$$N_{\text{dimes}} = 7.800 \times 10^3\ \cancel{g} \times \frac{7\text{ dimes}}{12.30\ \cancel{g}}$$

$$N_{\text{dimes}} = 4439\text{ dimes}$$

There are 4439 dimes in a bag that contains 7.800 kg of dimes.

9. m_{HBr} = 38.40 g HBr (key value)

   2 mol HBr = 159.8 g HBr (conversion factor equation)

$$n_{\text{HBr}} = 38.40\ \cancel{\text{g HBr}} \times \frac{2\text{ mol HBr}}{159.8\ \cancel{\text{g HBr}}}$$

$$n_{\text{HBr}} = 4.81 \times 10^{-1}\text{mol HBr}$$

   There are 4.81×10^{-1} mol of hydrogen bromide molecules in the cylinder.

10. (a) Molar mass is the mass in grams per mole of one mole (6.02×10^{23}) of chemical entities. The symbol for molar mass is *M* and its SI unit is g/mol.
    (b) M_C = 12.01 g/mol
    (c) The mass of 6.02×10^{23} atoms of zinc is 65.38 g. This value is equal to the molar mass of zinc (65.38 g/mol).
    (d) The element could be gold.

Applied Inquiry Skills

11. (a) 1. Measure the total mass of the coin mixture (in grams).
        2. Separate one penny, one nickel, one dime, and one quarter from the mixture.
        3. Measure the mass of one penny, one nickel, one dime, and one quarter together (in grams).
        4. To estimate the number of coins in the mixture, divide the mass of the mixture measured in step 1 by the mass of the four coins measured in step 3, and multiply the answer by 4.
    (b) To estimate the number of dimes, divide the answer in part 4 by 4.

Making Connections

12. (a) Chemists measure and mix chemicals to produce products with properties that differ from the properties of the reactants. Similarly, chefs measure and mix food ingredients to produce food products with properties that differ from the properties of the ingredients. Chemists balance the reactants and products in a chemical equation. Similarly, accountants prepare balance sheets to balance the income and expenditures of a person or a business.
    (b) Chemists work with entities and cannot see the particles. Chefs work with ingredients they can see and even count individually. Chemists balance reactants and products in a chemical equation to determine the quantities of reactants needed and the products formed in a chemical reaction. The balance between reactants and products is always equal. Accountants balance the income and expenditures for clients to determine if a profit or loss has occurred. The relationship between the income and expenditures do not always balance (i.e., one can be greater or less than the other).

13. (a) Student answers will vary. The scanning tunnelling microscope (STM) is able to display the protrusions and depressions caused by atoms on the surface of substances like metals. The shapes of atoms are detected by changes in electric current that occur when the fine tip of a piezoelectric tube moves over the material being observed.
    (b) The STM will most likely not replace our need to calculate quantities in chemistry because atoms and molecules are so small that we will always have to deal with huge numbers of a chemical entity than to count individual entities.

2.2 CALCULATIONS INVOLVING THE MOLE

PRACTICE

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Understanding Concepts

1. n_{Al} = 1.60 mol Al

   M_{Al} = 26.98 mol/Al

   1 mol Al = 26.98 g Al

$$m_{Al} = 1.60\ \cancel{\text{mol Al}} \times \frac{26.98\ \text{g Al}}{1\ \cancel{\text{mol Al}}}$$

$$m_{Al} = 43.2\ \text{g Al}$$

The mass of 1.60 mol aluminum atoms is 43.2 g.

2. n_S = 0.25 mol S
   M_S = 32.06 g/mol S
   1 mol S = 32.06 g S

$$m_S = 0.25\ \cancel{\text{mol S}} \times \frac{32.06\ \text{g S}}{1\ \cancel{\text{mol S}}}$$

$$m_S = 8.0\ \text{g S}$$

The mass of 0.25 mol sulfur is 8.0 g.

PRACTICE

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Understanding Concepts

3. m_{Fe} = 3.30 g Fe
   M_{Fe} = 55.85 g/mol Fe
   1 mol Fe = 55.85 g Fe

$$n_{Fe} = 3.30\ \cancel{\text{g Fe}} \times \frac{1\ \text{mol Fe}}{55.85\ \cancel{\text{g Fe}}}$$

$$n_{Fe} = 0.059\ \text{mol Fe}$$

There is 0.059 mol iron in a 3.30-g iron nail.

4. m_{Ag} = 23.6 g Ag
   M_{Ag} = 107.87 g/mol Ag
   1 mol Ag = 107.87 g/mol Ag

$$n_{Ag} = 23.6\ \cancel{\text{g Ag}} \times \frac{1\ \text{mol Ag}}{107.87\ \cancel{\text{g Ag}}}$$

$$n_{Ag} = 0.219\ \text{mol Ag}$$

There is 0.219 mol silver in the silver coin.

5. m_{Cu} = 7.65 g Cu
   M_{Cu} = 63.55 g/mol Cu
   1 mol Cu = 63.55 g Cu

$$n_{Cu} = 7.65\ \cancel{\text{g Cu}} \times \frac{1\ \text{mol Cu}}{63.55\ \cancel{\text{g Cu}}}$$

$$n_{Cu} = 0.120\ \text{mol Cu}$$

There is 0.120 mol copper in the bracelet.

PRACTICE

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Understanding Concepts

6. m_C = 3.30 g C
   M_C = 12.01 g/mol C
   1 mol C = 12.01 g C
   1 mol C = 6.02 × 10^{23} atoms C

$$N_C = 3.30\ \cancel{\text{g C}} \times \frac{1\ \cancel{\text{mol C}}}{12.01\ \cancel{\text{g C}}} \times \frac{6.02 \times 10^{23}\ \text{atoms C}}{1\ \cancel{\text{mol C}}}$$

$$N_C = 1.65 \times 10^{23}\ \text{atoms C}$$

There are 1.65×10^{23} atoms of carbon in a 3.30-g diamond.

