UNIT 2 REVIEW

(Pages 169–173)

Understanding Concepts

1. (a) The coefficients of aluminium, oxygen and aluminium oxide are 4, 3, and 2 respectively.
   (b) The equation states that 4 mol solid aluminium reacts with 3 mol of gaseous oxygen to yield 2 mol solid aluminium oxide.
2. (a) There are 12 (twelve) doughnuts in one dozen doughnuts.
   There are 6.02×10^{23} doughnuts in one mole of doughnuts.
   (b) 1 doughnut = 70 g
   1 mol doughnuts = 6.02×10^{23} doughnuts

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

$$N_{\text{doughnuts}} = 6.02 \times 10^{23}\ \text{doughnuts}$$

$$m_{\text{doughnuts}} = 6.02 \times 10^{23}\ \cancel{\text{doughnuts}} \times \frac{70\ \text{g}}{1\ \cancel{\text{doughnut}}}$$

$$m_{\text{doughnuts}} = 4 \times 10^{25}\ \text{g}$$

The mass of one mole of doughnuts is 4×10^{25} g.

The combined calculation is as follows:

$$m_{\text{doughnuts}} = 1\ \cancel{\text{mol doughnuts}} \times \frac{6.02 \times 10^{23}\ \cancel{\text{doughnuts}}}{1\ \cancel{\text{mol doughnuts}}} \times \frac{70\ \text{g}}{1\ \cancel{\text{doughnut}}}$$

$$m_{\text{doughnuts}} = 4 \times 10^{25}\ \text{g}$$

The mass of one mole of doughnuts is 4×10^{25} g.
   (c) Student answers will vary. One mole of doughnuts is not a reasonable number of doughnuts because this number is far too large. This many doughnuts would be unmanageable to do anything with, such as count, distribute, or eat.
3. (a) $n_{\text{Hg}} = 1\ \text{mol Hg}$

$$1\ \text{mol Hg} = 6.02 \times 10^{23}\ \text{atoms Hg}$$

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

$$N_{\text{Hg}} = 6.02 \times 10^{23}\ \text{atoms Hg}$$

There are 6.02×10^{23} atoms of mercury in 1 mol mercury.

   (b) $n_{\text{Hg}} = 1\ \text{mol Hg}$

$$m_{\text{Hg}} = 200.59\ \text{g Hg}$$

$$m_{\text{Hg}} = 1\ \cancel{\text{mol Hg}} \times \frac{200.59\ \text{g Hg}}{1\ \cancel{\text{mol Hg}}}$$

$$m_{\text{Hg}} = 200.59\ \text{g Hg}$$

One mole of mercury atoms has a mass of 200.59 g.
   (c) One mole of mercury atoms is a reasonable number of mercury atoms because it is a quantity that chemists can measure, observe, and work with.
4. We use Avogadro's constant because it allows a chemist to know how many chemical entities (atoms, molecules, or formula units) there are in a particular mass of the chemical.

5. (a) $m_{\mathrm{C}} = 0.50 \text{ carat C}$

$1 \text{ carat C} = 0.2 \text{ g C}$

$1 \text{ mol C} = 12.01 \text{ g C}$

$1 \text{ mol C} = 6.02 \times 10^{23} \text{ atoms C}$

$$m_{\mathrm{C}} = 0.50\ \cancel{\text{carat C}} \times \frac{0.2 \text{ g C}}{1\ \cancel{\text{carat C}}}$$

$m_{\mathrm{C}} = 0.10 \text{ g C}$

$$n_{\mathrm{C}} = 0.10\ \cancel{\text{g C}} \times \frac{1 \text{ mol C}}{12.01\ \cancel{\text{g C}}}$$

$n_{\mathrm{C}} = 8.3 \times 10^{-3} \text{ mol C}$

The amount of carbon in the diamond is 8.3×10^{-3} mol.

$$N_{\mathrm{C}} = 8.3 \times 10^{-3}\ \cancel{\text{mol C}} \times \frac{6.02 \times 10^{23} \text{ atoms C}}{1\ \cancel{\text{mol C}}}$$

$N_{\mathrm{C}} = 5.0 \times 10^{21} \text{ atoms C}$

There are 5.0×10^{21} atoms of carbon in the diamond.

The combined calculation for amount is as follows:

$$n_{\mathrm{C}} = 0.50\ \cancel{\text{carat C}} \times \frac{0.2\ \cancel{\text{g C}}}{1\ \cancel{\text{carat C}}} \times \frac{1 \text{ mol C}}{12.01\ \cancel{\text{g C}}}$$

$n_{\mathrm{C}} = 8.3 \times 10^{-3} \text{ mol C}$

The amount of carbon in the diamond is 8.3×10^{-3} mol.

