(c) $^{187}_{75}Re \rightarrow {}^{187}_{76}Os + {}^{0}_{-1}e$

(d) $^{11}_{5}B + {}^{1}_{1}p \rightarrow 3\,{}^{4}_{2}He$

(e) $^{98}_{42}Mo + {}^{2}_{1}H \rightarrow {}^{99}_{43}Tc + {}^{1}_{0}n$

7. The mass number drops by 28, and only alpha decay drops the mass number, and each alpha particle is 4, so 7 alpha particles are emitted. The atomic number drops by 10, which is 4 less than the drop of 14 caused by the alpha decays, so there must be 4 beta particles emitted, because each one raises the atomic number by 1.

Making Connections

8. A typical report would include information on directing a particle beam through the body to cause maximum damage at a tumour location — and probably on the development of the "cobalt bomb" cobalt-60 cancer therapy machines by AECL, and the extensive worldwide use of this treatment program.

GO TO www.science.nelson.com, Chemistry 11, Teacher Centre.

5.4 CALCULATING MASSES OF REACTANTS AND PRODUCTS

PRACTICE

(Page 227)

Understanding Concepts

1. $2\,Al_2O_{3(s)} \rightarrow 3\,O_{2(g)} + 4\,Al_{(s)}$

125 g ... m

101.96 g/mol ... 26.98 g/mol

$$n_{Al_2O_3} = 125\,\cancel{g} \times \frac{1\text{ mol}}{101.96\,\cancel{g}}$$
$$n_{Al_2O_3} = 1.23\text{ mol}$$
$$n_{Al} = 1.23\text{ mol} \times \frac{4}{2}$$
$$n_{Al} = 2.45\text{ mol}$$
$$m_{Al} = 2.45\,\cancel{\text{mol}} \times \frac{26.98\text{ g}}{1\,\cancel{\text{mol}}}$$
$$m_{Al} = 66.2\text{ g}$$

or

$$m_{Al} = 125\,\cancel{g\ Al_2O_3} \times \frac{1\,\cancel{\text{mol}\ Al_2O_3}}{101.96\,\cancel{g\ Al_2O_3}} \times \frac{4\,\cancel{\text{mol}\ Al}}{2\,\cancel{\text{mol}\ Al_2O_3}} \times \frac{26.98\text{ g Al}}{1\,\cancel{\text{mol}\ Al}}$$
$$m_{Al} = 66.2\text{ g}$$

The (maximum) mass of aluminum that can be produced is 66.2 g.

2. $C_3H_{8(g)} + 5\,O_{2(g)} \rightarrow 3\,CO_{2(g)} + 4\,H_2O_{(g)}$

10.0 g ... m

44.11 g/mol ... 32.00 g/mol

$$n_{C_3H_8} = 10.0\,\cancel{g} \times \frac{1\text{ mol}}{44.11\,\cancel{g}}$$
$$n_{C_3H_8} = 0.227\text{ mol}$$
$$n_{O_2} = 0.227\text{ mol} \times \frac{5}{1}$$
$$n_{O_2} = 1.13\text{ mol}$$
$$m_{O_2} = 1.13\,\cancel{\text{mol}} \times \frac{32.00\text{ g}}{1\,\cancel{\text{mol}}}$$

m_{O_2} = 36.3 g

or

$$m_{O_2} = 10.0\ \cancel{g}\ \cancel{C_3H_8} \times \frac{1\ \cancel{mol}\ \cancel{C_3H_8}}{44.11\ \cancel{g}\ \cancel{C_3H_8}} \times \frac{5\ \cancel{mol}\ \cancel{O_2}}{1\ \cancel{mol}\ \cancel{C_3H_8}} \times \frac{32.00\ g\ O_2}{1\ \cancel{mol}\ \cancel{O_2}}$$

m_{O_2} = 36.3 g

The (minimum) mass of oxygen required is 36.3 g.

