

(b) C₂H₆O₂ + 2 O₂ → 2 CO + 3 H₂O

4.5 0.433 mol hematite needs 0.433 mol CO2.

4.6 (a) 0.300 mol cassiterite leaves 0.300 mol Sn.

4.7 (a) 57 g C × \( \frac{1 \text{ mol C}}{12.01 \text{ g C}} \) × \( \frac{1 \text{ mol O}}{2 \text{ mol C}} \) = 2.50 g O

(b) 57 g C × \( \frac{1 \text{ mol C}}{12.01 \text{ g C}} \) × \( \frac{2 \text{ mol CO}}{1 \text{ mol C}} \) = 118.7 g CO

4.8 64.6 g MgCl₂ × \( \frac{1 \text{ mol MgCl₂}}{95.2104 \text{ g MgCl₂}} \) = 0.678 × 10⁻² mol MgCl₂

The same number of moles of Mg as MgCl₂ are involved, so

6.78 × 10⁻² mol Mg × \( \frac{24.3050 \text{ g Mg}}{1 \text{ mol Mg}} \) = 1.65 g Mg

1.65 g Mg × \( \frac{1 \text{ mol sample}}{1.72 \text{ g sample}} \) × 100% = 95.9% Mg in sample

4.9 0.75 mol CO₂ × \( \frac{1 \text{ mol (NH₄)₂CO₃}}{1 \text{ mol CO₂}} \) = 0.75 mol (NH₄)₂CO₃

4.10 (a) 4.01 g CO₂ × \( \frac{1 \text{ mol CO₂}}{44.01 \text{ g CO₂}} \) × \( \frac{1 \text{ mol C}}{1 \text{ mol CO₂}} \) = 0.091 mol C

(b) Determine the quantity of CO₂ produced by each reactant; the limiting reactant produces the lesser quantity.

3.5 g CS₂ × \( \frac{1 \text{ mol CO₂}}{76.0 g \text{ CS₂}} \) = 0.046 mol CO₂

4.4 0.433 mol hematite needs 0.433 mol CO₂.

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4.8 64.6 g MgCl₂ × \( \frac{1 \text{ mol MgCl₂}}{95.2104 \text{ g MgCl₂}} \) = 0.678 × 10⁻² mol MgCl₂

4.9 0.75 mol CO₂ × \( \frac{1 \text{ mol (NH₄)₂CO₃}}{1 \text{ mol CO₂}} \) = 0.75 mol (NH₄)₂CO₃

4.10 (a) 4.01 g CO₂ × \( \frac{1 \text{ mol CO₂}}{44.01 \text{ g CO₂}} \) × \( \frac{1 \text{ mol C}}{1 \text{ mol CO₂}} \) = 0.091 mol C

(c) The yield of SO₂ must be calculated using the limiting reactant, CS₂.

3.5 g CS₂ × \( \frac{1 \text{ mol CO₂}}{76.0 g \text{ CS₂}} \) × \( \frac{2 \text{ mol SO₂}}{1 \text{ mol CO₂}} \) × \( \frac{64.1 g \text{ SO₂}}{1 \text{ mol SO₂}} \) = 5.9 g SO₂

4.11 Find the number of moles of each reactant.

100. g SiCl₄ × \( \frac{1 \text{ mol SiCl₄}}{169.90 \text{ g SiCl₄}} \) = 0.589 mol SiCl₄

100. g Mg × \( \frac{1 \text{ mol Mg}}{24.3050 \text{ g Mg}} \) = 4.11 mol Mg

Find the mass of Si produced, based on the mass available of each reactant.

0.589 mol SiCl₄ × \( \frac{1 \text{ mol Si}}{1 \text{ mol SiCl₄}} \) × \( \frac{118.00 \text{ g Si}}{1 \text{ mol SiCl₄}} \) = 16.5 g Si

4.12 To make 1.0 kg CH₃OH with 85% yield will require using enough reactant to produce 1000/0.85, or 1180 g CH₃OH.

1180 g CH₃OH × \( \frac{1 \text{ mol CH₃OH}}{32.0504 \text{ g CH₃OH}} \) = 36.83 mol CH₃OH

73.65 mol H₂ × \( \frac{1 \text{ mol H₂}}{1 \text{ mol CH₃OH}} \) = 73.65 mol H₂

4.13 Calculate the mass of Cu₂S you should have produced and compare it with the amount actually produced.

2.50 g Cu × \( \frac{1 \text{ mol Cu}}{63.546 \text{ g Cu}} \) = 3.93 × 10⁻² mol Cu

3.93 × 10⁻² mol Cu × \( \frac{8 \text{ mol Cu₂S}}{1 \text{ mol Cu}} \) = 1.97 × 10⁻² mol Cu₂S

1.97 × 10⁻² mol Cu₂S × \( \frac{159.16 \text{ g Cu₂S}}{1 \text{ mol Cu₂S}} \) = 3.14 g Cu₂S

2.53 g × 100% = 80.6% yield was obtained

Your synthesis met the standard.

4.14 (a) 491 mg CO₂ × \( \frac{1 \text{ mol CO₂}}{10^3 \text{ mg CO₂}} \) × \( \frac{1 \text{ mol O₂}}{44.01 \text{ g CO₂}} \) × \( \frac{1 \text{ mol C}}{1 \text{ mol O₂}} \) = 1.116 × 10⁻² mol C

1.116 × 10⁻² mol C × \( \frac{12.01 \text{ g C}}{1 \text{ mol C}} \) = 0.1340 g C = 134.0 mg C
A.48 \hspace{1cm} ANSWERS TO PROBLEM-SOLVING PRACTICE PROBLEMS

4.15 (a) \( \text{BaCl}_2(\text{aq}) \)

5.2 (a) \( \text{This exchange reaction forms insoluble nickel hydroxide and aqueous sodium chloride} \)

5.1 (a) \( \text{NaF is soluble} \)

5.4 Any of the strong acids or bases in Table 5.2 would be strong electrolytes. Any of the weak acids or bases in Table 5.2 would be weak electrolytes. Any organic compound that yields no ions on dissolution would be a nonelectrolyte.