The combined calculation for number of atoms is as follows:

$$N_{\mathrm{C}} = 0.50\ \cancel{\text{carat C}} \times \frac{0.2\ \cancel{\text{g C}}}{1\ \cancel{\text{carat C}}} \times \frac{1\ \cancel{\text{mol C}}}{12.01\ \cancel{\text{g C}}} \times \frac{6.02 \times 10^{23} \text{ atoms C}}{1\ \cancel{\text{mol C}}}$$

$N_{\mathrm{C}} = 5.0 \times 10^{21} \text{ atoms C}$

There are 5.0×10^{21} atoms of carbon in the diamond.

(b) $m_{\mathrm{Au}} = 6.50 \text{ g Au}$

$1 \text{ mol Au} = 196.97 \text{ g Au}$

$1 \text{ mol Au} = 6.02 \times 10^{23} \text{ atoms Au}$

$$n_{\mathrm{Au}} = 6.50\ \cancel{\text{g Au}} \times \frac{1 \text{ mol Au}}{196.97\ \cancel{\text{g Au}}}$$

$n_{\mathrm{Au}} = 0.0330 \text{ mol Au}$

There is 0.0330 mol gold in the ring.

$$N_{\mathrm{Au}} = 0.0330\ \cancel{\text{mol Au}} \times \frac{6.02 \times 10^{23} \text{ atoms Au}}{1\ \cancel{\text{mol Au}}}$$

$N_{\mathrm{Au}} = 1.99 \times 10^{22} \text{ atoms Au}$

There are 1.99×10^{22} atoms of gold in the ring.

6. (a) $M_{C_8H_6O_4} = 6(M_C) + 6(M_H) + 4(M_O)$

$$= 8(12.01\text{ g/mol}) + 6(1.01\text{ g/mol}) + 4(16.00\text{ g/mol})$$

$$= 96.08\text{ g/mol} + 6.06\text{ g/mol} + 64.00\text{ g/mol}$$

$$M_{C_8H_6O_4} = 166.14\text{ g/mol}$$

The molar mass of 1,4-benzenedicarboxylic acid is 166.14 g/mol.

(b) $n_{C_8H_9NO_2} = 1.5 \times 10^{-3}\text{ mol }C_8H_9NO_2$

$$M_{C_8H_9NO_2} = 151.18\text{ g/mol }C_8H_9NO_2$$

$$m_{C_8H_9NO_2} = 1.5 \times 10^{-3}\ \cancel{\text{mol }C_8H_9NO_2} \times \frac{151.18\text{ g }C_8H_9NO_2}{1\ \cancel{\text{mol }C_8H_9NO_2}}$$

$$m_{C_8H_6O_4} = 0.23\text{ g }C_8H_9NO_2$$

The patient should take 0.23 g of Tylenol.

(c) $m_{C_4H_{10}} = 0.95\text{ g }C_4H_{10}$

$$M_{C_4H_{10}} = 58.14\text{ g/mol }C_4H_{10}$$

$$n_{C_4H_{10}} = 0.95\ \cancel{\text{g }C_4H_{10}} \times \frac{1\text{ mol }C_4H_{10}}{58.14\ \cancel{\text{g }C_4H_{10}}}$$

$$n_{C_4H_{10}} = 0.016\text{ mol }C_4H_{10}$$

There is 0.016 mol butane in the lighter.

(d) $m_{C_6H_8O_6} = 0.5\text{ g }C_6H_8O_6$

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

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

$$1\text{ molecule }C_6H_8O_6 = 6\text{ atoms C}$$

$$n_{C_6H_8O_6} = 0.5\ \cancel{\text{g }C_6H_8O_6} \times \frac{1\text{ mol }C_6H_8O_6}{176.14\ \cancel{\text{g }C_6H_8O_6}}$$

$$n_{C_6H_8O_6} = 2.8 \times 10^{-3}\text{ mol }C_6H_8O_6$$

$$N_{C_6H_8O_6} = 2.8 \times 10^{-3}\ \cancel{\text{mol }C_6H_8O_6} \times \frac{6.02 \times 10^{23}\text{ molecules }C_6H_8O_6}{1\ \cancel{\text{mol }C_6H_8O_6}}$$

$$N_{C_6H_8O_6} = 1.7 \times 10^{21}\text{ molecules }C_6H_8O_6$$

$$N_C = 1.7 \times 10^{21}\ \cancel{\text{molecules }C_6H_8O_6} \times \frac{6\text{ atoms C}}{1\ \cancel{\text{molecule }C_6H_8O_6}}$$

$$N_C = 1.0 \times 10^{22}\text{ atoms C}$$

The vitamin C table contains 1.0×10^{22} atoms of carbon.

7. A molecular element contains two or more atoms of the same element attached by covalent bonds. Examples include oxygen, $O_{2(g)}$, and bromine, $Br_{2(l)}$. A compound contains two or more different elements per molecule. Examples include carbon dioxide, $CO_{2(g)}$, and ammonia, $NH_{3(g)}$.

8. (a) A mass spectrometer provides the molar mass of the compound.