3. $2\ NaCl_{(aq)} + Pb(NO_3)_{2(aq)} \rightarrow 2\ NaNO_{3(aq)} + PbCl_{2(s)}$

2.57 g	m
58.44 g/mol	278.10 g/mol

$$n_{NaCl} = 2.57\ \cancel{g} \times \frac{1\ mol}{58.44\ \cancel{g}}$$

n_{NaCl} = 0.0440 mol

$$n_{PbCl_2} = 0.0440\ mol \times \frac{1}{2}$$

n_{PbCl_2} = 0.0220 mol

$$m_{PbCl_2} = 0.0220\ \cancel{mol} \times \frac{278.10\ g}{1\ \cancel{mol}}$$

m_{PbCl_2} = 6.11 g

or

$$m_{PbCl_2} = 2.57\ \cancel{g}\ \cancel{NaCl} \times \frac{1\ \cancel{mol}\ \cancel{NaCl}}{58.44\ \cancel{g}\ \cancel{NaCl}} \times \frac{1\ \cancel{mol}\ \cancel{PbCl_2}}{2\ \cancel{mol}\ \cancel{NaCl}} \times \frac{278.10\ g\ PbCl_2}{1\ \cancel{mol}\ \cancel{PbCl_2}}$$

m_{PbCl_2} = 6.11 g

The (maximum) mass of lead(II) chloride produced would be 6.11 g.

4. $2\ Al_{(s)} + 3\ H_2SO_{4(aq)} \rightarrow 3\ H_{2(g)} + 2\ Al_2(SO_4)_{3(aq)}$

2.73 g	m
26.98 g/mol	2.02 g/mol

$$n_{Al} = 2.73\ \cancel{g} \times \frac{1\ mol}{26.98\ \cancel{g}}$$

n_{Al} = 0.101 mol

$$n_{H_2} = 0.101\ mol \times \frac{3}{2}$$

n_{H_2} = 0.152 mol

$$m_{H_2} = 0.152\ \cancel{mol} \times \frac{2.02\ g}{1\ \cancel{mol}}$$

m_{H_2} = 0.307 g

or

$$m_{H_2} = 2.73\ \cancel{g}\ \cancel{Al} \times \frac{1\ \cancel{mol}\ \cancel{Al}}{26.98\ \cancel{g}\ \cancel{Al}} \times \frac{3\ \cancel{mol}\ \cancel{H_2}}{2\ \cancel{mol}\ \cancel{Al}} \times \frac{2.02\ g\ H_2}{1\ \cancel{mol}\ \cancel{H_2}}$$

m_{H_2} = 0.307 g

The (predicted) mass of hydrogen would be 0.307 g, or 307 mg.

5. $2\ KOH_{(aq)} + Cu(NO_3)_{2(aq)} \rightarrow 2\ KNO_{3(aq)} + Cu(OH)_{2(s)}$

2.67 g	m
56.11 g/mol	97.57 g/mol

$$n_{KOH} = 2.67\ \cancel{g} \times \frac{1\ mol}{56.11\ \cancel{g}}$$

n_{KOH} = 0.0476 mol

$$n_{Cu(OH)_2} = 0.0476\ mol \times \frac{1}{2}$$

$n_{Cu(OH)_2}$ = 0.0238 mol

$$m_{Cu(OH)_2} = 0.0238\ \cancel{mol} \times \frac{97.57\ g}{1\ \cancel{mol}}$$

$m_{Cu(OH)_2} = 2.32$ g

or

$$m_{Cu(OH)_2} = 2.67\ \cancel{g}\ \cancel{KOH} \times \frac{1\ \cancel{mol}\ \cancel{KOH}}{56.11\ \cancel{g}\ \cancel{KOH}} \times \frac{1\ \cancel{mol}\ Cu(\cancel{OH})_2}{2\ \cancel{mol}\ \cancel{KOH}} \times \frac{97.57\ g\ Cu(OH)_2}{1\ \cancel{mol}\ Cu(\cancel{OH})_2}$$

$m_{Cu(OH)_2} = 2.32$ g

The mass of copper(II) hydroxide produced would be 2.32 g.