5.5 \( \text{H}_3\text{PO}_4(\text{aq}) + 3 \text{NaOH}(\text{aq}) \rightarrow \text{Na}_3\text{PO}_4(\text{aq}) + 3 \text{H}_2\text{O}(\ell) \)

5.6 (a) Sulfuric acid and magnesium hydroxide
(b) Carbonic acid and strontium hydroxide

5.7 \( 2 \text{HCN}(\text{aq}) + \text{Ca(OH)}_2(\text{aq}) \rightarrow \text{Ca(NCN)}_2(\text{aq}) + 2 \text{H}_2\text{O}(\ell) \)

5.8 The oxidation numbers of Fe and Sb are 0 (Rule 1). The oxidation numbers in \( \text{Sb}_4\text{S}_3 \) are +3 for \( \text{Sb}^{3+} \) and −2 for \( \text{S}^{2−} \) (Rules 2 and 4). The oxidation numbers in \( \text{FeS} \) are +2 for \( \text{Fe}^{2+} \) and −2 for \( \text{S}^{2−} \) (Rules 2 and 4).

5.9 In the reaction \( \text{PbO}(s) + \text{CO}_2(g) \rightarrow \text{Pb}(s) + \text{CO}_2(g) \), \( \text{Pb}^{4+} \) is reduced to \( \text{Pb} \). \( \text{Pb}^{2+} \) is the oxidizing agent. \( \text{C}^{2−} \) is oxidized to \( \text{C}^{4+} \); \( \text{C}^{2−} \) is the reducing agent.

5.10 Reactions (a) and (b) will occur. Aluminum is above copper and chromium in Table 5.5; therefore, aluminum will be oxidized and acts as the reducing agent in reactions (a) and (b). In reaction (a), \( \text{Cr}^{3+} \) is reduced, and \( \text{Cr}^{3+} \) is the oxidizing agent. \( \text{Cr}^{3+} \) is the oxidizing agent in reaction (b) and is reduced to \( \text{Cr} \) metal. Reactions (c) and (d) do not occur because Pt cannot reduce \( \text{H}^{+} \), and \( \text{Au} \) cannot reduce \( \text{Ag}^{+} \).

5.11 \( 36.0 \text{~g Na}_2\text{SO}_4 \times \frac{1 \text{~mol Na}_2\text{SO}_4}{142.0 \text{~g Na}_2\text{SO}_4} = 0.254 \text{~mol Na}_2\text{SO}_4 \)

Therefore, the empirical formula is \( \text{Sn}_4 \).

5.12 \( V(\text{conc}) = \frac{0.500 \text{~mL}}{0.0523 \text{~mL}} = 0.015 L = 15 \text{~mL} \)

5.13 (a) \( 1.00 \text{~L of 0.125 M Na}_2\text{CO}_3 \) contains \( 0.125 \text{~mol Na}_2\text{CO}_3 \).

Therefore, put 40 mL of the more concentrated solution into a container and add water until the solution volume equals 100 mL.

(b) Use water to dilute a specific volume of the 0.125 M solution to 100 mL.

Therefore, put 40 mL of the more concentrated solution into a container and add water until the solution volume equals 100 mL.

5.14 \( 1.2 \times 10^{10} \text{~kg NaOH} \times \frac{1 \text{~mol NaOH}}{40.04 \text{~g NaOH}} \times \frac{2 \text{~mol NaCl}}{2 \text{~mol NaOH}} \times \frac{58.5 \text{~g NaCl}}{1 \text{~L brine}} \times \frac{1 \text{~L brine}}{360 \text{~g NaCl}} = 4.9 \times 10^{10} \text{~L} \)
Answers to Exercises

Chapter 1

1.1 (a) These temperatures can be compared to the boiling point of water, 212 °F or 100 °C. So 110 °C is a higher temperature than 100 °F. (b) These temperatures can be compared to normal body temperature, 98.6 °F or 37.0 °C. So 36 °C is a lower temperature than 100 °F. (c) This temperature can be compared to normal body temperature, 37.0 °C. Since body temperature is above the melting point, gallium held in one’s hand will melt.

1.2 Reference to the figure on page 10 indicates that kerosene is the top layer, vegetable oil is the middle layer, and water is the bottom layer. (a) Since the least dense liquid will be the top layer and the densest liquid will be the bottom layer, the densities increase in the order kerosene, vegetable oil, water. (b) If vegetable oil is added to the tube, the top and bottom layers will remain the same, but the middle layer will become larger. (c) If kerosene is now added to the tube the top layer will grow, but the middle and bottom layers will remain the same. The order of levels will not change. Density does not depend on the quantity of material present. So no matter how much of each liquid is present, the densities increase in the order kerosene, vegetable oil, water.

1.3 (a) Properties: blue (qualitative), melts at 99 °C (quantitative) Change: melting (b) Properties: white, cubic (both qualitative) Change: none (c) Properties: mass of 0.125 g, melts at 327 °C (both quantitative) Change: melting (d) Properties: colorless, vaporizes easily (both qualitative), boils at 78 °C, density of 0.789 g/mL (both qualitative) Changes: vaporizing, boiling

1.4 Physical change: boiling water Chemical changes: combustion of propane, cooking the egg

1.5 (a) Homogeneous mixture (solution) (b) Heterogeneous mixture (contains carbon dioxide gas bubbles in a solution of sugar and other substances in water) (c) Heterogeneous mixture of dirt and oil (d) Element: diamond is pure carbon (e) Modern quarters (since 1965) are composed of a pure copper core (that can be seen when they are viewed side-on) and an outer layer of 75% Cu, 25% Ni alloy, so they are heterogeneous matter. Pre-1965 quarters are fairly pure silver. (f) Compound: contains carbon, hydrogen, and oxygen

1.6 (a) Energy from the sun warms the ice and the water molecules vibrate more; eventually they break away from their fixed positions in the solid and liquid water forms. As the temperature of the liquid increases, some of the molecules have enough energy to become widely separated from the other molecules, forming water vapor (gas). (b) Some of the water molecules in the clothes have enough speed and energy to escape from the liquid state and become water vapor; these molecules are carried away from the clothes by breezes or air currents. Eventually nearly every water molecule in the clothes vaporizes, and the clothes become dry. (c) Water molecules from the air come into contact with the cold glass, and their speeds are decreased, allowing them to become liquid. As more and more molecules enter the liquid state, droplets form on the glass. (d) Some water molecules escape from the liquid state, forming water vapor. As more and more molecules escape, the ratio of sugar molecules to water molecules becomes larger and larger, and eventually some sugar molecules start to stick together. As more and more sugar molecules stick to each other, a visible crystal forms. Eventually all of the water molecules escape, leaving sugar crystals behind.