(b) The mass of the carbon dioxide and water traps are measured before and after they trap carbon dioxide and water, respectively, produced as a result of a combustion reaction. Subtracting the mass of the traps before the reaction from the mass of the traps after the reaction determines the masses of carbon dioxide and water produced in the combustion reaction.

9. (a) C = 38.72% C
H = 9.72% H
O = 51.56% O

$$m_{\text{C}} = \frac{38.72}{100} \times 100\%$$
$$m_{\text{C}} = 38.72 \text{ g C}$$

$$m_{\text{H}} = \frac{9.72}{100} \times 100\%$$
$$m_{\text{H}} = 9.72 \text{ g H}$$

$$m_{\text{O}} = \frac{51.56}{100} \times 100\%$$
$$m_{\text{O}} = 51.56 \text{ g O}$$

$$n_{\text{C}} = 38.72 \cancel{\text{ g C}} \times \frac{1 \text{ mol C}}{12.01 \cancel{\text{ g C}}}$$
$$n_{\text{C}} = 3.223 \text{ mol C}$$

$$n_{\text{H}} = 9.72 \cancel{\text{ g H}} \times \frac{1 \text{ mol H}}{1.01 \cancel{\text{ g H}}}$$
$$n_{\text{H}} = 9.62 \text{ mol H}$$

$$n_{\text{O}} = 51.56 \cancel{\text{ g O}} \times \frac{1 \text{ mol O}}{16.00 \cancel{\text{ g O}}}$$
$$n_{\text{O}} = 3.222 \text{ mol O}$$

$$\begin{aligned} n_{\text{C}} : n_{\text{H}} : n_{\text{O}} &= 3.223 : 9.62 : 3.222 \\ &= \frac{3.223}{3.222} : \frac{9.62}{3.222} : \frac{3.222}{3.222} \\ &= 1.000 : 2.99 : 1.000 \\ n_{\text{C}} : n_{\text{H}} : n_{\text{O}} &= 1 : 3 : 1 \end{aligned}$$

The empirical formula of the compound is CH_3O.

(b) Two possible molecular formulas for the compound are CH_3O or $C_2H_6O_2$.

(c) You need to know the molar mass of the compound to determine its molecular formula.

10. Compound A

$$\text{C} = 64.6\% \text{C}$$
$$\text{H} = 10.8\% \text{H}$$
$$\text{O} = 24.6\% \text{O}$$
$$M_{\text{compound}} = 260.0 \text{ g/mol}$$

$$m_{\text{C}} = \frac{64.6}{100} \times 100\%$$
$$m_{\text{C}} = 64.6 \text{ g C}$$

$$m_{\text{H}} = \frac{10.8}{100} \times 100\%$$
$$m_{\text{H}} = 10.8 \text{ g H}$$

$$m_{\text{O}} = \frac{24.6}{100} \times 100\%$$
$$m_{\text{O}} = 24.6 \text{ g O}$$

$$n_{\text{C}} = 64.6 \cancel{\text{ g C}} \times \frac{1 \text{ mol C}}{12.01 \cancel{\text{ g C}}}$$
$$n_{\text{C}} = 5.38 \text{ mol C}$$

$$n_{\text{H}} = 10.8 \cancel{\text{ g H}} \times \frac{1 \text{ mol H}}{1.01 \cancel{\text{ g H}}}$$
$$n_{\text{H}} = 10.7 \text{ mol H}$$

$$n_{\text{O}} = 24.6 \cancel{\text{ g O}} \times \frac{1 \text{ mol O}}{16.00 \cancel{\text{ g O}}}$$
$$n_{\text{O}} = 1.54 \text{ mol O}$$

$$\begin{aligned} n_{\text{C}} : n_{\text{H}} : n_{\text{O}} &= 5.38 : 10.7 : 1.54 \\ &= \frac{5.38}{1.54} : \frac{10.7}{1.54} : \frac{1.54}{1.54} \\ &= 3.49 : 6.95 : 1.00 \\ &= 2(3.49) : 2(6.95) : 2(1.00) \\ &= 6.98 : 13.9 : 2.00 \\ n_{\text{C}} : n_{\text{H}} : n_{\text{O}} &= 7 : 14 : 2 \end{aligned}$$

The empirical formula of the compound is $C_7H_{14}O_2$.

$$M_{C_7H_{14}O_2} = 7(12.01 \text{ g/mol}) + 14(1.01 \text{ g/mol}) + 2(16.00 \text{ g/mol})$$
$$M_{C_7H_{14}O_2} = 130.21 \text{ g/mol}$$

$$\frac{M_{\text{compound}}}{M_{C_7H_{14}O_2}} = \frac{260.0 \cancel{\text{ g/mol}}}{130.21 \cancel{\text{ g/mol}}}$$
$$\frac{M_{\text{compound}}}{M_{C_7H_{14}O_2}} = 1.997 \approx 2$$

$$\begin{aligned} \text{molecular formula} &= 2(\text{empirical formula}) \\ &= 2(C_7H_{14}O_2) \\ \text{molecular formula} &= C_{14}H_{28}O_4 \end{aligned}$$

The molecular formula of compound A is $C_{14}H_{28}O_4$.

