4 • Chemical Equations and Stoichiometry

STOICHIOMETRY PROBLEMS

General Stoichiometry

1. Several brands of antacid tablets use aluminum hydroxide to neutralize excess acid.

$$Al(OH)_3(s) + 3\ HCl(aq) \rightarrow AlCl_3(aq) + 3\ H_2O(l)$$

[Molar masses: 78.01 36.46 133.4 18.02]

What quantity of HCl, in grams, can a tablet with 0.750 g of $Al(OH)_3$ consume? What quantity of water is produced?

2. If 10.0 g of carbon is combined with an exact, stoichiometric amount of oxygen (26.6 g) to produce carbon dioxide, what mass, in grams, of CO_2 can be obtained? That is, what is the theoretical yield of CO_2? [Molar masses: C: 12.011 O_2: 32.00 CO_2: 44.01]

3. The equation for one of the reactions in the process of reducing iron ore to the metal is

$$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$$

[Molar masses: 159.7 28.01 55.85 44.01]

(a) What is the maximum mass of iron, in grams, that can be obtained from 454 g (1.00 lb) of iron(III) oxide?

(b) What mass of CO is required to reduce the iron(III) oxide to iron metal?

4. Burning coal and oil in a power plant produces pollutants such as sulfur dioxide, SO_2. The sulfur-containing compound can be removed from other waste gases, however, by the following reaction:

$$2\ SO_2(g) + 2\ CaCO_3(s) + O_2(g) \rightarrow 2\ CaSO_4(s) + 2\ CO_2(g)$$

[Molar masses: 64.07 100.1 32.00 136.2 44.01]

(a) Name the compounds involved in the reaction.

(b) What mass of $CaCO_3$ is required to remove 155 g of SO_2?

(c) What mass of $CaSO_4$ is formed when 155 g SO_2 is consumed completely?

5. Your body deals with excess nitrogen by excreting it in the form of urea, NH_2CONH_2. The reaction producing it is the combination of arginine ($C_6H_{14}N_4O_2$) with water to give urea and ornithine ($C_5H_{12}N_2O_2$).

$$C_6H_{14}N_4O_2 + H_2O \rightarrow NH_2CONH_2 + C_5H_{12}N_2O_2$$

[Molar masses: 174.2 18.02 60.06 132.2]

If you excrete 95 mg of urea, what quantity of arginine must have been used? What quantity of ornithine must have been produced?

General Stoichiometry

1. $Al(OH)_3(s) + 3\,HCl(aq) \rightarrow AlCl_3(aq) + 3\,H_2O(l)$

$$\frac{.750\,g\,Al(OH)_3}{1} \times \frac{1\,mol\,Al(OH)_3}{78.01\,g} \times \frac{3\,mol\,HCl}{1\,mol\,Al(OH)_3} \times \frac{36.46\,g\,HCl}{1\,mol\,HCl} = \boxed{1.05\,g\,HCl}$$

$$\frac{.750\,g\,Al(OH)_3}{1} \times \frac{1\,mol\,Al(OH)_3}{78.01\,g} \times \frac{3\,mol\,H_2O}{1\,mol\,Al(OH)_3} \times \frac{18.0\,g\,H_2O}{1\,mol} = \boxed{.519\,g\,H_2O}$$

2. $C + O_2 \rightarrow CO_2$

$$\frac{10\,g\,C}{1} \times \frac{1\,mol\,C}{12.011\,g} \times \frac{1\,mol\,CO_2}{1\,mol\,C} \times \frac{44.01\,g\,CO_2}{1\,mol\,CO_2} = \boxed{36.6\,g\,CO_2}$$

theoretical yield

$$\frac{26.6\,g\,O_2}{1} \times \frac{1\,mol\,O_2}{32.00\,g} \times \frac{1\,mol\,CO_2}{1\,mol\,O_2} \times \frac{44.01\,g\,CO_2}{1\,mol\,CO_2} = 36.6\,g\,CO_2$$

3. $Fe_2O_3(s) + 3\,CO_2(g) \rightarrow 2\,Fe(s) + 3\,CO_2(g)$

$$\frac{454\,g\,Fe_2O_3}{1} \times \frac{1\,mol\,Fe_2O_3}{159.7\,g} \times \frac{2\,mol\,Fe}{1\,mol\,Fe_2O_3} \times \frac{55.85\,g\,Fe}{1\,mol\,Fe} = \boxed{318\,g\,Fe}$$

$$\frac{454\,g\,Fe_2O_3}{1} \times \frac{1\,mol\,Fe_2O_3}{159.7\,g} \times \frac{3\,mol\,CO}{1\,mol\,Fe_2O_3} \times \frac{28.01\,g\,CO}{1\,mol\,CO} = \boxed{239\,g\,CO}$$

4. $2SO_2(g) + 2CaCO_3(s) + O_2(g) \rightarrow 2CaSO_4(s) + 2CO_2(g)$

a. sulfur dioxide SO_2 oxygen O_2 carbon dioxide CO_2
calcium carbonate $CaCO_3$ calcium sulfate $CaSO_4$

b. $\frac{155\,g\,SO_2}{1} \times \frac{1\,mol\,SO_2}{64.07\,g} \times \frac{2\,mol\,CaCO_3}{2\,mol\,SO_2} \times \frac{100.1\,g}{1\,mol\,CaCO_3} = \boxed{242\,g\,CaCO_3}$

c. $\frac{155\,g\,SO_2}{1} \times \frac{1\,mol\,SO_2}{64.07\,g} \times \frac{2\,mol\,CaSO_4}{2\,mol\,SO_2} \times \frac{136.2\,g}{1\,mol\,CaSO_4} = \boxed{329\,g\,CaSO_4}$

5. $C_6H_{14}N_4O_2 + H_2O \rightarrow NH_2CONH_2 + C_5H_{12}N_2O_2$

$\frac{95\,mg}{1} \times \frac{1\,g}{1000\,mg} \times \frac{1\,mol\,NH_2CONH_2}{60.06\,g} \times \frac{1\,mol\,C_6H_{14}N_4O_2}{1\,mol\,NH_2CONH_2} \times \frac{174.2\,g}{1\,mol\,C_6H_{14}N_4O_2} = \boxed{.28\,g\ C_6H_{14}N_4O_2}$

$\frac{95\,mg}{1} \times \frac{1\,g}{1000\,mg} \times \frac{1\,mol\,NH_2CONH_2}{60.06\,g} \times \frac{1\,mol}{1\,mol} \times \frac{132.2\,g}{1\,mol\,C_5H_{12}N_2O_2} = \boxed{.21\,g\,C_5H_{12}N_2O_2}$