6. $2\ H_2O_{(l)} \rightarrow 2\ H_{2(g)} + O_{2(g)}$

25.0 g — N

18.02 g/mol — 6.02×10^{23} molecules/mol

$$n_{H_2O} = 25.0\ \cancel{g} \times \frac{1\ mol}{18.02\ \cancel{g}}$$

$n_{H_2O} = 1.39$ mol

$$n_{O_2} = 1.39\ mol \times \frac{1}{2}$$

$n_{O_2} = 0.694$ mol

$$N_{O_2} = 0.694\ \cancel{mol} \times \frac{6.02 \times 10^{23}\ molecules}{1\ \cancel{mol}}$$

$N_{O_2} = 4.18 \times 10^{23}$ molecules

or

$$N_{O_2} = 25.0\ \cancel{g}\ \cancel{H_2O} \times \frac{1\ \cancel{mol}\ \cancel{H_2O}}{18.02\ \cancel{g}\ \cancel{H_2O}} \times \frac{1\ \cancel{mol}\ \cancel{O_2}}{2\ \cancel{mol}\ \cancel{H_2O}} \times \frac{6.02 \times 10^{23}\ molecules\ O_2}{1\ \cancel{mol}\ \cancel{O_2}}$$

$N_{O_2} = 4.18 \times 10^{23}$ molecules

In this reaction, 4.18×10^{23} molecules of oxygen would be produced.

PRACTICE

(Page 228)

Understanding Concepts

7. The fundamental test for a scientific concept is its ability to predict.
8. The reaction equation coefficients show the ratio of substances in moles, so measurements must be changed to amounts before the ratio can be applied.
9. (a) The mole ratio $CO_2 : C_8H_{18}$ (from the equation) is 16 : 2.

(b) $2\ C_8H_{18(g)} + 25\ O_{2(g)} \rightarrow 16\ CO_{2(g)} + 18\ H_2O_{(g)}$

22.8 g — m

114.26 g/mol — 44.01 g/mol

$$n_{C_8H_{18}} = 22.8\ \cancel{g} \times \frac{1\ mol}{114.26\ \cancel{g}}$$

$n_{C_8H_{18}} = 0.200$ mol

$$n_{CO_2} = 0.200\ mol \times \frac{16}{2}$$

$n_{CO_2} = 1.60$ mol

$$m_{CO_2} = 1.60\ \cancel{mol} \times \frac{44.01\ g}{1\ \cancel{mol}}$$

$m_{CO_2} = 70.3$ g

or

$$m_{CO_2} = 22.8\ \cancel{g}\ \cancel{C_8H_{18}} \times \frac{1\ \cancel{mol}\ \cancel{C_8H_{18}}}{114.26\ \cancel{g}\ \cancel{C_8H_{18}}} \times \frac{16\ \cancel{mol}\ \cancel{CO_2}}{2\ \cancel{mol}\ \cancel{C_8H_{18}}} \times \frac{44.01\ g\ CO_2}{1\ \cancel{mol}\ \cancel{CO_2}}$$

$m_{CO_2} = 70.3$ g

The mass of carbon dioxide produced will be 70.3 g.

(c) The mole ratio $O_2 : C_8H_{18}$ (from the equation) is 25 : 2.