Compound B
C = 38.67% C
H = 16.22% H
N = 45.11% N
M_{compound} = 31.06 g/mol

$$m_{\text{C}} = \frac{38.67}{100} \times 100\%$$
$$m_{\text{C}} = 38.67 \text{ g C}$$

$$m_{\text{H}} = \frac{16.22}{100} \times 100\%$$
$$m_{\text{H}} = 16.22 \text{ g H}$$

$$m_{\text{N}} = \frac{45.11}{100} \times 100\%$$
$$m_{\text{N}} = 45.11 \text{ g N}$$

$$n_{\text{C}} = 38.67 \ \cancel{\text{g C}} \times \frac{1 \text{ mol C}}{12.01 \ \cancel{\text{g C}}}$$
$$n_{\text{C}} = 3.22 \text{ mol C}$$

$$n_{\text{H}} = 16.22 \ \cancel{\text{g H}} \times \frac{1 \text{ mol H}}{1.01 \ \cancel{\text{g H}}}$$
$$n_{\text{H}} = 16.06 \text{ mol H}$$

$$n_{\text{N}} = 45.11 \ \cancel{\text{g N}} \times \frac{1 \text{ mol N}}{14.01 \ \cancel{\text{g N}}}$$
$$n_{\text{N}} = 3.220 \text{ mol N}$$

$$\begin{aligned} n_{\text{C}} : n_{\text{H}} : n_{\text{N}} &= 3.220 : 16.06 : 3.220 \\ &= \frac{3.220}{3.220} : \frac{16.06}{3.220} : \frac{3.220}{3.220} \\ &= 1.00 : 4.988 : 1.00 \end{aligned}$$
$$n_{\text{C}} : n_{\text{H}} : n_{\text{N}} = 1 : 5 : 1$$

The empirical formula of the compound is CH_5N.

$$M_{\text{CH}_5\text{N}} = 1(12.01 \text{ g/mol}) + 5(1.01 \text{ g/mol}) + 1(14.01 \text{ g/mol})$$
$$M_{\text{CH}_5\text{N}} = 31.07 \text{ g/mol}$$

$$\frac{M_{\text{compound}}}{M_{\text{CH}_5\text{N}}} = \frac{31.06 \ \cancel{\text{g/mol}}}{31.07 \ \cancel{\text{g/mol}}}$$
$$\frac{M_{\text{compound}}}{M_{\text{CH}_5\text{N}}} = 1$$

$$\text{molecular formula} = 1(\text{empirical formula})$$
$$= 1(CH_5N)$$
$$\text{molecular formula} = CH_5N$$

The molecular formula of compound B is CH_5N.

11. The molar concentration of a solution is measured in moles per litre of solution instead of moles per litres of water because solutes occupy some of the volume of a solution. If 1.0 mol $NaCl_{(s)}$ is dissolved in 100 mL of water, the final volume of solution will be slightly greater than 100 mL. Since different solutes occupy different volumes, a solution containing 1.0 mol $NaCl_{(s)}$ in 100 mL of water will have a different concentration than a solution containing 1.0 mol $NH_3NO_{3(s)}$ in 100 mL of water.
12. A dilute solution has a relatively smaller amount of solute per unit volume of solution than a concentrated solution.
13. $c_{NO_3^-} = 2.3 \text{ ppm or } 2.3 \text{ mg/L}$

$$v_{NO_3^-} = 250 \cancel{\text{mL}} \times \frac{1 \text{ L}}{1000 \cancel{\text{mL}}}$$
$$v_{NO_3^-} = 0.25 \text{ L}$$
$$m_{NO_3^-} = ?$$
$$c_{NO_3^-} = \frac{m_{NO_3^-}}{v_{NO_3^-}}$$
$$m_{NO_3^-} = c_{NO_3^-} v_{NO_3^-}$$
$$= \frac{2.3 \text{ mg } NO_3^-}{\cancel{\text{L}}} \times 0.25 \cancel{\text{L}}$$
$$m_{NO_3^-} = 0.58 \text{ mg } NO_3^-$$

The mass of nitrate in the drinking water is 0.58 mg.

14. (a)
$$m_{NaOH} = 12.0 \text{ g NaOH}$$
$$M_{NaOH} = 40.00 \text{ g/mol NaOH}$$
$$v_{NaOH} = 2.5 \text{ L}$$
$$c_{NaOH} = ?$$
$$n_{NaOH} = 12.0 \cancel{\text{g NaOH}} \times \frac{1 \text{ mol NaOH}}{40.00 \cancel{\text{g NaOH}}}$$
$$n_{NaOH} = 0.300 \text{ mol NaOH}$$
$$c_{NaOH} = \frac{n_{NaOH}}{v_{NaOH}}$$
$$= \frac{0.300 \text{ mol}}{2.5 \text{ L}}$$
$$c_{NaOH} = 0.12 \text{ mol/L}$$

The molar concentration of the sodium hydroxide is 0.12 mol/L.

