Additional Problems

1. Heating zinc sulfide in the presence of oxygen yields the following:

\[ \text{ZnS} + \text{O}_2 \rightarrow \text{ZnO} + \text{SO}_2 \]

If 1.72 mol of ZnS is heated in the presence of 3.04 mol of O\(_2\), which reactant will be used up? Balance the equation first.

2. Use the following equation for the oxidation of aluminum in the following problems.

\[ 4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3 \]

   a. Which reactant is limiting if 0.32 mol Al and 0.26 mol O\(_2\) are available?
   b. How many moles of Al\(_2\)O\(_3\) are formed from the reaction of 6.38 \times 10^{-3} \text{ mol of O}_2\) and 9.15 \times 10^{-3} \text{ mol of Al}?
   c. If 3.17 g of Al and 2.55 g of O\(_2\) are available, which reactant is limiting?

3. In the production of copper from ore containing copper(II) sulfide, the ore is first roasted to change it to the oxide according to the following equation:

\[ 2\text{CuS} + 3\text{O}_2 \rightarrow 2\text{CuO} + 2\text{SO}_2 \]

   a. If 100 g of CuS and 56 g of O\(_2\) are available, which reactant is limiting?
   b. What mass of CuO can be formed from the reaction of 18.7 g of CuS and 12.0 g of O\(_2\)?

4. A reaction such as the one shown here is often used to demonstrate a single replacement reaction.

\[ 3\text{CuSO}_4(aq) + 2\text{Fe}(s) \rightarrow 3\text{Cu}(s) + \text{Fe}_2(\text{SO}_4)_3(aq) \]

If you place 0.062 mol of iron filings in a solution containing 0.158 mol of CuSO\(_4\), what is the limiting reactant? How many moles of Cu will be formed?

5. In the reaction \( \text{BaCO}_3 + 2\text{HNO}_3 \rightarrow \text{Ba(NO}_3)_2 + \text{CO}_2 + \text{H}_2\text{O} \), what mass of Ba(NO\(_3\))\(_2\) can be formed by combining 55 g BaCO\(_3\) and 26 g HNO\(_3\)?

6. Bromine replaces iodine in magnesium iodide by the following process:

\[ \text{MgI}_2 + \text{Br}_2 \rightarrow \text{MgBr}_2 + \text{I}_2 \]

   a. Which is the excess reactant when 560 g of MgI\(_2\) and 360 g of Br\(_2\) react, and what mass remains?
   b. What mass of I\(_2\) is formed in the same process?

7. Nickel replaces silver from silver nitrate in solution according to the following equation:

\[ 2\text{AgNO}_3 + \text{Ni} \rightarrow 2\text{Ag} + \text{Ni(NO}_3)_2 \]

   a. If you have 22.9 g of Ni and 112 g of AgNO\(_3\), which reactant is in excess?
   b. What mass of nickel(II) nitrate would be produced given the quantities above?
8. Carbon disulfide, CS₂, is an important industrial substance. Its fumes can burn explosively in air to form sulfur dioxide and carbon dioxide.

\[ \text{CS}_2(g) + O_2(g) \rightarrow \text{SO}_2(g) + \text{CO}_2(g) \]

If 1.60 mol of CS₂ burns with 5.60 mol of O₂, how many moles of the excess reactant will still be present when the reaction is over?

9. Although poisonous, mercury compounds were once used to kill bacteria in wounds and on the skin. One was called “ammoniated mercury” and is made from mercury(II) chloride according to the following equation:

\[ \text{HgCl}_2(aq) + 2\text{NH}_3(aq) \rightarrow \text{Hg(NH}_2\text{Cl}(s) + \text{NH}_4\text{Cl}(aq) \]

a. What mass of Hg(NH₂)Cl could be produced from 0.91 g of HgCl₂ assuming plenty of ammonia is available?

b. What mass of Hg(NH₂)Cl could be produced from 0.91 g of HgCl₂ and 0.15 g of NH₃ in solution?

10. Aluminum chips are sometimes added to sodium hydroxide-based drain cleaners because they react to generate hydrogen gas which bubbles and helps loosen material in the drain. The equation follows.

\[ \text{Al}(s) + \text{NaOH}(aq) + H_2O(l) \rightarrow \text{NaAlO}_2(aq) + H_2(g) \]

a. Balance the equation.

b. How many moles of H₂ can be generated from 0.57 mol Al and 0.37 mol NaOH in excess water?

c. Which reactant should be limiting in order for the mixture to be most effective as a drain cleaner? Explain your choice.

11. Copper is changed to copper(II) ions by nitric acid according to the following equation:

\[ 4\text{HNO}_3 + \text{Cu} \rightarrow \text{Cu(NO}_3)_2 + 2\text{NO}_2 + 2\text{H}_2\text{O} \]

a. How many moles each of HNO₃ and Cu must react in order to produce 0.0845 mol of NO₂?

b. If 5.94 g of Cu and 23.23 g of HNO₃ are combined, which reactant is in excess?