7. $m_{Ne} = 6.80$ g Ne
   $M_{Ne} = 20.18$ g/mol Ne
   1 mol Ne = 20.18 g Ne
   1 mol Ne = 6.02×10^{23} atoms Ne

$$N_{Ne} = 6.80\ \cancel{\text{g Ne}} \times \frac{1\ \cancel{\text{mol Ne}}}{20.18\ \cancel{\text{g Ne}}} \times \frac{6.02 \times 10^{23}\ \text{atoms Ne}}{1\ \cancel{\text{mol Ne}}}$$

$$N_{Ne} = 2.03 \times 10^{23}\ \text{atoms Ne}$$

There are 2.03×10^{23} atoms of neon in a sign containing 6.80 g of neon.

8. $m_{Hg} = 78.2$ g Hg
   $M_{Hg} = 200.59$ g/mol Hg
   1 mol Hg = 200.59 g Hg
   1 mol Hg = 6.02×10^{23} atoms Hg

$$N_{Hg} = 78.2\ \cancel{\text{g Hg}} \times \frac{1\ \cancel{\text{mol Hg}}}{200.59\ \cancel{\text{g Hg}}} \times \frac{6.02 \times 10^{23}\ \text{atoms Hg}}{1\ \cancel{\text{mol Hg}}}$$

$$N_{Hg} = 2.35 \times 10^{23}\ \text{atoms Hg}$$

There are 2.35×10^{23} atoms of mercury in the thermometer.

PRACTICE

(Page 99)

Understanding Concepts

9. $$\begin{aligned} M_{C_8H_{18}} &= 8(M_C) + 18(M_H) \\ &= 8(12.01\ \text{g/mol}) + 18(1.01\ \text{g/mol}) \\ &= 96.08\ \text{g/mol} + 18.18\ \text{g/mol} \\ M_{C_8H_{18}} &= 114.26\ \text{g/mol} \end{aligned}$$

   The molar mass of octane is 114.26 g/mol.

10. $$\begin{aligned} M_{C_9H_8O_4} &= 9(M_C) + 8(M_H) + 4(M_O) \\ &= 9(12.01\ \text{g/mol}) + 8(1.01\ \text{g/mol}) + 4(16.00\ \text{g/mol}) \\ &= 108.09\ \text{g/mol} + 8.08\ \text{g/mol} + 64.00\ \text{g/mol} \\ M_{C_9H_8O_4} &= 180.17\ \text{g/mol} \end{aligned}$$

    The molar mass of acetylsalicylic acid is 180.17 g/mol.

11. $$\begin{aligned} M_{CaSO_4} &= 1(M_{Ca}) + 1(M_S) + 4(M_O) \\ &= 1(40.08\ \text{g/mol}) + 1(32.06\ \text{g/mol}) + 4(16.00\ \text{g/mol}) \\ &= 40.08\ \text{g/mol} + 32.06\ \text{g/mol} + 64.00\ \text{g/mol} \\ M_{CaSO_4} &= 136.14\ \text{g/mol} \end{aligned}$$

    The molar mass of calcium sulfate is 136.14 g/mol.

PRACTICE

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Understanding Concepts

12. n_{NH_3} = 0.900 mol NH_3

M_{NH_3} = 1(14.01 g/mol) + 3(1.01 g/mol)

M_{NH_3} = 17.04 g/mol NH_3

1 mol NH_3 = 17.04 g NH_3

$$m_{NH_3} = 0.900\ \cancel{\text{mol NH}_3} \times \frac{17.04\text{ g NH}_3}{1\ \cancel{\text{mol NH}_3}}$$

$$m_{NH_3} = 15.3\text{ g NH}_3$$

The mass of the ammonia is 15.3 g.

13. $n_{CCl_2F_2}$ = 3.60 mol CCl_2F_2

$M_{CCl_2F_2}$ = 1(12.01 g/mol) + 2(35.45 g/mol) + 2(19.00 g/mol)

$M_{CCl_2F_2}$ = 120.91 g/mol CCl_2F_2

1 mol CCl_2F_2 = 120.91 g CCl_2F_2

$$m_{CCl_2F_2} = 3.60\ \cancel{\text{mol CCl}_2\text{F}_2} \times \frac{120.91\text{ g CCl}_2\text{F}_2}{1\ \cancel{\text{mol CCl}_2\text{F}_2}}$$

$$m_{CCl_2F_2} = 435\text{ g CCl}_2\text{F}_2$$

The mass of 3.60 mol freon-12 is 435 g.

PRACTICE

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Understanding Concepts

14. $m_{Mg(OH)_2}$ = 204.0 g $Mg(OH)_2$

$M_{Mg(OH)_2}$ = 1(24.31 g/mol) + 2(16.00 g/mol) + 2(1.01 g/mol)

$M_{Mg(OH)_2}$ = 58.33 g/mol $Mg(OH)_2$

1 mol $Mg(OH)_2$ = 58.33 g $Mg(OH)_2$

$$N_{Mg(OH)_2} = 2.040\ \cancel{\text{g Mg(OH)}_2} \times \frac{1\text{ mol Mg(OH)}_2}{58.33\ \cancel{\text{g Mg(OH)}_2}}$$

$$N_{Mg(OH)_2} = 3.497\text{ mol Mg(OH)}_2$$

There is 3.497 mol magnesium hydroxide in 204.0 g of magnesium hydroxide.

15. $$m_{C_{12}H_{22}O_{11}} = 1.00\text{ kg C}_{12}\text{H}_{22}\text{O}_{11} \times \frac{1000\text{ g C}_{12}\text{H}_{22}\text{O}_{11}}{1\text{ kg C}_{12}\text{H}_{22}\text{O}_{11}}$$

$$m_{C_{12}H_{22}O_{11}} = 1.00 \times 10^3\text{ g C}_{12}\text{H}_{22}\text{O}_{11}$$

$$M_{C_{12}H_{22}O_{11}} = 12(12.01\text{ g/mol}) + 22(1.01\text{ g/mol}) + 11(16.00\text{ g/mol})$$

$$M_{C_{12}H_{22}O_{11}} = 342.34\text{ g/mol C}_{12}\text{H}_{22}\text{O}_{11}$$

$$1\text{ mol C}_{12}\text{H}_{22}\text{O}_{11} = 342.34\text{ g C}_{12}\text{H}_{22}\text{O}_{11}$$

$$n_{C_{12}H_{22}O_{11}} = 1.00 \times 10^3\ \cancel{\text{g C}_{12}\text{H}_{22}\text{O}_{11}} \times \frac{1\text{ mol C}_{12}\text{H}_{22}\text{O}_{11}}{342.34\ \cancel{\text{g C}_{12}\text{H}_{22}\text{O}_{11}}}$$

$$n_{C_{12}H_{22}O_{11}} = 2.92\text{ mol C}_{12}\text{H}_{22}\text{O}_{11}$$

There is 2.92 mol sucrose in a bag that contains 1.00 kg of sucrose.