(d) $2\ C_8H_{18(g)} \quad + \quad 25\ O_{2(g)} \quad \rightarrow \quad 16\ CO_{2(g)} \quad + \quad 18\ H_2O_{(g)}$

22.8 g $\qquad$ m

114.26 g/mol $\qquad$ 32.00 g/mol

$$n_{C_8H_{18}} = 22.8\ \cancel{g} \times \frac{1\ \text{mol}}{114.26\ \cancel{g}}$$
$$n_{C_8H_{18}} = 0.200\ \text{mol}$$
$$n_{O_2} = 0.200\ \text{mol} \times \frac{25}{2}$$
$$n_{O_2} = 2.49\ \text{mol}$$
$$m_{O_2} = 2.49\ \cancel{\text{mol}} \times \frac{32.00\ \text{g}}{1\ \cancel{\text{mol}}}$$
$$m_{O_2} = 79.8\ \text{g}$$

or

$$m_{O_2} = 22.8\ \cancel{g}\ \cancel{C_8H_{18}} \times \frac{1\ \cancel{\text{mol}}\ \cancel{C_8H_{18}}}{114.26\ \cancel{g}\ \cancel{C_8H_{18}}} \times \frac{25\ \cancel{\text{mol}}\ \cancel{O_2}}{2\ \cancel{\text{mol}}\ \cancel{C_8H_{18}}} \times \frac{32.00\ \text{g}\ O_2}{1\ \cancel{\text{mol}}\ \cancel{O_2}}$$
$$m_{O_2} = 79.8\ \text{g}$$

The mass of oxygen consumed will be 79.8 g.

(e) If oxygen is the limiting reagent, some carbon will not react completely to $CO_{2(g)}$, but instead will react incompletely to form $CO_{(g)}$, which is very toxic.

10. $TiO_{2(s)} + 2\ Cl_{2(g)} + 2\ C_{(s)} \rightarrow TiCl_{4(l)} + 2\ CO_{(g)}$

1.00 kg

79.88 g/mol

$TiCl_{4(l)} \quad + \quad 2\ Mg_{(s)} \quad \rightarrow \quad Ti_{(s)} \quad + \quad 2\ MgCl_{2(s)}$

m

47.88 g/mol

Note: This question requires the students to see that the mole ratio $TiCl_4 : TiO_2$ from the first equation can be combined with the mole ratio $Ti : TiCl_4$ from the second equation.

$$n_{TiO_2} = 1.00\ \text{k}\cancel{g} \times \frac{1\ \text{mol}}{79.88\ \cancel{g}}$$
$$n_{TiO_2} = 0.0125\ \text{kmol}$$
$$n_{TiCl_4} = 0.125\ \text{kmol} \times \frac{1}{1} \qquad \text{(mole ratio } TiCl_4 : TiO_2 \text{ is } 1 : 1 \text{ — step 1)}$$
$$n_{TiCl_4} = 0.125\ \text{kmol}$$
$$n_{Ti} = 0.125\ \text{kmol} \times \frac{1}{1} \qquad \text{(mole ratio } Ti : TiCl_4 \text{ is } 1 : 1 \text{ — step 2)}$$
$$n_{Ti} = 0.125\ \text{kmol}$$
$$m_{Ti} = 0.125\ \text{k}\cancel{\text{mol}} \times \frac{47.88\ \text{g}}{1\ \cancel{\text{mol}}}$$
$$m_{Ti} = 0.599\ \text{kg or } 599\ \text{g}$$

or

$$m_{Ti} = 1.00\ \text{k}\cancel{g}\ \cancel{TiO_2} \times \frac{1\ \cancel{\text{mol}}\ \cancel{TiO_2}}{79.88\ \cancel{g}\ \cancel{TiO_2}} \times \frac{1\ \cancel{\text{mol}}\ \cancel{TiCl_4}}{1\ \cancel{\text{mol}}\ \cancel{TiO_2}} \times \frac{1\ \cancel{\text{mol}}\ \cancel{Ti}}{1\ \cancel{\text{mol}}\ \cancel{TiCl_4}} \times \frac{47.88\ \text{g Ti}}{1\ \cancel{\text{mol}}\ \cancel{Ti}}$$
$$m_{Ti} = 0.599\ \text{kg or } 599\ \text{g}$$

The (maximum) mass of titanium produced would be 599 g.