1.7 (a) Tellurium, Te, earth (Latin tellus means earth); uranium, U, for Uranus; neptunium, Np, for Neptune; and plutonium, Pu, for Pluto. (b) Californium, Cf (c) Curium, Cm, for Marie Curie; and meitnerium, Mt, for Lise Meitner (d) Scandium, Sc, for Scandinavia; gallium, Ga, for France (Latin Gallia means France); germanium, Ge, for Germany; ruthenium, Ru, for Russia; europium, Eu, for Europe; polonium, Po, for Poland; francium, Fr, for France; americium, Am, for America; californium, Cf, for California (e) H, He, C, N, O, F, Ne, P, S, Cl, Ar, Se, Br, K, I, Xe, At, Rn

1.8 (a) Elements that consist of diatomic molecules are H, N, O, F, Cl, Br, and I. At is radioactive and there is probably less than 50 mg of naturally occurring At on earth, but it does form diatomic molecules; H, N, O, plus group 7A. (b) Metalloids are B, Si, Ge, As, Sb, and Te; along a zigzag line from B to Te.

1.9 Tin and lead are two different elements, allotropes are two different forms of the same element, so tin and lead are not allotropes.

Chapter 2

2.1 The movement of the comb though your hair removes some electrons, leaving slight charges on your hair and the comb. The charges must sum to zero; therefore, one must be slightly positive and one must be slightly negative, so they attract each other.

2.2 (a) A nucleus is about one ten-thousandth as large as an atom, so 100 m × (1 × 10^-2) = 1 × 10^-1 m = 1 cm. (b) Many everyday objects are about 1 cm in size—for example, a grape.

2.3 The statement is wrong because two atoms that are isotopes always have the same number of protons. It is the number of neutrons that varies from one isotope of an element to another.

2.4 Atomic weight of lithium = (0.07500)(6.015121 amu) + (0.9250)(7.016003 amu) = 6.499802 amu = 6.94936 amu, or 6.941 amu

2.5 Because the most abundant isotope is magnesium-24 (78.70%), the atomic weight of magnesium is closer to 24 than to 25 or 26, the mass numbers of the other magnesium isotopes, which make up approximately 21% of the remaining mass. The simple arithmetic average is (24 + 25 + 26)/3 = 25, which is larger than the atomic weight. In the arithmetic average, the relative abundance of each magnesium isotope is 53%, far less than the actual percent abundance of magnesium-24, and much more than the natural percent abundances of magnesium-25 and magnesium-26.

2.6 There is no reasonable pair of values for the mass numbers for Ga that would have an average value of 69.72.

2.7 Start by calculating the number of moles in 10.00 g of each element

\[
\begin{align*}
10.00 \text{ g Li} & \times \frac{1 \text{ mol Li}}{6.941 \text{ g Li}} = 1.441 \text{ mol Li} \\
10.00 \text{ g Ir} & \times \frac{1 \text{ mol Ir}}{192.22 \text{ g Ir}} = 0.05202 \text{ mol Ir}
\end{align*}
\]

Multiply the number of moles of each element by Avogadro’s number.
A.64  ANSWERS TO EXERCISES

1.441 mol Li × 6.022 × 10²³ atoms/mol = 8.678 × 10²⁵ atoms Li
0.05202 mol Ir × 6.022 × 10²³ atoms/mol = 3.133 × 10²² atoms Ir

Find the difference:
(8.678 × 10²⁵) − (3.133 × 10²²) = 5.545 × 10²² more atoms of Li than Ir

2.8 1. (a) 15 metals: potassium (K), calcium (Ca), scandium (Sc), titanium (Ti), vanadium (V), chromium (Cr), manganese (Mn), iron (Fe), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), and gallium (Ga)
(b) Three nonmetals: selenium (Se), bromine (Br), and krypton (Kr)
(c) Two metalloids: germanium (Ge) and arsenic (As)
2. (a) Groups 1A (except hydrogen), 2A, 1B, 2B, 3B, 4B, 5B, 6B, 7B, 8B
(b) Groups 7A and 8
(c) None
3. Period 6
2.9 The question should ask: Which of the following men does not have an element named after him? The correct answer to the question, after it is properly posed, is Isaac Newton.

Chapter 3

3.1 Propylene glycol structural formula:
\[ \text{HO} - \text{C} = \text{C} - \text{OH} \]
H H H
Condensed formula:
\[ \text{HO} - \text{OH} \]
\[ \text{CH}_3 \text{CH}_2 \text{CH}_2 \]

Molecular formula: \( \text{C}_3\text{H}_8\text{O}_2 \)
3.2 (a) \( \text{CS}_2 \)
(b) \( \text{PCl}_3 \)
(c) \( \text{SBr}_3 \)
(d) \( \text{SeO}_2 \)
(e) \( \text{OF}_2 \)
(f) \( \text{XeO}_3 \)
3.3 (a) \( \text{C}_6\text{H}_{12} \) and \( \text{C}_6\text{H}_{16} \)
(b) \( \text{C}_4\text{H}_{10} \) and \( \text{C}_3\text{H}_8 \)
14 carbon atoms and 30 hydrogen atoms
3.4 The structural and condensed formulas for three constitutional isomers of five-carbon alkanes (pentanes) are:

\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \]
H H H H H
CH\(_3\)CH\(_2\)CH\(_2\)CH\(_3\)

\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} \]
H H H H H
CH\(_3\)CH\(_2\)CH\(_2\)CH\(_3\)

\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{H} \]
H H H H
CH\(_3\)CH\(_2\)CH\(_3\)

\[ \text{H} - \text{C} - \text{C} - \text{C} - \text{H} \]
H H H
CH\(_3\)CH\(_2\)CH\(_3\)