PRACTICE

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Understanding Concepts

16. m_{H_2O} = 250.0 g H_2O

M_{H_2O} = 2(1.01 g/mol) + 1(16.00 g/mol)

M_{H_2O} = 18.02 g/mol H_2O

1 mol H_2O = 18.02 g/mol H_2O

$$N_{H_2O} = 250.0\ \cancel{g\ H_2O} \times \frac{1\ \cancel{mol\ H_2O}}{18.02\ \cancel{g\ H_2O}} \times \frac{6.02 \times 10^{23}\ \text{molecules } H_2O}{1\ \cancel{mol\ H_2O}}$$

$$N_{H_2O} = 8.35 \times 10^{24}\ \text{molecules} H_2O$$

There are 8.35×10^{24} molecules of water in a bottle that contains 250.0 g of water.

17. $$m_{Co_2(Cr_2O_7)_3} = 3.30\ \cancel{kg\ Co_2(Cr_2O_7)_3} \times \frac{10^3\ g\ Co_2(Cr_2O_7)_3}{1\ \cancel{kg\ Co_2(Cr_2O_7)_3}}$$

$$m_{Co_2(Cr_2O_7)_3} = 3.30 \times 10^3\ g\ Co_2(Cr_2O_7)_3$$

$$M_{Co_2(Cr_2O_7)_3} = 2(58.93\ g/mol) + 6(52.00\ g/mol) + 21(16.00\ g/mol)$$

$$M_{Co_2(Cr_2O_7)_3} = 765.86\ g/mol\ Co_2(Cr_2O_7)_3$$

$$1\ mol\ Co_2(Cr_2O_7)_3 = 765.86\ g\ Co_2(Cr_2O_7)_3$$

$$N_{Co_2(Cr_2O_7)_3} = 3.30 \times 10^3\ \cancel{g\ Co_2(Cr_2O_7)_3} \times \frac{1\ \cancel{mol\ Co_2(Cr_2O_7)_3}}{765.86\ \cancel{g\ Co_2(Cr_2O_7)_3}} \times \frac{6.02 \times 10^{23}\ \text{formula units } Co_2(Cr_2O_7)_3}{1\ \cancel{mol\ Co_2(Cr_2O_7)_3}}$$

$$N_{Co_2(Cr_2O_7)_3} = 2.59 \times 10^{24}\ \text{formula units } Co_2(Cr_2O_7)_3$$

There are 2.59×10^{24} formula units of cobalt(III) dichromate in a 3.30-kg sample.

PRACTICE

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Understanding Concepts

18. m_{F_2} = 4.4 g F_2

M_{F_2} = 2(19.00 g/mol)

M_{F_2} = 38.00 g/mol F_2

1 mol F_2 = 38.00 g F_2

$$N_{F_2} = 4.4\ \cancel{g\ F_2} \times \frac{1\ \cancel{mol\ F_2}}{38.00\ \cancel{g\ F_2}} \times \frac{6.02 \times 10^{23}\ \cancel{\text{molecules } F_2}}{1\ \cancel{mol\ F_2}} \times \frac{2\ \text{atoms F}}{1\ \cancel{\text{molecule } F_2}}$$

$$N_{F_2} = 1.4 \times 10^{23}\ \text{atoms F}$$

There are 1.4×10^{23} atoms of fluorine in 4.4 g of fluorine gas.

19. $$m_{N_2} = 1.26\ \cancel{kg\ N_2} \times \frac{1000\ g\ N_2}{1\ \cancel{kg\ N_2}}$$

$$m_{N_2} = 1.26 \times 10^3\ g\ N_2$$

$M_{N_2} = 2(14.01\ \text{g/mol})$

$M_{N_2} = 28.02\ \text{g/mol}\ N_2$

$1\ \text{mol}\ N_2 = 28.02\ \text{g}\ N_2$

$$N_N = 1.26\times10^3\ \cancel{\text{g}\ N_2} \times \frac{1\ \cancel{\text{mol}\ N_2}}{28.02\ \cancel{\text{g}\ N_2}} \times \frac{6.02\times10^{23}\ \cancel{\text{molecules}\ N_2}}{1\ \cancel{\text{mol}\ N_2}} \times \frac{2\ \text{atoms N}}{1\ \cancel{\text{molecule}\ N_2}}$$

$N_N = 5.41\times10^{25}\ \text{atoms N}$

There are 5.41×10^{25} atoms of nitrogen in 1.26 kg of nitrogen gas.

20. $m_{C_2H_4} = 29.5\ \text{g}\ C_2H_4$

$M_{C_2H_4} = 2(12.01\ \text{g/mol}) + 4(1.01\ \text{g/mol})$

$M_{C_2H_4} = 28.06\ \text{g/mol}\ C_2H_4$

$1\ \text{mol}\ C_2H_4 = 28.06\ \text{g}\ C_2H_4$

$$N_H = 29.5\ \cancel{\text{g}\ C_2H_4} \times \frac{1\ \cancel{\text{mol}\ C_2H_4}}{28.06\ \cancel{\text{g}\ C_2H_4}} \times \frac{6.02\times10^{23}\ \cancel{\text{molecules}\ C_2H_4}}{1\ \cancel{\text{mol}\ C_2H_4}} \times \frac{4\ \text{atoms H}}{1\ \cancel{\text{molecule}\ C_2H_4}}$$

$N_H = 2.53\times10^{24}\ \text{atoms H}$

There are 2.53×10^{24} atoms of hydrogen in 29.5 g of ethane.