(b)
$$m_{KC_4H_5O_6} = 2.28 \text{ g}$$
$$M_{KC_4H_5O_6} = 188.19 \text{ g/mol } KC_4H_5O_6$$
$$v_{KC_4H_5O_6} = 100.0 \cancel{\text{mL}} \times \frac{1 \text{ L}}{1000 \cancel{\text{mL}}}$$
$$v_{KC_4H_5O_6} = 0.1000 \text{ L}$$
$$n_{KC_4H_5O_6} = 2.28 \cancel{\text{g } KC_4H_5O_6} \times \frac{1 \text{ mol } KC_4H_5O_6}{188.19 \cancel{\text{g } KC_4H_5O_6}}$$
$$n_{KC_4H_5O_6} = 0.0121 \text{ mol } KC_4H_5O_6$$

$$c_{KC_4H_5O_6} = \frac{n_{KC_4H_5O_6}}{v_{KC_4H_5O_6}}$$
$$= \frac{0.0121 \text{ mol} KC_4H_5O_6}{0.1000 \text{ L}}$$
$$c_{KC_4H_5O_6} = 0.121 \text{ mol/L}$$

The molar concentration of potassium hydrogen tartrate is 0.121 mol/L.

(c) $m_{C_2H_6O} = 0.08 \text{ g } C_2H_6O$

$$M_{C_2H_6O} = 46.08 \text{ g/mol } C_2H_6O$$
$$v_{C_2H_6O} = 100 \cancel{\text{mL}} \times \frac{1 \text{ L}}{1000 \cancel{\text{mL}}}$$
$$v_{C_2H_6O} = 0.1 \text{ L}$$
$$n_{C_2H_6O} = 0.08 \cancel{\text{g } C_2H_6O} \times \frac{1 \text{ mol } C_2H_6O}{46.08 \cancel{\text{g } C_2H_6O}}$$
$$n_{C_2H_6O} = 1.7 \times 10^{-3} \text{ mol } C_2H_6O$$
$$c_{C_2H_6O} = \frac{n_{C_2H_6O}}{v_{C_2H_6O}}$$
$$= \frac{1.7 \times 10^{-3} \text{mol } C_2H_6O}{0.1 \text{ L}}$$
$$c_{C_2H_6O} = 1.7 \times 10^{-2} \text{ mol/L}$$

The legal limit of blood alcohol concentration in Canada is 1.7×10^{-2} mol/L.

15. $m_{NaOH} = 0.40$ g

$$v_{solution} = 100 \cancel{\text{mL}} \times \frac{1 \text{ L}}{1000 \cancel{\text{mL}}}$$
$$v_{solution} = 0.1 \text{ L}$$

(a) $c_{solution} = ?$

W/V = ?

molar concentration

$$M_{NaOH} = M_{Na} + M_O + M_H$$
$$= 22.99 \text{ g/mol} + 16.00 \text{ g/mol} + 1.01 \text{ g/mol}$$
$$M_{NaOH} = 40.00 \text{ g/mol}$$
$$n_{NaOH} = 0.40 \cancel{\text{g NaOH}} \times \frac{1 \text{ mol NaOH}}{40.00 \cancel{\text{g NaOH}}}$$
$$n_{NaOH} = 0.010 \text{ mol NaOH}$$
$$c_{solution} = \frac{n_{NaOH}}{v_{solution}}$$
$$= \frac{0.010 \text{ mol NaOH}}{0.1 \text{ L}}$$
$$c_{solution} = 0.1 \text{ mol/L}$$

The molar concentration is 0.1 mol/L NaOH.

weight by volume

$$c_{\text{solution}} = \frac{m_{\text{solute}}}{v_{\text{solution}}} \times 100\%$$

$$= \frac{0.40\ \text{g}}{100\ \text{mL}} \times 100\%$$

$$c_{\text{solution}} = 0.4\%\ \text{W/V}$$

The concentration of the sodium hydroxide solution is 0.4% W/V.

(b) molar concentration

$c_i = 0.1$ mol/L
$v_i = 10$ mL
$v_f = 50$ mL
$c_f = ?$

$$c_i v_i = c_f v_f$$

$$c_f = \frac{c_i v_i}{v_f}$$

$$= \frac{(0.1\ \text{mol/L})(0.010\ \text{mL})}{0.050\ \text{mL}}$$

$$c_f = 0.02\ \text{mol/L NaOH}$$

The final molar concentration is 0.02 mol/L of sodium hydroxide solution.

weight by volume

$c_i = 0.4\%$ W/V
$v_i = 10$ mL
$v_f = 50$ mL
$c_f = ?$

$$c_i v_i = c_f v_f$$

$$c_f = \frac{c_i v_i}{v_f}$$

$$= \frac{(0.4\%)(10\ \text{mL})}{50\ \text{mL}}$$

$$c_f = 0.08\%\ \text{W/V}$$

The final concentration of the sodium hydroxide solution is 0.08% W/V.