5.5 The compound is a solid at room temperature and is soluble in water, so it is likely to be an ionic compound.
3.6 (a) 174.18 g/mol
(b) 386.60 g/mol
(c) 398.07 g/mol
(d) 194.19 g/mol
3.7 The statement is true. Because both compounds have the same formula, they have the same molar mass. Thus, 100 g of each compound contains the same number of moles.
3.8 Epsom salt is \( \text{MgSO}_4 \cdot 7\text{H}_2\text{O} \), which has a molar mass of 246 g/mol.
\[ 20 \text{ g} \times \frac{1 \text{ mol}}{246 \text{ g}} = 8.1 \times 10^{-2} \text{ mol} \] Epsom salt
3.9 (a) \( \text{SF}_6 \) molar mass is 146.06 g/mol; 1.000 mol \( \text{SF}_6 \) contains 32.07 g S and 18.9984 \( \times 6 = 115.99 \) g F The mass percents are
\[ \frac{32.07 \text{ g S}}{146.06 \text{ g SF}_6} \times 100\% = 21.96\% \text{ S} \]
\[ 100\% - 21.96\% = 78.04\% \text{ F} \]
(b) \( \text{C}_2\text{H}_{12}\text{O}_{11} \) has a molar mass of 342.3 g/mol; 1.000 mol \( \text{C}_2\text{H}_{12}\text{O}_{11} \) contains
\[ 12.011 \times 12 = 144.13 \text{ g C} \]
\[ 1.0079 \times 22 = 22.17 \text{ g H} \]
\[ 15.9994 \times 11 = 175.99 \text{ g O} \]
The mass percents of the three elements are
\[ \frac{144.13 \text{ g C}}{342.3 \text{ g}} \times 100\% = 42.12\% \text{ C} \]
\[ \frac{22.17 \text{ g H}}{342.3 \text{ g}} \times 100\% = 6.478\% \text{ H} \]
\[ \frac{175.99 \text{ g O}}{342.3 \text{ g}} \times 100\% = 51.41\% \text{ O} \]
(c) \( \text{Al}_2(\text{SO}_4)_3 \) molar mass is 342.15 g/mol; 1.000 mol \( \text{Al}_2(\text{SO}_4)_3 \) contains
\[ 26.9815 \times 2 = 53.96 \text{ g Al} \]
\[ 32.066 \times 3 = 96.20 \text{ g S} \]
\[ 15.9994 \times 12 = 192.0 \text{ g O} \]
The mass percents of the three elements are
\[ \frac{53.96 \text{ g Al}}{342.15 \text{ g}} \times 100\% = 15.77\% \text{ Al} \]
\[ \frac{96.20 \text{ g S}}{342.15 \text{ g}} \times 100\% = 28.12\% \text{ S} \]
\[ \frac{192.0 \text{ g O}}{342.15 \text{ g}} \times 100\% = 56.12\% \text{ O} \]
(d) \( \text{U(OTeF}_6) \) molar mass is 1669.6 g/mol; 1.000 mol \( \text{U(OTeF}_6) \) contains 238.0289 g of U and
\[ 15.9994 \times 6 = 96.00 \text{ g O} \]
\[ 127.60 \times 6 = 765.6 \text{ g Te} \]
\[ 18.9984 \times 30 = 570.0 \text{ g F} \]
The mass percents of the four elements are
\[ \frac{238.0289 \text{ g U}}{1669.6 \text{ g}} \times 100\% = 14.26\% \text{ U} \]
\[ \frac{96.00 \text{ g O}}{1669.6 \text{ g}} \times 100\% = 5.750\% \text{ O} \]
3.10 (a) Carbon, nitrogen, oxygen, phosphorus, hydrogen, selenium, sulfur, Cl, Br, I (b) Calcium and magnesium (c) Chloride, bromide, and iodide (d) Iron, copper, zinc, vanadium (also chromium, manganese, cobalt, nickel, molybdenum, and cadmium)

Chapter 4

4.1 One mol of methane reacts with 2 mol oxygen to produce 1 mol carbon dioxide and 2 mol water.

4.2 (a) The total mass of reactants (4 Fe(s) + 3 O2(g)) must equal the total mass of products (2 Fe2O3(s), which is 2.50 g). (b) The stoichiometric coefficients are 4, 3, and 2. (c) $1.000 \times 10^4 \text{ O atoms} \times \frac{1 \text{ O}_2 \text{ molecule}}{2 \text{ O atoms}} \times \frac{4 \text{ Fe atoms}}{3 \text{ O}_2 \text{ molecules}} = 6.667 \times 10^3 \text{ Fe atoms}$

4.3 (a) Not balanced; the number of nitrogen atoms do not match. (b) Not balanced; the number of bromine atoms do not match. (c) Not balanced; the number of sulfur atoms do not match.

4.4 (a) To predict a product of a combination reaction between two elements, we need to know the ion that will be formed by each element when combined. (b) For calcium, Ca$^{2+}$ ions are formed, and for fluorine, F$^-$ ions are formed. (c) The product is CaF$_2$.

4.5 (a) Magnesium chloride, MgCl$_2$. (b) Magnesium oxide, MgO, and carbon dioxide, CO$_2$.

4.6 $\frac{2 \text{ mol Al}}{3 \text{ mol Br}_2} \times \frac{1 \text{ mol AlBr}_3}{1 \text{ mol AlBr}_3}$, and their reciprocals

4.7 $0.500 \text{ mol CH}_4 \times \frac{2 \text{ mol H}_2\text{O}}{1 \text{ mol CH}_4} = 1.000 \text{ mol H}_2\text{O}$

4.8 (a) $300.0 \text{ g urca} \times \frac{1 \text{ mol urca}}{60.06 \text{ g urca}} \times \frac{2 \text{ mol NH}_4}{1 \text{ mol urca}} \times \frac{17.03 \text{ g NH}_4}{1 \text{ mol NH}_4} = 170.0 \text{ g urca}$

4.9 (1) Impure reactants; (2) Inaccurate weighing of reactants and products

4.10 Assuming that the nicotine is pure, weigh a sample of nicotine and burn the sample. Separately collect and weigh the carbon dioxide and water generated, and calculate the moles and grams of carbon and hydrogen collected. By mass difference, determine the mass of nitrogen in the original sample, then calculate the moles of nitrogen. Calculate the mole ratios of carbon, hydrogen, and nitrogen in nicotine to determine its empirical formula.

Chapter 5

5.1 It is possible for an exchange reaction to form two different precipitates—for example, the reaction between barium hydroxide and iron(II) sulfate:

$$\text{Ba(OH)}_2(aq) + \text{FeSO}_4(aq) \rightarrow \text{BaSO}_4(s) + \text{Fe(OH)}_2(s)$$

5.2 $\text{H}_2\text{PO}_4(aq) \rightarrow \text{H}_3\text{PO}_4(aq) + \text{H}^+(aq)$

5.3 (a) Hydrogen ions and perchlorate ions:

$$\text{HClO}_4(aq) \rightarrow \text{H}^+(aq) + \text{ClO}_4^-(aq)$$

5.4 (a) $\text{H}^+(aq) + \text{Cl}^-(aq) + \text{K}^+(aq) + \text{OH}^-(aq) \rightarrow \text{H}_2\text{O}(l) + \text{K}^+(aq) + \text{Cl}^-(aq)$

5.5 Al(OH)$_3(s)$ + $3 \text{ H}^+(aq)$ + $3 \text{ Cl}^-(aq) \rightarrow 3 \text{ H}_2\text{O}(l) + \text{AlCl}_3(aq) + 3 \text{ Cl}^-(aq)$

5.6 (a) The products are aqueous sodium sulfate, water, and carbon dioxide gas.

$$\text{Na}_2\text{SO}_4(aq) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{Na}_2\text{SO}_4(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g)$$

5.7 (a) Gas-forming reaction; the products are aqueous nickel sulfate, water, and carbon dioxide gas.