21. $m_{Sr(OH)_2} = 0.170\ \cancel{\text{mg}\ Sr(OH)_2} \times \dfrac{10^{-3}\ \text{g}\ Sr(OH)_2}{1\ \cancel{\text{mg}\ Sr(OH)_2}}$

$m_{Sr(OH)_2} = 1.70\times10^{-4}\ \text{g}\ Sr(OH)_2$

$M_{Sr(OH)_2} = 1(87.62\ \text{g/mol}) + 2(16.00\ \text{g/mol}) + 2(1.01\ \text{g/mol})$

$M_{Sr(OH)_2} = 121.64\ \text{g/mol}\ Sr(OH)_2$

$1\ \text{mol}\ Sr(OH)_2 = 121.64\ \text{g}\ Sr(OH)_2$

$$N_O = 1.70x10^{-4}\ \cancel{\text{g}\ Sr(OH)_2} \times \frac{1\ \cancel{\text{mol}\ Sr(OH)_2}}{121.64\ \cancel{\text{g}\ Sr(OH)_2}} \times \frac{6.02\times10^{23}\ \cancel{\text{molecules}\ Sr(OH)_2}}{1\ \cancel{\text{mol}\ Sr(OH)_2}} \times \frac{2\ \text{atoms O}}{1\ \cancel{\text{molecule}\ Sr(OH)_2}}$$

$N_O = 1.68\times10^{18}\ \text{atoms O}$

There are 1.68×10^{18} atoms of oxygen in 0.170 mg of strontium hydroxide.

TRY THIS ACTIVITY: COUNTING ATOMS, MOLECULES, AND OTHER ENTITIES

(Page 105)

1. mass of 50 drops of water = 1.95 g

$$\text{mass of 1 drop of water} = \frac{1.95\ \text{g}}{50}$$

mass of 1 drop of water = 0.039 g

The mass of 1 drop of water is 0.039 g.

2. time of 1 drop of water to evaporate = 65 min, or 3.9×10^3 s

$$N_{H_2O} = 0.039\ \cancel{\text{g}\ H_2O} \times \frac{1\ \cancel{\text{mol}\ H_2O}}{18.02\ \cancel{\text{g}\ H_2O}} \times \frac{6.02\times10^{23}\ \text{molecules}\ H_2O}{1\ \cancel{\text{mol}\ H_2O}}$$

$N_{H_2O} = 1.30\times10^{21}\ \text{molecules}\ H_2O$

There are 1.30×10^{21} molecules of water in every drop.

$$\text{evaporation rate} = \frac{1.30 \times 10^{21} \text{ molecules } H_2O}{3.9 \times 10^{3} \text{ s}}$$

$$\text{evaporation rate} = 3.34 \times 10^{17} \text{ molecules/s}$$

Water molecules evaporate at the average rate of 3.34×10^{17} molecules/s.

3. mass of 1 penny = 2.44 g

$$N_{Cu} = 2.44 \ \cancel{\text{g Cu}} \times \frac{1 \ \cancel{\text{mol Cu}}}{63.55 \ \cancel{\text{g Cu}}} \times \frac{6.02 \times 10^{23} \text{ atoms Cu}}{1 \ \cancel{\text{mol Cu}}}$$

$$N_{Cu} = 2.31 \times 10^{22} \text{ atoms Cu}$$

There are 2.31×10^{22} copper atoms in a copper penny.

$$\text{value of a copper atom} = \frac{1 \text{ cent}}{2.31 \times 10^{22} \text{ atoms}}$$

$$\text{value of a copper atom} = 4.33 \times 10^{-23} \text{ cents}$$

Each copper atom in a penny has a value of 4.33×10^{-23} cents.

4. $M_{C_{12}H_{22}O_{11}}$ = 337.34 g/mol $C_{12}H_{22}O_{11}$

$$\text{mass of half a mole of sucrose} = \frac{337.34 \text{ g}}{1 \ \cancel{\text{mol}}} \times \frac{1 \ \cancel{\text{mol}}}{2}$$

$$\text{mass of half a mole of sucrose} = 168.67 \text{ g}$$

When poured into a graduated cylinder, the volume of half a mole of sucrose is 185 mL.

5. One mole of sucrose, $C_{12}H_{22}O_{11(s)}$, contains 12 mol carbon atoms. Therefore, you would need one-sixth of a mole of sucrose to get 2 mol carbon atoms.

$$\text{required mass of sucrose} = \frac{337.34 \text{ g}}{1 \ \cancel{\text{mol}}} \times \frac{1 \ \cancel{\text{mol}}}{6}$$

$$\text{required mass of sucrose} = 56.22 \text{ g}$$

When poured into a graduated cylinder, the volume of sucrose is 60 mL.

6. initial mass of chalk = 14.23 g
final mass of chalk = 14.15 g
change in mass of chalk = 0.08 g

$$M_{CaCO_3} = 100.09 \text{ g/mol}$$

$$N_{CaCO_3} = 0.08 \ \cancel{\text{g } CaCO_3} \times \frac{1 \ \cancel{\text{mol } CaCO_3}}{100.09 \ \cancel{\text{g } CaCO_3}} \times \frac{6.02 \times 10^{23} \text{ formula units } CaCO_3}{1 \ \cancel{\text{mol } CaCO_3}}$$

$$N_{CaCO_3} = 4.81 \times 10^{20} \text{ formula units } CaCO_3$$

Since there are 5 atoms in each formula unit of calcium carbonate, we must multiply the answer by 5 atoms.

$$\text{number of atoms} = 4.81 \times 10^{20} \ \cancel{\text{formula unit}} \times \frac{5 \text{ atoms}}{1 \ \cancel{\text{formula unit}}}$$

$$\text{number of atoms} = 2.40 \times 10^{21} \text{ atoms}$$

The number of atoms needed to write my name in chalk is 2.40×10^{21} atoms.

7. m_{NaCl} = 3.00 g NaCl
M_{NaCl} = 58.44 g/mol NaCl

$$N_{NaCl} = 3.00\ \cancel{\text{g NaCl}} \times \frac{1\ \cancel{\text{mol NaCl}}}{57.44\ \cancel{\text{g NaCl}}} \times \frac{6.02 \times 10^{23}\ \text{formula units NaCl}}{1\ \cancel{\text{mol NaCl}}}$$

$$N_{NaCl} = 3.09 \times 10^{22}\ \text{formula units NaCl}$$

Since there is one sodium ion in every formula unit of sodium chloride, the number of sodium ions is 3.09×10^{22}.