16. (a) $3\ Fe + 4\ H_2O \rightarrow Fe_3O_4 + 4\ H_2$
(b) $H_2SO_4 + 2\ NaOH \rightarrow 2\ H_2O + Na_2SO_4$
(c) $4\ Cu + O_2 \rightarrow 2\ Cu_2O$
(d) $Fe_2(SO_4)_3 + 12\ KSCN \rightarrow 2\ K_3Fe(SCN)_6 + 3\ K_2SO_4$

17. (a) $C_2H_6O_{(l)} + 3\ O_{2(g)} \rightarrow 2\ CO_{2(g)} + 3\ H_2O_{(g)}$
(b) $C_3H_8O_3 + 3\ HNO_3 \rightarrow C_3H_5N_3O_9 + 3\ H_2O_{(l)}$

18. (a) $M_{Fe_2O_3} = 3.00 \times 10^2\ \text{g}\ Fe_2O_3$

Balanced equation	$Fe_2O_{3(s)}$ +	$3\ CO_{(g)}$ $\rightarrow$	$2\ Fe_{(s)}$ +	$3\ CO_{2(g)}$
Given mass (g)	3.00×10^2		?	
Molar mass (g/mol)	159.70		55.85	

$$n_{Fe_2O_3} = 3.00 \times 10^2 \cancel{\text{ g } Fe_2O_3} \times \frac{1 \text{ mol } Fe_2O_3}{159.70 \cancel{\text{ g } Fe_2O_3}}$$

$$n_{Fe_2O_3} = 1.88 \text{ mol } Fe_2O_3$$

$$n_{Fe} = 1.88 \cancel{\text{ mol } Fe_2O_3} \times \frac{2 \text{ mol Fe}}{1 \cancel{\text{ mol } Fe_2O_3}}$$

$$n_{Fe} = 3.76 \text{ mol Fe}$$

$$m_{Fe} = 3.76 \cancel{\text{ mol Fe}} \times \frac{55.85 \text{ g Fe}}{1 \cancel{\text{ mol Fe}}}$$

$$m_{Fe} = 2.10 \times 10^2 \text{ g Fe}$$

The reaction produces 3.76 mol iron, which is 2.10×10^2 g of iron.

The combined calculation is as follows:

$$n_{Fe} = 3.00 \times 10^2 \cancel{\text{ g } Fe_2O_3} \times \frac{1 \cancel{\text{ mol } Fe_2O_3}}{159.70 \cancel{\text{ g } Fe_2O_3}} \times \frac{2 \text{ mol Fe}}{1 \cancel{\text{ mol } Fe_2O_3}}$$

$$n_{Fe} = 3.76 \text{ mol Fe}$$

$$m_{Fe} = 300 \cancel{\text{ g } Fe_2O_3} \times \frac{1 \cancel{\text{ mol } Fe_2O_3}}{159.70 \cancel{\text{ g } Fe_2O_3}} \times \frac{2 \cancel{\text{ mol Fe}}}{1 \cancel{\text{ mol } Fe_2O_3}} \times \frac{55.85 \text{ g Fe}}{1 \cancel{\text{ mol Fe}}}$$

$$m_{Fe} = 2.10 \times 10^2 \text{ g Fe}$$

The reaction produces 3.76 mol iron, which is 2.10×10^2 g of iron.

(b) actual yield = 178 g Fe
theoretical yield = 2.1×10^2 g Fe

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$= \frac{178 \cancel{\text{ g}}}{2.10 \times 10^2 \cancel{\text{ g}}} \times 100\%$$

$$\text{percentage yield} = 84.8\%$$

The percentage yield of iron is 84.8%.

19. M_{Al} = 5.00 g Al

Balanced equation	$4\ Al_{(s)}$ +	$3\ O_{2(g)}$ →	$2\ Al_2O_{3(s)}$
Given mass (g)	5.00	?	
Molar mass (g/mol)	26.98	32.00	

$$n_{Al} = 5.00\ \cancel{g\ Al} \times \frac{1\ mol\ Al}{26.98\ \cancel{g\ Al}}$$
$$n_{Al} = 0.185\ mol\ Al$$

$$n_{O_2} = 0.185\ \cancel{mol\ Al} \times \frac{3\ mol\ O_2}{4\ \cancel{mol\ Al}}$$
$$n_{O_2} = 0.139\ mol\ O_2$$

$$m_{O_2} = 0.139\ \cancel{mol\ O_2} \times \frac{32.00\ g\ O_2}{1\ \cancel{mol\ O_2}}$$
$$m_{O_2} = 4.45\ g\ O_2$$

The reaction requires 0.139 mol oxygen, which is 4.45 g of oxygen.