SECTION 5.4 QUESTIONS

(Page 229)

Understanding Concepts

1. Reaction equations read in amounts, not masses, so combining reagents by mass according to equation values will not work.
2. (a) $Fe_2O_{3(s)} \quad + \quad 3\,H_{2(g)} \quad \rightarrow \quad 2\,Fe_{(s)} \quad + \quad 3\,H_2O_{(g)}$

   500 kg ... m (Fe)

   159.70 g/mol ... 55.85 g/mol

$$n_{Fe_2O_3} = 500\ \mathrm{k}\cancel{\mathrm{g}} \times \frac{1\ \mathrm{mol}}{159.70\ \cancel{\mathrm{g}}}$$
$$n_{Fe_2O_3} = 3.13\ \mathrm{kmol}$$
$$n_{Fe} = 3.13\ \mathrm{kmol} \times \frac{2}{1}$$
$$n_{Fe} = 6.26\ \mathrm{kmol}$$
$$m_{Fe} = 6.26\ \mathrm{k}\cancel{\mathrm{mol}} \times \frac{55.85\ \mathrm{g}}{1\ \cancel{\mathrm{mol}}}$$
$$m_{Fe} = 350\ \mathrm{kg}$$

or

$$m_{Fe} = 500\ \mathrm{k}\cancel{\mathrm{g}}\ \cancel{Fe_2O_3} \times \frac{1\ \cancel{\mathrm{mol}}\ \cancel{Fe_2O_3}}{159.70\ \cancel{\mathrm{g}}\ \cancel{Fe_2O_3}} \times \frac{2\ \cancel{\mathrm{mol}}\ \cancel{Fe}}{1\ \cancel{\mathrm{mol}}\ \cancel{Fe_2O_3}} \times \frac{55.85\ \mathrm{g\ Fe}}{1\ \cancel{\mathrm{mol}}\ \cancel{Fe}}$$
$$m_{Fe} = 350\ \mathrm{kg}$$

   The mass of iron produced would be 350 kg.

   (b) $Fe_2O_{3(s)} \quad + \quad 3\,H_{2(g)} \quad \rightarrow \quad 2\,Fe_{(s)} \quad + \quad 3\,H_2O_{(g)}$

   1.0 t = 1.0 Mg ... m (H$_2$)

   159.70 g/mol ... 2.02 g/mol

$$n_{Fe_2O_3} = 1.0\ \mathrm{M}\cancel{\mathrm{g}} \times \frac{1\ \mathrm{mol}}{159.70\ \cancel{\mathrm{g}}}$$
$$n_{Fe_2O_3} = 0.0063\ \mathrm{Mmol} = 6.3\ \mathrm{kmol}$$
$$n_{H_2} = 0.0063\ \mathrm{Mmol} \times \frac{3}{1}$$
$$n_{H_2} = 0.019\ \mathrm{Mmol}$$
$$m_{H_2} = 0.019\ \mathrm{M}\cancel{\mathrm{mol}} \times \frac{2.02\ \mathrm{g}}{1\ \cancel{\mathrm{mol}}}$$
$$m_{H_2} = 0.038\ \mathrm{Mg} = 38\ \mathrm{kg}$$

or

$$m_{H_2} = 1.0\ \mathrm{M}\cancel{\mathrm{g}}\ \cancel{Fe_2O_3} \times \frac{1\ \cancel{\mathrm{mol}}\ \cancel{Fe_2O_3}}{159.70\ \cancel{\mathrm{g}}\ \cancel{Fe_2O_3}} \times \frac{3\ \cancel{\mathrm{mol}}\ \cancel{H_2}}{1\ \cancel{\mathrm{mol}}\ \cancel{Fe_2O_3}} \times \frac{2.02\ \mathrm{g}\ H_2}{1\ \cancel{\mathrm{mol}}\ \cancel{H_2}}$$
$$m_{H_2} = 0.038\ \mathrm{Mg} = 38\ \mathrm{kg}$$

   The mass of hydrogen required would be 38 kg.