8. m_{nail} = 4.16 g Fe
   M_{Fe} = 55.85 g/mol Fe

$$N_{Fe} = 4.16\ \cancel{\text{g Fe}} \times \frac{1\ \cancel{\text{mol Fe}}}{55.85\ \cancel{\text{g Fe}}} \times \frac{6.02 \times 10^{23}\ \text{atoms Fe}}{1\ \cancel{\text{mol Fe}}}$$

$$N_{Fe} = 4.48 \times 10^{22}\ \text{atoms}$$

There are 4.48×10^{22} atoms in the iron nail.

9. $$\text{number of seconds in one year} = \frac{60\ \text{s}}{1\ \cancel{\text{min}}} \times \frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}} \times \frac{24\ \cancel{\text{h}}}{1\ \cancel{\text{d}}} \times \frac{365\ \cancel{\text{d}}}{1\ \text{year}}$$

$$\text{number of seconds in one year} = 3.15 \times 10^{7}\ \text{s/year}$$

$$\text{years in one mole of seconds} = \frac{6.02 \times 10^{23}\ \cancel{\text{s}}}{1\ \text{mol}} \times \frac{1\ \text{year}}{3.15 \times 10^{7}\ \cancel{\text{s}}}$$

$$\text{years in one mole of seconds} = 1.91 \times 10^{16}\ \text{year/mol}$$

It takes 1.91×10^{16} years to span one mole of seconds.

SECTION 2.2 QUESTIONS

(Page 106)

Understanding Concepts

1. $$M_{Mg(OH)_2} = 1(M_{Mg}) + 2(M_O) + 2(M_H)$$
$$= 1(24.31\ \text{g/mol}) + 2(16.00\ \text{g/mol}) + 2(1.01\ \text{g/mol})$$
$$M_{Mg(OH)_2} = 58.33\ \text{g/mol}$$

   The molar mass of magnesium hydroxide is 58.33 g/mol.

2. $$M_{O_3} = 3(M_O)$$
$$= 3(16.00\ \text{g/mol})$$
$$M_{O_3} = 48.00\ \text{g/mol } O_3$$

   The molar mass of ozone is 48.00 g/mol.

3. Student answers will vary.
   Let the substance be represented by Z.
   M_Z = 67.2 g/mol

$$1.0\ \text{mol Z} = 67.2\ \text{g Z}$$
$$8.0\ \text{mol Z} = 67.2\ \text{g Z} \times 8$$
$$m_Z = 538\ \text{g Z}$$

   The mass of 8.0 mol of the substance is 538 g.

4. The mass of one mole of sucrose is equal to its molar mass.

$$M_{C_{12}H_{22}O_{11}} = 12(M_C) + 22(M_H) + 11(M_O)$$
$$= 12(12.01\ \text{g/mol}) + 22(1.01\ \text{g/mol}) + 11(16.00\ \text{g/mol})$$
$$M_{C_{12}H_{22}O_{11}} = 342.34\ \text{g/mol } C_{12}H_{22}O_{11}$$

   Since the molar mass of sucrose is equal to 342.34 g/mol, the mass of one mole of sucrose is 342.34 g.

5. (a) $n_{Al} = 0.1$ mol Al

1 mol Al = 6.02×10^{23} atoms Al

$$N_{Al} = 0.1 \cancel{\text{mol Al}} \times \frac{6.02 \times 10^{23} \text{ atoms Al}}{1 \cancel{\text{mol Al}}}$$

$$N_{Al} = 6.02 \times 10^{22} \text{ atoms Al}$$

There are 6.02×10^{22} atoms of aluminum in 0.1 mol aluminum.

(b) $n_{MgCl_2} = 3.5$ mol $MgCl_2$

1 mol $MgCl_2$ = 6.02×10^{23} formula units $MgCl_2$

$$N_{MgCl_2} = 3.5 \cancel{\text{mol MgCl}_2} \times \frac{6.02 \times 10^{23} \text{ formula units MgCl}_2}{1 \cancel{\text{mol MgCl}_2}}$$

$$N_{MgCl_2} = 2.1 \times 10^{24} \text{ formula units MgCl}_2$$

There are 2.1×10^{24} formula units of magnesium chloride in 3.5 mol magnesium chloride.

6. (a)
$$m_{C_{12}H_{22}O_{11}} = 5.00 \cancel{\text{kg C}_{12}\text{H}_{22}\text{O}_{11}} \times \frac{1000 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}}{1 \cancel{\text{kg C}_{12}\text{H}_{22}\text{O}_{11}}}$$

$$m_{C_{12}H_{22}O_{11}} = 5.00 \times 10^3 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}$$

$$M_{C_{12}H_{22}O_{11}} = 12(12.01 \text{ g/mol}) + 22(1.01 \text{ g/mol}) + 11(16.00 \text{ g/mol})$$

$$M_{C_{12}H_{22}O_{11}} = 342.34 \text{ g/mol C}_{12}\text{H}_{22}\text{O}_{11}$$

$$1 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11} = 342.34 \text{ g C}_{12}\text{H}_{22}\text{O}_{11}$$

$$n_{C_{12}H_{22}O_{11}} = 5.00 \times 10^3 \cancel{\text{g C}_{12}\text{H}_{22}\text{O}_{11}} \times \frac{1 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}}{342.34 \cancel{\text{g C}_{12}\text{H}_{22}\text{O}_{11}}}$$

$$n_{C_{12}H_{22}O_{11}} = 14.6 \text{ mol C}_{12}\text{H}_{22}\text{O}_{11}$$

There is 14.6 mol sucrose in 5.00 kg of table sugar.

(b)
$$m_{C_{10}H_8} = 250 \text{ g C}_{10}\text{H}_8$$

$$M_{C_{10}H_8} = 10(12.01 \text{ g/mol}) + 8(1.01 \text{ g/mol})$$

$$M_{C_{10}H_8} = 128.18 \text{ g/mol C}_{10}\text{H}_8$$

$$1 \text{ mol C}_{10}\text{H}_8 = 128.18 \text{ g C}_{10}\text{H}_8$$

$$n_{C_{10}H_8} = 250 \cancel{\text{g C}_{10}\text{H}_8} \times \frac{1 \text{ mol C}_{10}\text{H}_8}{128.18 \cancel{\text{g C}_{10}\text{H}_8}}$$

$$n_{C_{10}H_8} = 1.95 \text{ mol C}_{10}\text{H}_8$$

There is 1.95 mol naphthalene in 250 g of naphthalene moth balls.