The combined calculation can be done as follows:

$$n_{O_2} = 5.00\ \cancel{g\ Al} \times \frac{1\ \cancel{mol\ Al}}{26.98\ \cancel{g\ Al}} \times \frac{3\ mol\ O_2}{4\ \cancel{mol\ Al}}$$
$$n_{O_2} = 0.139\ mol\ O_2$$

$$m_{O_2} = 5.00\ \cancel{g\ Al} \times \frac{1\ \cancel{mol\ Al}}{26.98\ \cancel{g\ Al}} \times \frac{3\ \cancel{mol\ O_2}}{4\ \cancel{mol\ Al}} \times \frac{32.00\ g\ O_2}{1\ \cancel{mol\ O_2}}$$
$$m_{O_2} = 4.45\ g\ O_2$$

reaction requires 0.139 mol oxygen, which is 4.45 g of oxygen.

20. (a) $m_{Al} = 135.0\ g\ Al$

Balanced equation	$Fe_2O_{3(s)}$ +	$2\ Al_{(s)}$ →	$2\ Fe_{(l)}$ +	$Al_2O_{3(s)}$
Given mass (g)		135.0		?
Molar mass (g/mol)		26.98		101.96

$$n_{Al} = 135.0\ \cancel{g\ Al} \times \frac{1\ mol\ Al}{26.98\ \cancel{g\ Al}}$$
$$n_{Al} = 5.004\ mol\ Al$$

$$n_{Al_2O_3} = 5.004\ \cancel{mol\ Al} \times \frac{1\ mol\ Al_2O_3}{2\ \cancel{mol\ Al}}$$
$$n_{Al_2O_3} = 2.502\ mol\ Al_2O_3$$

$$m_{Al_2O_3} = 2.502\ \cancel{mol\ Al_2O_3} \times \frac{101.96\ g\ Al_2O_3}{1\ \cancel{mol\ Al_2O_3}}$$
$$m_{Al_2O_3} = 255.1\ g\ Al_2O_3$$

The maximum mass of aluminum oxide that can be produced is 255.1 g.

The combined calculation can be done as follows:

$$m_{Al_2O_3} = 135.0\ \cancel{\text{g Al}} \times \frac{1\text{ mol Al}}{26.98\ \cancel{\text{g Al}}} \times \frac{1\ \cancel{\text{mol Al}_2\text{O}_3}}{2\ \cancel{\text{mol Al}}} \times \frac{101.96\text{ g Al}_2\text{O}_3}{1\ \cancel{\text{mol Al}_2\text{O}_3}}$$

$$m_{Al_2O_3} = 255.1\text{ g Al}_2\text{O}_3$$

The maximum mass of aluminum oxide that can be produced is 255.1 g.

(b) percentage yield = 87%
theoretical yield = 255.1g Al_2O_3
actual yield = ?

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$\text{actual yield} = \frac{(\text{percentage yield})(\text{theoretical yield})}{100\%}$$

$$= \frac{(87\%)(255.1\text{ g Al}_2\text{O}_3)}{100\%}$$

$$\text{actual yield} = 2.22 \times 10^2\text{ g Al}_2\text{O}_3$$

The mass of aluminum oxide actually produced is 2.22×10^2 g.

Applying Inquiry Skills

21. **Analysis**

(a) rainwater $H_{2(g)} : O_{2(g)} = 23.72 : 11.80$
$H_{2(g)} : O_{2(g)} = 2 : 1$
tap water $H_{2(g)} : O_{2(g)} = 8.39 : 4.18$
$H_{2(g)} : O_{2(g)} = 2 : 1$
The hydrogen-to-oxygen ratio is 2:1 for both rainwater and tap water.

(b) Yes, the law of constant composition holds for water molecules.

Evaluation

(c) We assume that the gases produced in the Hoffman apparatus are hydrogen and oxygen only, and that the hydrogen and oxygen gas in the collection tubes are only produced by the decomposition of water molecules.

(d) The Observations support the Prediction so the Prediction is valid.