$$\text{NiCO}_3(s) + \text{H}_2\text{SO}_4(aq) \rightarrow \text{NiSO}_4(aq) + \text{H}_2\text{O}(l) + \text{CO}_2(g)$$

5.8 Acid-base reaction; nitric acid reacts with strontium hydroxide, a base, to produce water and strontium nitrate, a salt.

$$2 \text{HNO}_3(aq) + \text{Sr(OH)}_2(s) \rightarrow \text{Sr(NO}_3)_2(aq) + 2 \text{H}_2\text{O}(l)$$

5.9 Precipitation reaction; aqueous sodium chloride and insoluble barium oxalate are produced.

$$\text{BaCl}_2(aq) + \text{Na}_2C_2\text{O}_4(aq) \rightarrow \text{BaC}_2\text{O}_4(s) + 2 \text{NaCl}(aq)$$
Answers to Selected Questions for Review and Thought

Chapter 1

11. (a) Quantitative (b) Qualitative (c) Qualitative (d) Quantitative and qualitative (e) Qualitative

13. (a) Qualitative (b) Quantitative (c) Qualitative and qualitative (d) Qualitative

15. Sulfur is a pale yellow, powdery solid. Bromine is a dark, red-brown liquid and a red/brown gas that fills the upper part of the flask. Both the melting point and the boiling point of sulfur must be above room temperature. The boiling point, but not the melting point, of bromine must be above room temperature. Both substances are colored. Most of their other properties appear to be different.

17. The liquid will boil because your body temperature of 37 °C is above the boiling point of 20 °C.

19. (a) 20 °C (b) 100 °C (c) 60 °C (d) 20 °F

21. Copper

23. Aluminum

25. 3.9 × 10^25 g

29. (a) Chemical (b) Chemical (c) Physical

31. (a) An outside source of energy is forcing a chemical reaction to occur. (b) A chemical reaction is releasing energy and causing work to be done. (c) A chemical reaction is releasing energy and causing work to be done. (d) An outside source of energy is forcing a chemical reaction to occur.

33. Heterogeneous; use a magnet.

35. (a) Homogeneous (b) Heterogeneous (c) Heterogeneous (d) Heterogeneous

37. (a) A compound decomposed (b) A compound decomposed

39. (a) Heterogeneous mixture (b) Pure compound (c) Heterogeneous mixture (d) Homogeneous mixture

41. (a) Heterogeneous mixture (b) Pure compound (c) Element (d) Homogeneous mixture

43. (a) No (b) Maybe

45. The macroscopic world; a parallelepiped shape; the atom crystal arrangement is a parallelepiped shape.

47. Microscopic world

51. When sucrose is heated, the motion of the atoms increases. Only when that motion is extreme enough, will the bonds in the sucrose break, allowing for the formation of new bonds to produce the “caramelization” products.

53. (a) 3.275 × 10^4 m (b) 3.42 × 10^4 nm (c) 1.21 × 10^-3 μm

55. Because atoms in the starting materials must all be accounted for in the substances produced, and because the mass of each atom does not change, there would be no change in the mass.

57. (Remember, you are instructed to use your own words to answer this question.) Consider two compounds that both contain the same two elements. In each compound, the proportion of these two elements is a whole-number integer ratio. Because they are different compounds, these ratios must be different. If you pick a sample of each of these compounds such that both samples contain the same number of atoms of the first element, and then you count the number of atoms of the second type, you will find that a small integer relationship exists between the number of atoms of the second type in the first compound and the number of atoms of the second type in the second compound.

59. If two compounds contain the same elements and samples of those two compounds both contain the same mass of one element, then the ratio of the masses of the other elements will be small whole numbers.

61. Many responses are equally valid here. Common examples given here: (a) iron, Fe; gold, Au (b) carbon, C; hydrogen, H (c) boron, B; silicon, Si (d) nitrogen, N; oxygen, O

63. 2H_2(g) + O_2(g) → 2H_2O(g)

65. (a) H_2O (b) N_2

67. I_2(s) → I_2(g)

71. In solid calcium, smaller radius atoms are more closely packed, making a smaller volume. In solid potassium, larger radius atoms are less closely packed, making a larger volume.

73. They are different by how the atoms are organized and bonded together.

75. (a) Bromobenzene (b) Gold (c) Lead

77. (a) 2.7 × 10^3 mL ice (b) Bulging, cracking, deformed, or broken (c) Gold

81. (a) Water layer on top of bromobenzene layer (b) If it is poured slowly and carefully, ethanol will float on top of the water and slowly dissolve in the water. Both ethanol and water will float on the bromobenzene.
A.84  ANSWERS TO SELECTED QUESTIONS FOR REVIEW AND THOUGHT

83. Drawing (b)
85. $6.02 \times 10^{-23}$ m$^3$
87. (a) Gray and blue  (b) Lavender  (c) Orange
89. It is difficult to prove that something cannot be broken down (see Section 1.3).
91. (a) Nickel, lead, and magnesium  (b) Titanium
93. Obtain four or more lemons. Keep one unaltered to be the “control” case. Perform designated tasks to others, including applying both tasks to the same lemon; then juice all of them, recording results, such as juice volume and ease of task. Repeat with more lemons to achieve better reliability. Hypothesis: Disrupting the “juice sacks” inside the pulp helps to release the juice more easily.

Chapter 2

7. 40,000 cm
9. 614 cm, 242 cm, 20.1 ft
11. 76.2 kg
13. 2.0 $\times 10^3$ cm$^3$, 2.0 L
15. 1550 m$^2$
17. 2.8 $\times 10^5$ m$^3$
22. (a) 4  (b) 5  (c) 4
24. (a) $4.53 \times 10^{-4}$  (b) $4.47 \times 10^1$
26. (a) 1.9 g/mL  (b) 218.4 cm
28. 80.1% silver, 19.9% copper
30. 245 g sulfuric acid
32. 0.9% Na
37. Number of neutrons
39. 27 protons, 27 electrons, and 35 neutrons
41. 78.92 amu/atom
43. (a) 9  (b) 48  (c) 70
45. (a) $\frac{1}{2}$Na  (b) $^{39}$Ar  (c) $^{69}$Ga
47. (a) 20 e$^-$, 20 p$^+$, 20 n$^0$  (b) 50 e$^-$, 50 p$^+$, 69 n$^0$
(c) 94 e$^-$, 94 p$^+$, 150 n$^0$
49. $Z$ | $A$ | Number of Neutrons | Element
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<tr>
<td>35</td>
<td>81</td>
<td>46</td>
<td>Br</td>
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<tr>
<td>36</td>
<td>108</td>
<td>62</td>
<td>Pd</td>
</tr>
<tr>
<td>37</td>
<td>122</td>
<td>115</td>
<td>Ir</td>
</tr>
<tr>
<td>38</td>
<td>151</td>
<td>88</td>
<td>Pt</td>
</tr>
</tbody>
</table>