(c)
$$m_{C_3H_8} = 35.0 \text{ g C}_3\text{H}_8$$

$$M_{C_3H_8} = 3(12.01 \text{ g/mol}) + 8(1.01 \text{ g/mol})$$

$$M_{C_3H_8} = 44.11 \text{ g/mol C}_3\text{H}_8$$

$$1 \text{ mol C}_3\text{H}_8 = 44.11 \text{ g C}_3\text{H}_8$$

$$n_{C_3H_8} = 35.0 \cancel{\text{g C}_3\text{H}_8} \times \frac{1 \text{ mol C}_3\text{H}_8}{44.11 \cancel{\text{g C}_3\text{H}_8}}$$

$$n_{C_3H_8} = 0.793 \text{ mol C}_3\text{H}_8$$

There is 0.793 mol propane in the stove cylinder.

(d) $m_{C_9H_8O_4} = 275 \text{ mg } C_9H_8O_4 \times \dfrac{10^{-3} \text{ g } C_9H_8O_4}{1 \text{ mg } C_9H_8O_4}$

$m_{C_9H_8O_4} = 0.275 \text{ g} C_9H_8O_4$

$M_{C_9H_8O_4} = 9(12.01 \text{ g/mol}) + 8(1.01 \text{ g/mol}) + 4(16.00 \text{ g/mol})$

$M_{C_9H_8O_4} = 180.17 \text{ g/mol } C_9H_8O_4$

$1 \text{ mol} C_9H_8O_4 = 180.17 \text{ g/mol } C_9H_8O_4$

$$n_{C_9H_8O_4} = 0.275 \cancel{\text{ g } C_9H_8O_4} \times \frac{1 \text{ mol } C_9H_8O_4}{180.17 \cancel{\text{ g } C_9H_8O_4}}$$

$$n_{C_9H_8O_4} = 1.53 \times 10^{-3} \text{ mol } C_9H_8O_4$$

There is 1.53 × 10^{-3} mol acetylsalicylic acid in a 275-mg headache relief tablet.

(e) $m_{C_3H_8O} = 240 \text{ g} C_3H_8O$

$M_{C_3H_8O} = 3(12.01 \text{ g/mol}) + 8(1.01 \text{ g/mol}) + 1(16.00 \text{ g/mol})$

$M_{C_3H_8O} = 60.11 \text{ g/mol } C_3H_9O$

$1 \text{ mol } C_3H_8O = 60.11 \text{ g } C_3H_8O$

$$n_{C_3H_8O} = 240 \cancel{\text{ g } C_3H_8O} \times \frac{1 \text{ mol } C_3H_8O}{60.11 \cancel{\text{ g } C_3H_8O}}$$

$$n_{C_3H_8O} = 4.0 \text{ mol } C_3H_8O$$

There is 4.0 mol 2-propanol in 240 g of rubbing alcohol.

7. (a) $n_{NH_3} = 2.67 \text{ mol } NH_3$

$M_{NH_3} = 1(14.01 \text{ g/mol}) + 3(1.01 \text{ g/mol})$

$M_{NH_3} = 17.04 \text{ g/mol } NH_3$

$1 \text{ mol } NH_3 = 17.4 \text{ g } NH_3$

$$m_{NH_3} = 2.67 \cancel{\text{ mol } NH_3} \times \frac{17.04 \text{ g } NH_3}{1 \cancel{\text{ mol } NH_3}}$$

$$m_{NH_3} = 45.5 \text{ g } NH_3$$

The mass of 2.67 mol ammonia is 45.5 g.

(b) $n_{NaOH} = 0.965 \text{ mol NaOH}$

$M_{NaOH} = 1(22.99 \text{ g/mol}) + 1(16.00 \text{ g/mol}) + 1(1.01 \text{ g/mol})$

$M_{NaOH} = 40.00 \text{ g/mol NaOH}$

$1 \text{ mol NaOH} = 40.00 \text{ g NaOH}$

$$m_{NaOH} = 0.965 \cancel{\text{ mol NaOH}} \times \frac{40.00 \text{ g NaOH}}{1 \cancel{\text{ mol NaOH}}}$$

$$m_{NaOH} = 38.6 \text{ g NaOH}$$

The mass of 0.965 mol sodium hydroxide is 38.6 g.

(c) $n_{H_2O} = 19.7 \text{ mol } H_2O$

$M_{H_2O} = 2(1.01 \text{ g/mol}) + 1(16.00 \text{ g/mol})$

$M_{H_2O} = 18.02 \text{ g/mol } H_2O$

$1 \text{ mol } H_2O = 18.02 \text{ g } H_2O$

$$m_{H_2O} = 19.7 \cancel{\text{mol } H_2O} \times \frac{18.02 \text{ g } H_2O}{1 \cancel{\text{ mol } H_2O}}$$

$$m_{H_2O} = 355 \text{ g } H_2O$$

The mass of 19.7 mol water vapour is 355 g.

(d) $n_{KMnO_4} = 3.85 \text{ mol } KMnO_4$

$M_{KMnO_4} = 1(39.10 \text{ g/mol}) + 1(54.94 \text{ g/mol}) + 4(16.00 \text{ g/mol})$

$M_{KMnO_4} = 158.04 \text{ g/mol } KMnO_4$

$1 \text{ mol } KMnO_4 = 158.04 \text{ g } KMnO_4$

$$m_{KMnO_4} = 3.85 \cancel{\text{ mol } KMnO_4} \times \frac{158.04 \text{ g } KMnO_4}{1 \cancel{\text{ mol } KMnO_4}}$$

$$m_{KMnO_4} = 608 \text{ g } KMnO_4$$

The mass of 3.85 mol potassium permanganate is 608 g.