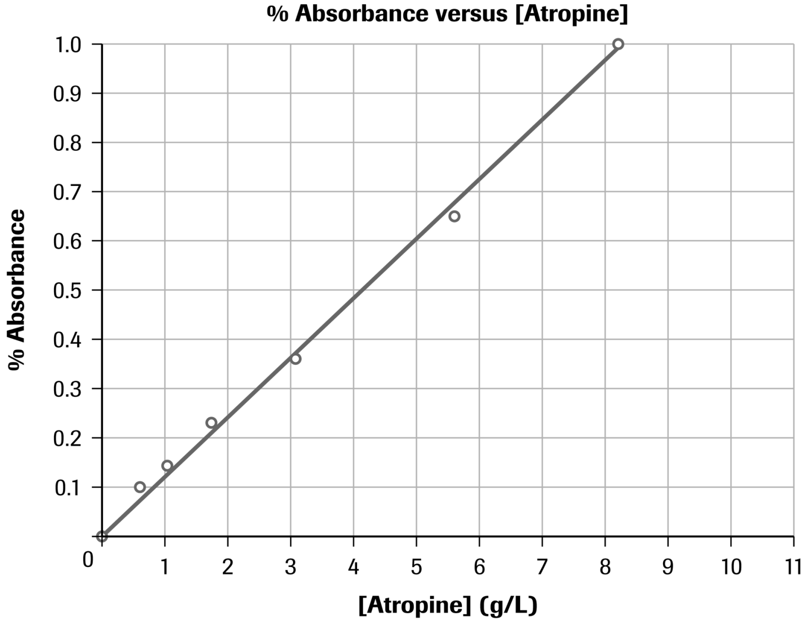
22. (a) A small sample of calcium of known mass is placed in a crucible and heated strongly over a Bunsen burner flame until it has completely reacted with oxygen in air to produce calcium oxide. The mass of the calcium oxide is measured. The difference in mass between the original sample of calcium and the calcium oxide gives the mass of oxygen that has combined with calcium in the reaction. The percentage composition by mass of calcium oxide is determined by dividing the mass of calcium by the mass of calcium oxide, and dividing the mass of oxygen by the mass of calcium oxide.

(b) No, the same experimental design cannot be used because the carbon and hydrogen atoms of the octane molecules separate and form different product molecules (carbon dioxide and water).

23. (a) Step 1: Place 2.8 g (0.015 mol) of $Cu(NO_3)_{2(s)}$ into a clean, dry 100-mL volumetric flask.
Step 2: Add a small volume (approximately 25 mL) of distilled water to the flask.
Step 3: Stopper the flask and shake until all of the solid copper(II) nitrate crystals have dissolved.
Step 4: Remove the stopper and add enough distilled water to reach the 100-mL mark on the flask.
Step 5: Stopper the flask and invert several times to mix.

(b) Step 1: Place 200 mL of the 0.15-mol/L $Cu(NO_3)_{2(aq)}$ solution into a clean, dry 1.0-L volumetric flask.
Step 2: Add enough distilled water to reach the 1.0 L mark on the flask.
Step 3: Stopper the flask and invert several times to mix.

24. (a)



(b) The concentration of atropine solution is approximately 4 g/L.
(c) No, every chemical has a different standard curve associated with it, so the curve in (a) may not be used.

25. We cannot be sure that all of the lead(II) nitrate has reacted to form the lead(II) sulfate precipitate. The student must continue adding sodium sulfate solution to the lead(II) nitrate solution until no more precipitate forms, which indicates that all of the lead(II) nitrate in solution has reacted. Only then may the mass of the lead(II) sulfate precipitate formed be used to calculate the concentration of the original lead(II) nitrate solution.

Making Connections

26. (a) To measure alcohol concentration in breath, a driver breathes into the Breathalyzer. The breath bubbles into a vial containing a mixture of sulfuric acid, potassium dichromate, silver nitrate, and water. The reaction between these reactants and the ethyl alcohol in the person's breath changes the colour of the solution in the vial from red-orange to green. The degree of the colour change is directly related to the concentration of alcohol in the person's blood. The machine compares the colour of the reacted mixture to the colour of an unreacted solution in a second vial using a photocell system. The needle in the meter moves according to the intensity of the colour difference.
(b) The legal BAC limit for fully qualified drivers in Ontario is 0.08 g of alcohol per 100 mL of blood. However, for drivers with G1 or G2 licences, it is 0 g of alcohol per 100 mL of blood.
(c) A portable Breathalyzer is a hand-held device that is small and compact. It operates on the chemical reactions described in (a). A stationary Breathalyzer is a larger desktop device, usually located in a laboratory. It is a spectrophotometer that identifies and measures the concentration of molecules based on the way they absorb infrared light.
(d) Common defences for drunk driving convictions include having been given drinks laced with alcohol, inhaling alcohol vapours at work, use of skin antiseptics containing alcohol, alleged mix-up of blood specimens, consumption of elixirs or health tonics containing alcohol, and faulty Breathalyzer readings caused by interference between the Breathalyzer machine and the police officer's radio or cell phone.
(e) Student papers will vary. Students should give clear, concise arguments and should argue for or against the issue only. Students may wish to use questions from **Workbook 2.6 Alternative Exercise: Tech Connect: The Breathalyzer** to help them get started.

27. (a) Student answers will vary. Possible sources of hydrogen include water and methane. One possible source of nitrogen is atmospheric nitrogen.
(b) Hydrogen for the Haber process is produced by reacting methane, $CH_{4(g)}$, with steam, $H_2O_{(g)}$, which produces carbon dioxide gas, $CO_{2(g)}$, and hydrogen gas, $H_{2(g)}$. The nitrogen gas, $N_{2(g)}$, is produced by the fractional distillation of air (air is approximately 78% nitrogen).