   (c) $Fe_2O_{3(s)} \quad + \quad 3\,H_{2(g)} \quad \rightarrow \quad 2\,Fe_{(s)} \quad + \quad 3\,H_2O_{(g)}$

   m (Fe$_2$O$_3$) ... 220 kg

   159.70 g/mol ... 18.02 g/mol

$$n_{H_2O} = 220\ \mathrm{k}\cancel{\mathrm{g}} \times \frac{1\ \mathrm{mol}}{18.02\ \cancel{\mathrm{g}}}$$
$$n_{H_2O} = 12.2\ \mathrm{kmol}$$
$$n_{Fe_2O_3} = 12.2\ \mathrm{kmol} \times \frac{1}{3}$$
$$n_{Fe_2O_3} = 4.07\ \mathrm{kmol}$$
$$m_{Fe_2O_3} = 4.07\ \mathrm{k}\cancel{\mathrm{mol}} \times \frac{159.70\ \mathrm{g}}{1\ \cancel{\mathrm{mol}}}$$

$m_{Fe_2O_3}$ = 650 kg

or

$$m_{Fe_2O_3} = 220 \text{ k}\cancel{\text{g}}\ \cancel{H_2O} \times \frac{1\ \cancel{\text{mol}}\ \cancel{H_2O}}{18.02\ \cancel{\text{g}}\ \cancel{H_2O}} \times \frac{1\ \cancel{\text{mol}}\ \cancel{Fe_2O_3}}{3\ \cancel{\text{mol}}\ \cancel{H_2O}} \times \frac{159.70 \text{ g } Fe_2O_3}{1\ \cancel{\text{mol}}\ \cancel{Fe_2O_3}}$$

$m_{Fe_2O_3}$ = 650 kg

The mass of iron(III) oxide consumed would be 650 kg.

3. (a) $2\ C_6H_{12(l)} + 5\ O_{2(g)} \rightarrow 2\ C_6H_{10}O_{4(s)} + 2\ H_2O_{(g)}$

m		280 kg	
84.18 g/mol		146.16 g/mol	

$$n_{C_6H_{10}O_4} = 280 \text{ k}\cancel{\text{g}} \times \frac{1 \text{ mol}}{146.16\ \cancel{\text{g}}}$$

$n_{C_6H_{10}O_4}$ = 1.92 kmol

$$n_{C_6H_{12}} = 1.92 \text{ kmol} \times \frac{2}{2}$$

$n_{C_6H_{12}}$ = 1.92 kmol

$$m_{C_6H_{12}} = 1.92 \text{ k}\cancel{\text{mol}} \times \frac{84.18 \text{ g}}{1\ \cancel{\text{mol}}}$$

$m_{C_6H_{12}}$ = 161 kg

or

$$m_{C_6H_{12}} = 280 \text{ k}\cancel{\text{g}}\ \cancel{C_6H_{10}O_4} \times \frac{1\ \cancel{\text{mol}}\ \cancel{C_6H_{10}O_4}}{146.16\ \cancel{\text{g}}\ \cancel{C_6H_{10}O_4}} \times \frac{2\ \cancel{\text{mol}}\ \cancel{C_6H_{12}}}{2\ \cancel{\text{mol}}\ \cancel{C_6H_{10}O_4}} \times \frac{84.18 \text{ g } C_6H_{12}}{1\ \cancel{\text{mol}}\ \cancel{C_6H_{12}}}$$

$m_{C_6H_{12}}$ = 161 kg

The mass of cyclohexane required is 161 kg.