51. $^{18}$X, $^{20}$X and $^{22}$X
53. Ions
55. Using a magnetic field
57. 6.941 amu/atom
59. 60.12% $^{46}$Ga, 39.87% $^{71}$Ga
61. $^{6}$Li
63. Pair (2), dozen (12), gross (144), million
66. (a) 27 g Br  (b) 0.48 g O$_2$
(c) $6.98 \times 10^{-2}$ g Fe  (d) $2.61 \times 10^3$ g H
68. (a) 1.9998 mol Cu  (b) 0.499 mol Ca
(c) 0.6208 mol Al  (d) $3.1 \times 10^{-4}$ mol K
(e) $2.1 \times 10^{-5}$ mol Am
70. 2.19 mol Na
72. $9.42 \times 10^{-5}$ mol Kr
74. 4.131 $\times 10^3$ Cr atoms
76. 1.055 $\times 10^{-2}$ g Cu
78. In a group, elements share the same vertical column. In a period, elements share the same horizontal row.

83. Transition elements: iron, copper, chromium
Halogen: fluorine and chlorine
Alkali metal: sodium
(Other answers are possible.)
85. Five; nonmetal: carbon (C), metalloids: silicon (Si) and germanium (Ge), and metals: tin (Sn) and lead (Pb).
87. (a) I  (b) In  (c) Ir  (d) Fe
89. Sixth period
91. (a) Mg  (b) Na  (c) Cu  (d) S
(c) I  (f) Mg  (g) Kr  (h) S
(i) Ge [Other answers are possible for (a), (b), and (i).]
93. (a) Iron or magnesium  (b) Hydrogen  (c) Silicon
(d) Iron  (e) Chlorine
97. (a) 0.197 nm  (b) 197 pm
99. (a) 0.178 nm$^3$  (b) $1.78 \times 10^{-22}$ cm$^3$
102. 89 tons/yr
104. $^{74}$K
107. (a) Ti, 22; 47.88 (b) Group 4B; Period 4; zirconium, hafnium, rutherfordium (c) light-weight and strong (d) strong; low-density, highly corrosion resistant, occurs widely, light weight, high-temperature stability (Other answers are possible.)
109. 0.038 mol
111. $\$3,800
113. 3.4 mol, 2.0 $\times 10^{24}$ atoms
114. (a) Not possible  (b) Possible  (c) Not possible
(d) Not possible  (e) Possible  (f) Not possible
116. (a) Same  (b) Second  (c) Same
(d) Same  (e) Same  (f) Second
121. (a) $^{79}$Br—$^{81}$Br, $^{83}$Br—$^{85}$Br, $^{87}$Br—$^{89}$Br (b) 78.918 g/mol, 80.196 g/mol
(c) 79.90 g/mol  (d) 51.1% $^{79}$Br, 48.9% $^{81}$Br
123. (a) K  (b) Ar  (c) Cu  (d) Ge
(e) H  (f) Al  (g) O  (h) Ca
(i) Br  (j) P
125. (a) Se  (b) $^{70}$K  (c) $^{79}$Br  (d) $^{20}$Ne