(e) $n_{(NH_4)_2SO_4} = 0.47 \text{ mol } (NH_4)_2SO_4$

$M_{(NH_4)_2SO_4} = 2(14.01 \text{ g/mol}) + 8(1.01 \text{ g/mol}) + 1(32.06 \text{ g/mol}) + 4(16.00 \text{ g/mol})$

$M_{(NH_4)_2SO_4} = 132.16 \text{ g/mol } (NH_4)_2SO_4$

$1 \text{ mol } (NH_4)_2SO_4 = 132.16 \text{ g } (NH_4)_2SO_4$

$$m_{(NH_4)_2SO_4} = 0.47 \cancel{\text{ mol } (NH_4)_2SO_4} \times \frac{132.16 \text{ g } NH_4)_2SO_4}{1 \cancel{\text{ mol } (NH_4)_2SO_4}}$$

$$m_{(NH_4)_2SO_4} = 62 \text{ g } (NH_4)_2SO_4$$

The mass of 0.47 mol ammonium sulfate is 62 g.

8. (a) $n_{CO_2} = 2.5 \text{ mol } CO_2$

$1 \text{ mol } CO_2 = 6.02 \times 10^{23} \text{ molecules } CO_2$

$$N_{CO_2} = 2.5 \cancel{\text{ mol } CO_2} \times \frac{6.02 \times 10^{23} \text{ molecules } CO_2}{1 \cancel{\text{ mol } CO_2}}$$

$$N_{CO_2} = 1.5 \times 10^{24} \text{ molecules } CO_2$$

There are 1.5×10^{24} molecules OF solid carbon dioxide in 2.5 mol carbon dioxide.

(b) $m_{NH_3} = 2.5 \text{ g } NH_3$

$M_{NH_3} = 1(14.01 \text{ g/mol}) + 3(1.01 \text{ g/mol})$

$M_{NH_3} = 17.04 \text{ g/mol } NH_3$

$1 \text{ mol } NH_3 = 17.04 \text{ g } NH_3$

$1 \text{ mol } NH_3 = 6.02 \times 10^{23} \text{ molecules } NH_3$

$$N_{NH_3} = 2.5 \cancel{\text{ g } NH_3} \times \frac{1 \cancel{\text{ mol } NH_3}}{17.04 \cancel{\text{ g } NH_3}} \times \frac{6.02 \times 10^{23} \text{ molecules } NH_3}{1 \cancel{\text{ mol } NH_3}}$$

$$N_{NH_3} = 8.8 \times 10^{22} \text{ molecules } NH_3$$

There are 8.8×10^{22} molecules of ammonia in 2.5 g of ammonia gas.

(c) $m_{HCl} = 2.5 \text{ g HCl}$

$M_{HCl} = 1(1.01 \text{ g/mol}) + 1(35.45 \text{ g/mol})$

$M_{HCl} = 36.46 \text{ g/mol HCl}$

$1 \text{ mol HCl} = 36.46 \text{ g HCl}$

$1 \text{ mol HCl} = 6.02 \times 10^{23} \text{ molecules HCl}$

$$N_{HCl} = 2.5 \ \cancel{\text{g HCl}} \times \frac{1 \ \cancel{\text{mol HCl}}}{36.46 \ \cancel{\text{g HCl}}} \times \frac{6.02 \times 10^{23} \text{ molecules HCl}}{1 \ \cancel{\text{mol HCl}}}$$

$$N_{HCl} = 4.1 \times 10^{22} \text{ molecules HCl}$$

There are 4.1×10^{22} molecules in 2.5 g of hydrogen chloride gas.

9. (a) $N_{CO_2} = 0.10 \text{ mol } CO_2$

$M_{CO_2} = 1(12.01 \text{ g/mol}) + 2(16.00 \text{ g/mol})$

$M_{CO_2} = 44.01 \text{ g/mol } CO_2$

$1 \text{ mol } CO_2 = 44.01 \text{ g } CO_2$

$$m_{CO_2} = 0.10 \ \cancel{\text{mol } CO_2} \times \frac{44.01 \text{ g } CO_2}{1 \ \cancel{\text{mol } CO_2}}$$

$$m_{CO_2} = 4.4 \text{ g } CO_2$$

The mass of 0.10 mol carbon dioxide is 4.4 g.

(b) $n_{C_6H_{12}O_6} = 0.10 \text{ mol } C_6H_{12}O_6$

$M_{C_6H_{12}O_6} = 6(12.01 \text{ g/mol}) + 12(1.01 \text{ g/mol}) + 6(16.00 \text{ g/mol})$

$M_{C_6H_{12}O_6} = 180.18 \text{ g/mol } C_6H_{12}O_6$

$1 \text{ mol } C_6H_{12}O_6 = 180.18 \text{ g } C_6H_{12}O_6$

$$m_{C_6H_{12}O_6} = 0.10 \ \cancel{\text{mol } C_6H_{12}O_6} \times \frac{180.18 \text{ g } C_6H_{12}O_6}{1 \ \cancel{\text{mol } C_6H_{12}O_6}}$$

$$m_{C_6H_{12}O_6} = 18 \text{ g } C_6H_{12}O_6$$

The mass of 0.10 mol glucose is 18 g.

(c) $N_{O_2} = 0.10 \text{ mol } O_2$

$M_{O_2} = 2(16.00 \text{ g/mol})$

$M_{O_2} = 32.00 \text{ g/mol } O_2$

$1 \text{ mol} O_2 = 32.00 \text{ g } O_2$

$$m_{O_2} = 0.10 \ \cancel{\text{mol } O_2} \times \frac{32.00 \text{ g } O_2}{1 \ \cancel{\text{mol } O_2}}$$

$$m_{O_2} = 3.2 \text{ g } O_2$$

The mass of 0.10 mol oxygen gas is 3.2 g.

10. $N_{O_2} = 2.7 \text{ mol } O_2$

$1 \text{ mol} O_2 = 6.02 \times 10^{23} \text{ molecules } O_2$

$$N_{O_2} = 2.7 \ \cancel{\text{mol } O_2} \times \frac{6.02 \times 10^{23} \text{ molecules } O_2}{1 \ \cancel{\text{mol } O_2}}$$

$$N_{O_2} = 1.6 \times 10^{24} \text{ molecules } O_2$$

There are 1.6×10^{24} oxygen molecules in 2.7 mol oxygen gas.