(b) $2\ C_6H_{12(l)} + 5\ O_{2(g)} \rightarrow 2\ C_6H_{10}O_{4(s)} + 2\ H_2O_{(g)}$

125 kg	m		
84.18 g/mol	32.00 g/mol		

$$n_{C_6H_{12}} = 125 \text{ k}\cancel{\text{g}} \times \frac{1 \text{ mol}}{84.18\ \cancel{\text{g}}}$$

$n_{C_6H_{12}}$ = 1.48 kmol

$$n_{O_2} = 1.48 \text{ kmol} \times \frac{5}{2}$$

n_{O_2} = 3.71 kmol

$$m_{O_2} = 3.71 \text{ k}\cancel{\text{mol}} \times \frac{32.00 \text{ g}}{1\ \cancel{\text{mol}}}$$

m_{O_2} = 119 kg

or

$$m_{O_2} = 125 \text{ k}\cancel{\text{g}}\ \cancel{C_6H_{12}} \times \frac{1\ \cancel{\text{mol}}\ \cancel{C_6H_{12}}}{84.18\ \cancel{\text{g}}\ \cancel{C_6H_{12}}} \times \frac{5\ \cancel{\text{mol}}\ \cancel{O_2}}{2\ \cancel{\text{mol}}\ \cancel{C_6H_{12}}} \times \frac{32.00 \text{ g } O_2}{1\ \cancel{\text{mol}}\ \cancel{O_2}}$$

m_{O_2} = 119 kg

The mass of oxygen required is 119 kg.

(c) $2\ C_6H_{12(l)} + 5\ O_{2(g)} \rightarrow 2\ C_6H_{10}O_{4(s)} + 2\ H_2O_{(g)}$

m	200 g		
84.18 g/mol	32.00 g/mol		

$$n_{O_2} = 200\ \cancel{\text{g}} \times \frac{1 \text{ mol}}{32.00\ \cancel{\text{g}}}$$

n_{O_2} = 6.25 mol

$$n_{C_6H_{12}} = 6.25 \text{ mol} \times \frac{2}{5}$$

$n_{C_6H_{12}}$ = 2.50 mol

$$m_{C_6H_{12}} = 2.50\ \cancel{mol} \times \frac{84.18\ g}{1\ \cancel{mol}}$$

$$m_{C_6H_{12}} = 210\ g$$

or

$$m_{C_6H_{12}} = 200\ \cancel{g}\ \cancel{O_2} \times \frac{1\ \cancel{mol}\ \cancel{O_2}}{32.00\ \cancel{g}\ \cancel{O_2}} \times \frac{2\ \cancel{mol}\ \cancel{C_6H_{12}}}{5\ \cancel{mol}\ \cancel{O_2}} \times \frac{84.18\ g\ C_6H_{12}}{1\ \cancel{mol}\ \cancel{C_6H_{12}}}$$

$$m_{C_6H_{12}} = 210\ g$$

The maximum mass of cyclohexane that can be reacted is 210 g.

4. $2\ Fe_{(s)} \quad + \quad O_{2(g)} \quad \rightarrow \quad 2\ FeO_{(s)}$

56.8 g		m
55.85 g/mol		71.85 g/mol

$$n_{Fe} = 56.8\ \cancel{g} \times \frac{1\ mol}{55.85\ \cancel{g}}$$

$$n_{Fe} = 1.02\ mol$$

$$n_{FeO} = 1.02\ mol \times \frac{2}{2}$$

$$n_{FeO} = 1.02\ mol$$

$$m_{FeO} = 1.02\ \cancel{mol} \times \frac{71.85\ g}{1\ \cancel{mol}}$$

$$m_{FeO} = 73.1\ g$$

or

$$m_{FeO} = 56.8\ \cancel{g}\ \cancel{Fe} \times \frac{1\ \cancel{mol}\ \cancel{Fe}}{55.85\ \cancel{g}\ \cancel{Fe}} \times \frac{2\ \cancel{mol}\ \cancel{FeO}}{2\ \cancel{mol}\ \cancel{Fe}} \times \frac{71.85\ g\ FeO}{1\ \cancel{mol}\ \cancel{FeO}}$$

$$m_{FeO} = 73.1\ g$$

The mass of iron(II) oxide that can be produced is 73.1 g.

Applying Inquiry Skills

5. (a) **Prediction**

From the balanced reaction equation, one mole of calcium ions produces one mole of solid calcium oxalate precipitate, so the amount of calcium ions in a sample will be the same as the amount of calcium oxalate precipitate that forms.