Chapter 3

9. (a) BrF$_3$  (b) XeF$_2$  (c) P$_4$F$_{	ext{14}}$  (d) C$_4$H$_{12}$  (e) N$_2$H$_4$
11. Butanol, C$_3$H$_7$O, CH$_3$CH$_2$CH$_2$OH
14. (a) C$_6$H$_{14}$  (b) C$_6$H$_8$O$_2$
16. (a) 1 calcium atom, 2 carbon atoms, and 4 oxygen atoms
(b) 8 carbon atoms and 8 hydrogen atoms
(c) 2 nitrogen atoms, 8 hydrogen atoms, 1 sulfur atom, and 4 oxygen atoms
(d) 1 platinum atom, 2 nitrogen atoms, 6 hydrogen atoms, and 2 chlorine atoms
(e) 4 potassium atoms, 1 iron atom, 6 carbon atoms, and 6 nitrogen atoms
<table>
<thead>
<tr>
<th>Problem</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. (a)</td>
<td>Same number of atoms of each kind</td>
</tr>
<tr>
<td>(b)</td>
<td>Different bonding arrangements</td>
</tr>
<tr>
<td>20. (a)</td>
<td>( \text{Li}^+ )</td>
</tr>
<tr>
<td>(b)</td>
<td>( \text{Se}^{2+} )</td>
</tr>
<tr>
<td>(c)</td>
<td>( \text{Al}^{3+} )</td>
</tr>
<tr>
<td>(d)</td>
<td>( \text{Ca}^{2+} )</td>
</tr>
<tr>
<td>(c)</td>
<td>( \text{Zn}^{2+} )</td>
</tr>
<tr>
<td>22. Ba</td>
<td>2⁺, Br⁻ = 1</td>
</tr>
<tr>
<td>24. (a)</td>
<td>+2</td>
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<tr>
<td>(b)</td>
<td>+2</td>
</tr>
<tr>
<td>(c)</td>
<td>+2 or +3</td>
</tr>
<tr>
<td>(d)</td>
<td>+3</td>
</tr>
<tr>
<td>26.</td>
<td>( \text{CoO}, \text{Co}_2\text{O}_3 )</td>
</tr>
<tr>
<td>28. (c) and (d)</td>
<td>are correct formulas. (a) ( \text{AlCl}_3 ) (b) NaF</td>
</tr>
<tr>
<td>30.</td>
<td>Mn</td>
</tr>
<tr>
<td>32. (a)</td>
<td>( 1 \text{Pb}^{2+} ) and ( 2 \text{NO}_3^- )</td>
</tr>
<tr>
<td>(b)</td>
<td>( 1 \text{Ni}^{2+} ) and ( 1 \text{CO}_3^{2-} )</td>
</tr>
<tr>
<td>(c)</td>
<td>( 3 \text{NH}_4^+ ) and ( 1 \text{PO}_4^{3-} )</td>
</tr>
<tr>
<td>(d)</td>
<td>( 2 \text{K}^+ ) and ( 1 \text{SO}_4^{2-} )</td>
</tr>
<tr>
<td>34.</td>
<td>BaSO₄, barium ion, 2⁺, sulfate, 2⁻; Mg(NO₃)₂, magnesium ion, 2⁺, nitrate, 1⁻; NaCH₃CO₂, sodium ion, 1⁺, acetate, 1⁻</td>
</tr>
<tr>
<td>36. (a)</td>
<td>( \text{Ni(NO}_3)_2 )</td>
</tr>
<tr>
<td>(b)</td>
<td>( \text{NaHCO}_3 )</td>
</tr>
<tr>
<td>(c)</td>
<td>( \text{LiClO}_4 )</td>
</tr>
<tr>
<td>(d)</td>
<td>( \text{MgCl}_2 )</td>
</tr>
<tr>
<td>(c)</td>
<td>( \text{CaSO}_4 )</td>
</tr>
<tr>
<td>38. (b), (c), and (e)</td>
<td>are ionic.</td>
</tr>
<tr>
<td>40. Only (c) is ionic, with metal and nonmetal combined. (a)–(d) are composed of only nonmetals.</td>
<td></td>
</tr>
<tr>
<td>42. (a)</td>
<td>( \text{NH}_2\text{CO}_3 )</td>
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<tr>
<td>(b)</td>
<td>( \text{CaF}_2 )</td>
</tr>
<tr>
<td>(c)</td>
<td>( \text{CuBr}_3 )</td>
</tr>
<tr>
<td>(d)</td>
<td>( \text{AlPO}_3 )</td>
</tr>
<tr>
<td>44. (a)</td>
<td>Potassium sulfide (b) Nickel(II) sulfate (c) Ammonium phosphate (d) Aluminum hydroxide (e) Cobalt(III) sulfate</td>
</tr>
<tr>
<td>46. MgO</td>
<td>MgO has higher ionic charges and smaller ion sizes than NaCl.</td>
</tr>
<tr>
<td>48. Conducts electricity in water: check electrical conductivity. Examples: NaCl and ( \text{Ca}_2\text{H}_2\text{O}_4 ). (Other answers are possible.)</td>
<td></td>
</tr>
<tr>
<td>50. Molecular compounds are generally not ionic compounds and, therefore, would not ionize in water.</td>
<td></td>
</tr>
<tr>
<td>52. (a)</td>
<td>( \text{K}^+ ) and ( \text{OH}^- )</td>
</tr>
<tr>
<td>(b)</td>
<td>( \text{K}^+ ) and ( \text{SO}_4^{2-} )</td>
</tr>
<tr>
<td>(c)</td>
<td>( \text{Na}^+ ) and ( \text{NO}_3^- )</td>
</tr>
<tr>
<td>(d)</td>
<td>( \text{NH}_4^+ ) and ( \text{Cl}^- )</td>
</tr>
<tr>
<td>54. (a) and (d)</td>
<td></td>
</tr>
<tr>
<td>56.</td>
<td>( \text{CH}_3\text{OH} )</td>
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<tr>
<td>No of</td>
<td></td>
</tr>
<tr>
<td>No of</td>
<td></td>
</tr>
<tr>
<td>No of</td>
<td>( 6.022 \times 10^{23} )</td>
</tr>
<tr>
<td>No of</td>
<td>( 6.022 \times 10^{23} )</td>
</tr>
<tr>
<td>Molar mass</td>
<td>( 32.0417 )</td>
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<tr>
<td>Molar mass</td>
<td>( 12.0107 )</td>
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<tr>
<td>58. (a)</td>
<td>159.688 g/mol</td>
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<tr>
<td>(b)</td>
<td>67.806 g/mol</td>
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<td>(c)</td>
<td>44.0128 g/mol</td>
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<tr>
<td>(d)</td>
<td>197.905 g/mol</td>
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<tr>
<td>60. (a)</td>
<td>( 0.0512 ) mol</td>
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<tr>
<td>(b)</td>
<td>( 0.0101 ) mol</td>
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<tr>
<td>(c)</td>
<td>( 0.0125 ) mol</td>
</tr>
<tr>
<td>(d)</td>
<td>( 0.0006 ) mol</td>
</tr>
<tr>
<td>(c)</td>
<td>( 0.00599 ) mol</td>
</tr>
<tr>
<td>62. (a)</td>
<td>( 179.855 ) g/mol</td>
</tr>
<tr>
<td>(b)</td>
<td>( 36.0 ) g</td>
</tr>
<tr>
<td>(c)</td>
<td>( 0.0259 ) mol</td>
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<tr>
<td>64. (a)</td>
<td>( 151.162 ) g/mol</td>
</tr>
<tr>
<td>(b)</td>
<td>( 0.0352 ) mol</td>
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<tr>
<td>(c)</td>
<td>( 25.1 ) g</td>
</tr>
<tr>
<td>66. (a)</td>
<td>( 0.400 ) mol</td>
</tr>
<tr>
<td>(b)</td>
<td>( 0.250 ) mol</td>
</tr>
<tr>
<td>(c)</td>
<td>( 0.628 ) mol</td>
</tr>
<tr>
<td>68.</td>
<td>( 2.7 \times 10^{23} ) atoms</td>
</tr>
<tr>
<td>70.</td>
<td>( 1.2 \times 10^{24} ) molecules</td>
</tr>
<tr>
<td>72. (a)</td>
<td>( 0.250 ) mol ( \text{CF}_2\text{CHF}_2 )</td>
</tr>
<tr>
<td>(b)</td>
<td>( 6.02 \times 10^{23} ) F atoms</td>
</tr>
<tr>
<td>75. (a)</td>
<td>( 259.3 ) g/mol PbS, 86.60% Pb, 13.40% S</td>
</tr>
<tr>
<td>(b)</td>
<td>( 30.0688 ) g/mol ( \text{C}_2\text{H}_6 ), 79.8881% C, 20.1119% H</td>
</tr>
<tr>
<td>(c)</td>
<td>( 60.0518 ) g/mol ( \text{CH}_3\text{CO}_2\text{H} ), 40.0011% C, 6.7135% H, 53.2854% O</td>
</tr>
<tr>
<td>(d)</td>
<td>( 80.0532 ) g/mol ( \text{NH}_4\text{NO}_3 ), 34.9979% C, 5.0368% H, 59.9654% O</td>
</tr>
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</table>
Chapter 4

10.

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<tr>
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<th>KOH</th>
<th>HCl</th>
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<tr>
<td>No. molecules</td>
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<td>1</td>
</tr>
<tr>
<td>No. atoms</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Total mass of reactants</td>
<td>92.5656 g</td>
<td></td>
</tr>
<tr>
<td>Total mass of products</td>
<td>92.5656 g</td>
<td></td>
</tr>
</tbody>
</table>

12. (a) 1.00 g (b) 2 for Mg, 1 for O₂, and 2 for MgO (c) 50 atoms of Mg

14. 4 Fe(s) + 3 O₂(g) → 2 Fe₂O₃(s)

16. Equation (b)

18.