12. One industrial process for producing nitric acid begins with the following reaction:

\[ 4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O} \]

a. If 2.90 mol NH₃ and 3.75 mol O₂ are available, how many moles of each product are formed?

b. Which reactant is limiting if 4.20 \times 10^4 g of NH₃ and 1.31 \times 10^5 g of O₂ are available?

c. What mass of NO is formed in the reaction of 869 kg of NH₃ and 2480 kg O₂?
13. Acetaldehyde CH₃CHO is manufactured by the reaction of ethanol with copper(II) oxide according to the following equation:

\[ \text{CH}_3\text{CH}_2\text{OH} + \text{CuO} \rightarrow \text{CH}_3\text{CHO} + \text{H}_2\text{O} + \text{Cu} \]

What mass of acetaldehyde can be produced by the reaction between 620 g of ethanol and 1020 g of CuO? What mass of which reactant will be left over?

14. Hydrogen bromide can be produced by a reaction among bromine, sulfur dioxide, and water as follows.

\[ \text{SO}_2 + \text{Br}_2 + \text{H}_2\text{O} \rightarrow 2\text{HBr} + \text{H}_2\text{SO}_4 \]

If 250 g of SO₂ and 650 g of Br₂ react in the presence of excess water, what mass of HBr will be formed?

15. Sulfur dioxide can be produced in the laboratory by the reaction of hydrochloric acid and a sulfite salt such as sodium sulfite.

\[ \text{Na}_2\text{SO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{SO}_2 + \text{H}_2\text{O} \]

What mass of SO₂ can be made from 25.0 g of Na₂SO₃ and 22.0 g of HCl?

16. The rare-earth metal terbium is produced from terbium(III) fluoride and calcium metal by the following displacement reaction:

\[ 2\text{TbF}_3 + 3\text{Ca} \rightarrow 3\text{CaF}_2 + 2\text{Tb} \]

a. Given 27.5 g of TbF₃ and 6.96 g of Ca, how many grams of terbium could be produced?

b. How many grams of the excess reactant are left over?
Additional Problems

1. Ethyl acetate is a sweet-smelling solvent used in varnishes and fingernail-polish remover. It is produced industrially by heating acetic acid and ethanol together in the presence of sulfuric acid, which is added to speed up the reaction. The ethyl acetate is distilled off as it is formed. The equation for the process is as follows.

\[
\text{acetic acid} \quad \text{ethanol} \quad \text{ethyl acetate} \\
\text{CH}_3\text{COOH} + \text{CH}_3\text{CH}_2\text{OH} \xrightleftharpoons{\text{H}_2\text{SO}_4} \text{CH}_3\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O}
\]

Determine the percentage yield in the following cases:

a. 68.3 g of ethyl acetate should be produced but only 43.9 g is recovered.

b. 0.0419 mol of ethyl acetate is produced but 0.0722 mol is expected. (Hint: Percentage yield can also be calculated by dividing the actual yield in moles by the theoretical yield in moles.)

c. 4.29 mol of ethanol is reacted with excess acetic acid, but only 2.98 mol of ethyl acetate is produced.

d. A mixture of 0.58 mol ethanol and 0.82 mol acetic acid is reacted and 0.46 mol ethyl acetate is produced. (Hint: What is the limiting reactant?)

2. Assume the following hypothetical reaction takes place.

\[2A + 7B \rightarrow 4C + 3D\]

Calculate the percentage yield in each of the following cases:

a. The reaction of 0.0251 mol of A produces 0.0349 mol of C.

b. The reaction of 1.19 mol of A produces 1.41 mol of D.

c. The reaction of 189 mol of B produces 39 mol of D.

d. The reaction of 3500 mol of B produces 1700 mol of C.

3. Elemental phosphorus can be produced by heating calcium phosphate from rocks with silica sand (SiO\(_2\)) and carbon in the form of coke. The following reaction takes place.

\[\text{Ca}_3(\text{PO}_4)_2 + 3\text{SiO}_2 + 5\text{C} \rightarrow 3\text{CaSiO}_3 + 2\text{P} + 5\text{CO}\]

a. If 57 mol of Ca\(_3\)(PO\(_4\))\(_2\) is used and 101 mol of CaSiO\(_3\) is obtained, what is the percentage yield?

b. Determine the percentage yield obtained if 1280 mol of carbon is consumed and 622 mol of CaSiO\(_3\) is produced.

c. The engineer in charge of this process expects a yield of 81.5%. If 1.4 \times 10\(^5\) mol of Ca\(_3\)(PO\(_4\))\(_2\) is used, how many moles of phosphorus will be produced?

4. Tungsten (W) can be produced from its oxide by reacting the oxide with hydrogen at a high temperature according to the following equation:

\[\text{WO}_3 + 3\text{H}_2 \rightarrow \text{W} + 3\text{H}_2\text{O}\]

a. What is the percentage yield if 56.9 g of WO\(_3\) yields 41.4 g of tungsten?