(b) **Experimental Design**

Excess sodium oxalate solution will be added to a measured sample (independent variable) of hard water. The precipitate formed will be dried and the mass measured (dependent variable). The stoichiometric method will be used to calculate an answer to the question.

(c) The mass of calcium oxalate precipitate will be divided by its molar mass, 128.10 g/mol, to determine the amount of precipitate. The amount of calcium ions is the same, since the mole ratio is 1 : 1.

(d) **Materials**

- hard-water sample
- sodium oxalate solution
- wash bottle with pure water
- two 100-mL graduated cylinders
- 250-mL beaker
- filtration apparatus
- filter paper
- centigram balance

(e) **Procedure**

1. Use a graduated cylinder to add 10.0 mL of hard water to a 250-mL beaker.
2. Use another graduated cylinder to add about 10 mL of sodium oxalate solution to the beaker.
3. Allow the precipitate to settle.
4. Add another 10-mL aliquot of sodium oxalate solution to the beaker, observing whether or not more precipitate forms as the added solution mixes with the clear upper portion of the solution in the beaker.
5. Repeat step 4 until no more precipitate forms.
6. Measure and record the mass of a piece of filter paper.
7. Filter, wash, and dry the precipitate.
8. Measure and record the mass of the filter paper plus dry precipitate.
9. Dispose of all materials as instructed.

Making Connections

6. (a) Raw materials, like aluminum oxide, are purchased according to the amount needed for reaction.
(b) Products, like aluminum, are priced so that the amount produced will be profitable.
(c) Pollutant amounts will be calculated and decisions on processes to control them will be made accordingly.
(d) Amounts of all materials must be calculated to allow costing of things like packaging, disposal, and shipping.

5.5 CALCULATING LIMITING AND EXCESS REAGENTS

PRACTICE

(Page 231)

Understanding Concepts

1. (a) $2\ CH_{4(g)} \quad + \quad 3\ O_{2(g)} \quad \rightarrow \quad 2\ CO_{(g)} \quad + \quad 4\ H_2O_{(g)}$

m

16.05 g/mol   3.0 mol

$$n_{CH_4} = 3.0 \text{ mol} \times \frac{2}{3}$$
$$n_{CH_4} = 2.0 \text{ mol}$$
$$m_{CH_4} = 2.0 \cancel{\text{mol}} \times \frac{16.05 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{CH_4} = 32 \text{ g}$$

or

$$m_{CH_4} = 3 \cancel{\text{mol}}\ \cancel{O_2} \times \frac{2 \cancel{\text{mol}}\ \cancel{CH_4}}{3 \cancel{\text{mol}}\ \cancel{O_2}} \times \frac{16.05 \text{ g } CH_4}{1 \cancel{\text{mol}}\ \cancel{CH_4}}$$
$$m_{CH_4} = 32 \text{ g}$$

The mass of methane that will react is 32 g.

(b) $CH_{4(g)} \quad + \quad 2\ O_{2(g)} \quad \rightarrow \quad CO_{2(g)} \quad + \quad 2\ H_2O_{(g)}$

m

16.05 g/mol   3.0 mol

$$n_{CH_4} = 3.0 \text{ mol} \times \frac{1}{2}$$
$$n_{CH_4} = 1.5 \text{ mol}$$
$$m_{CH_4} = 1.5 \cancel{\text{mol}} \times \frac{16.05 \text{ g}}{1 \cancel{\text{mol}}}$$
$$m_{CH_4} = 24 \text{ g}$$

or

$$m_{CH_4} = 3 \cancel{\text{mol}}\ \cancel{O_2} \times \frac{1 \cancel{\text{mol}}\ \cancel{CH_4}}{2 \cancel{\text{mol}}\ \cancel{O_2}} \times \frac{16.05 \text{ g } CH_4}{1 \cancel{\text{mol}}\ \cancel{CH_4}}$$