20. (a) Combination (b) Decomposition (c) Exchange (d) Displacement

22. (a) Decomposition (b) Displacement (c) Combination (d) Exchange

24. (a) 2 C₂H₂(g) + 13 O₂(g) → 8 CO₂(g) + 10 H₂O(g) (b) C₂H₂O₃(s) + 6 O₂(g) → 6 CO₂(g) + 6 H₂O(g) (c) 2 C₂H₂O₄(l) + 11 O₂(g) → 8 CO₂(g) + 8 H₂O(g)

26. (a) 2 Mg(s) + 1 O₂(g) → 2 MgO(s), magnesium oxide (b) 2 Ca(s) + O₂(g) → 2 CaO(s), calcium oxide (c) 4 In(s) + 3 O₂(g) → 2 In₂O₃(s), indium oxide

28. (a) 2 K(s) + Cl₂(g) → 2 KCℓ, potassium chloride (b) Mg(s) + Br₂(g) → MgBr₂, magnesium bromide (c) 2 Al(s) + 3 F₂(g) → 2 AlF₃(s), aluminum fluoride

30. (a) 4 Al(s) + 3 O₂(g) → 2 Al₂O₃(s) (b) N₂(g) + 5 H₂(g) → 2 NH₃(g) (c) 2 C₂H₂O₃(l) + 15 O₂(g) → 6 CO₂(g) + 12 H₂O(g)

32. (a) UO₂(s) + 4 HCl(g) → UF₄(s) + 2 H₂O(l) (b) MnO₂(s) + 6 HCl(g) → 2 BF₃(g) + 3 H₂O(l) (c) BF₃(g) + 3 H₂O(l) → 3 BF₃(g) + H₃BO₃(s)

34. (a) H₂NCl₂(qaq) + 2 NH₃(g) → NH₄Cl(aq) + N₂H₆(aq) (b) (CH₃)₂NCl_H₂O → 5 N₂(g) + 4 H₂O(g) + 2 CO₂(g) (c) CaC₂O₄ + 2 H₂O(l) → Ca(OH)₂(s) + C₂H₂O₄(g)

36. (a) C₂H₂O₃(s) + 6 O₂(g) → 6 CO₂(g) + 6 H₂O (b) C₂H₂O₄(l) + 8 O₂ → 5 CO₂ + 6 H₂O (c) 2 C₂H₂O₄(l) + 19 O₂ → 14 CO₂ + 14 H₂O (d) C₂H₂O₄(l) + 2 O₂ → 2 CO₂ + 2 H₂O

38. 50.0 mol HCl

40. 12.8 g

42. 1.1 mol O₂, 35 g O₂, 1.0 × 10⁷ g NO₂

44. 12.7 g Cl₂, 0.179 mol FeCl₂, 22.7 g FeCl₃ expected

46. (NH₄)₂PtCl₆

<table>
<thead>
<tr>
<th></th>
<th>Pt</th>
<th>HCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.55 g</td>
<td>5.428 g</td>
<td>5.410 g</td>
</tr>
</tbody>
</table>

48. (a) 0.148 mol H₂O (b) 5.89 g TiO₂, 10.8 g HCl

50. 2.0 mol, 36.0304 g

52. 0.699 g Ga and 0.751 g As

54. (a) Fe(s) + 3 O₂(g) → 2 Fe₂O₃(s) (b) 7.98 g (c) 2.40 g

56. (a) CCl₂F₂ + 2 Na₂CO₃ → C + 4 CO₂ + 2 NaCl + 2 NaF (b) 170. g Na₂CO₃ (c) 112 g CO₂

58. (a) 699 g (b) 526 g

60. BaCl₂, 1.12081 g, BaSO₄

62. (a) Cl₂ is limiting. (b) 5.08 g Al₂Cl₆ (c) 1.67 g Al unreacted

66. 0.19 mol NH₄Cl, 2.00 mol H₂O₂, 4.00 mol NH₃, 2.00 mol CaCl₂

68. 1.40 kg Fe

71. 699 g, 93.5%

73. 56.0%

75. 8.8%

77. 5.3 g SCl₂

80. SO₂

82. CH

84. C₂H₆O₂

86. (a) CH₄ (b) 200 g (c) 700 g

88. 86.3 g

91. 12.5 g Pt(NH₃)₂Cl₂

93. SiH₄

95. KOH, KOH

97. Two butane molecules react with 13 diatomic oxygen molecules to produce 8 carbon dioxide molecules and 10 water molecules. Two moles of gaseous butane molecules react with 15 moles of gaseous diatomic oxygen molecules to produce 8 moles of gaseous carbon dioxide molecules and 10 moles of liquid water molecules.

99. A, B

101. Ag⁺, Cu²⁺, and NO₃⁻

104. Equation (b)

106. When the metal mass is less than 1.2 g, the metal is the limiting reactant. When the metal mass is greater than 1.2 g, the bromine is the limiting reactant.

109. H₂O(g) + 3 Fe₂O₃(s) → H₂O(l) + 2 Fe₂O₃(s)

110. 86.5 g

112. (a) CH₄ (b) 200 g (c) 700 g

114. 44.9 amu

116. 9 g Ag₂NO₃, 9.82 g Na₂CO₃, 6.79 g Ag₂CO₃, 4.19 g NaNO₃

118. 99.7% CH₃OH, 0.3% C₂H₅OH

120. (a) C₂H₂N₂O₄ (b) C₂H₁₁NO₄

Chapter 5

11. All soluble (a) Fe²⁺ and ClO₄⁻ (b) Na⁺ and SO₄²⁻ (c) K⁺ and Br⁻ (d) Na⁺ and CO₃²⁻

13. All soluble (a) K⁺ and HPO₄²⁻ (b) Na⁺ and ClO₄⁻ (c) Mg²⁺ and Cl⁻ (d) Ca²⁺ and OH⁻ (e) Al³⁺ and Br⁻

15. 2 HNO₃(aq) + Ca(OH)₂(aq) → 2 H₂O(l) + Ca(NO₃)₂(aq)

17. (a) MnCl₂(aq) + Na₂S(aq) → MnS(s) + 2 NaCl(aq)

(b) No precipitate (c) No precipitate (d) Hg(NO₃)₂(aq) + Na₂S(aq) → HgS(s) + 2 NaNO₃(aq)

(e) Pb(NO₃)₂(aq) + 2 HCl(aq) → PbCl₂(s) + 2 HNO₃(aq) (f) BaCl₂(aq) + H₂SO₄(aq) → BaSO₄(s) + 2 HCl(aq)