11. $m_{C_6H_8O_6} = 90\ \text{mg}\ C_6H_8O_6 \times \dfrac{10^{-3}\ \text{g}\ C_6H_8O_6}{1\ \text{mg}\ C_6H_8O_6}$

$m_{C_6H_8O_6} = 9 \times 10^{-2}\ \text{g}\ C_6H_8O_6$

$M_{C_6H_8O_6} = 6(12.01\ \text{g/mol}) + 8(1.01\ \text{g/mol}) + 6(16.00\ \text{g/mol})$

$M_{C_6H_8O_6} = 176.14\ \text{g/mol}\ C_6H_8O_6$

$1\ \text{mol}\ C_6H_8O_6 = 176.14\ \text{g/mol}$

$1\ \text{mol}\ C_6H_8O_6 = 6.02 \times 10^{23}\ \text{molecules}\ C_6H_8O_6$

$$N_{C_6H_8O_6} = 9 \times 10^{-2}\ \cancel{\text{g}\ C_6H_8O_6} \times \frac{1\ \cancel{\text{mol}\ C_6H_8O_6}}{176.14\ \cancel{\text{g}\ C_6H_8O_6}} \times \frac{6.02 \times 10^{23}\ \text{molecules}\ C_6H_8O_6}{1\ \cancel{\text{mol}\ C_6H_8O_6}}$$

$N_{C_6H_8O_6} = 3.1 \times 10^{20}\ \text{molecules}\ C_6H_8O_6$

The number of molecules of vitamin C taken each day would be 3.1×10^{20} molecules.

12. **water**

$m_{H_2O} = 450\ \text{g}H_2O$

$M_{H_2O} = 2(1.01\ \text{g/mol}) + 1(16.00\ \text{g/mol})$

$M_{H_2O} = 18.02\ \text{g/mol}\ H_2O$

$1\ \text{mol}\ H_2O = 18.02\ \text{g}\ H_2O$

$$n_{H_2O} = 450\ \cancel{\text{g}H_2O} \times \frac{1\ \text{mol}\ H_2O}{18.02\ \cancel{\text{g}\ H_2O}}$$

$n_{H_2O} = 25\ \text{mol}\ H_2O$

sugar

$m_{C_{12}H_{22}O_{11}} = 100\ \text{g}\ C_{12}H_{22}O_{11}$

$M_{C_{12}H_{22}O_{11}} = 12(12.01\ \text{g/mol}) + 22(1.01\ \text{g/mol}) + 11(16.00\ \text{g/mol})$

$M_{C_{12}H_{22}O_{11}} = 342.34\ \text{g/mol}\ C_{12}H_{22}O_{11}$

$1\ \text{mol}\ C_{12}H_{22}O_{11} = 342.34\ \text{g}\ C_{12}H_{22}O_{11}$

$$n_{C_{12}H_{22}O_{11}} = 100\ \cancel{\text{g}\ C_{12}H_{22}O_{11}} \times \frac{1\ \text{mol}\ C_{12}H_{22}O_{11}}{342.34\ \cancel{\text{g}\ C_{12}H_{22}O_{11}}}$$

$n_{C_{12}H_{22}O_{11}} = 0.3\ \text{mol}\ C_{12}H_{22}O_{11}$

vinegar

$m_{HC_2H_3O_2} = 2.4\ \text{g}\ HC_2H_3O_2$

$M_{HC_2H_3O_2} = 4(1.01\ \text{g/mol}) + 2(12.01\ \text{g/mol}) + 2(16.00\ \text{g/mol})$

$M_{HC_2H_3O_2} = 60.06\ \text{g/mol}\ HC_2H_3O_2$

$1\ \text{mol}\ HC_2H_3O_2 = 60.06\ \text{g}\ HC_2H_3O_2$

$$n_{HC_2H_3O_2} = 2.4\ \cancel{\text{g}\ HC_2H_3O_2} \times \frac{1\text{mol}\ HC_2H_3O_2}{60.06\ \cancel{\text{g}\ HC_2H_3O_2}}$$

$n_{HC_2H_3O_2} = 0.040\ \text{mol}\ HC_2H_3O_2$

salt

$m_{NaCl} = 2 \text{ g NaCl}$

$M_{NaCl} = 1(22.99 \text{ g/mol}) + 1(35.45 \text{ g/mol})$

$M_{NaCl} = 58.44 \text{ g/mol NaCl}$

$1 \text{ mol NaCl} = 58.44 \text{ g NaCl}$

$$n_{NaCl} = 2\ \cancel{\text{g NaCl}} \times \frac{1 \text{ mol NaCl}}{58.44\ \cancel{\text{g NaCl}}}$$

$$n_{NaCl} = 0.03 \text{ mol NaCl}$$

The recipe calls for 25 mol water, 0.3 mol sugar, 0.040 mol acetic acid (vinegar), and 0.03 mol salt.

Applied Inquiry Skills

13. **Materials**

eye protection
lab apron
250-mL beaker
silver nitrate
distilled water
stirring rod
coil of copper wire
filter paper
scoopula

Warning: Silver chloride may stain skin and cause skin irritation. Avoid contact with skin. Do not taste.

Procedure

1. Prepare a solution of silver ions by dissolving 0.1 g of silver nitrate in 100 mL water in a 250-mL beaker.
2. Place a coil of copper wire into the silver nitrate solution and let sit for 24 h.
3. Measure the mass of a piece of filter paper, $m_{\text{filter paper}}$.
4. Carefully remove the copper coil from the silver nitrate solution and scrape all the silver crystals from the coil onto the filter paper.
5. Allow the silver crystals to dry.
6. Determine the mass of the filter paper and dry silver crystals, $m_{\text{filter paper + Ag}}$.
7. Calculate the mass of the silver crystals by subtracting the mass of the filter paper (Step 4) from the mass of the filter paper and silver crystals (step 7).

   $m_{Ag} = m_{\text{filter paper + Ag}} - m_{\text{filter paper}}$
8. Calculate the amount of silver recovered, n_{Ag}, as follows.

   $$n_{Ag_{(s)}} = m_{Ag} \times \frac{1 \text{ mol}}{107.87 \text{ g}}$$

Making Connections

14. Student answers will vary. The mole deserves to win this award because without the mole, chemists could not calculate the number of chemical entities they use in chemical reactions. Knowing the number of entities used in reactions enables chemists to maximize the amount of product formed, and minimize the amount of reactants that remain unreacted. When chemicals are mixed haphazardly, excess reactants mix with products and must be separated in order to purify the products. This effect increases the cost associated with the industrial preparation of chemicals, and may lead to increased levels of chemical waste and chemical pollution.