STOICHIOMETRY

3.74 Nickel(II) chloride reacts with sodium phosphate to precipitate nickel(II) phosphate.

How many moles of nickel(II) chloride are needed to produce 0.479 mol nickel(II) phosphate?

3.76 White phosphorus, P_4, is prepared by fusing calcium phosphate, $Ca_3(PO_4)_2$, with carbon, C, and sand, SiO_2, in an electric furnace.

$$2Ca_3(PO_4)_2(s) + 6SiO_2(s) + 10C(s) \longrightarrow P_4(g) + 6CaSiO_3(l) + 10CO(g)$$

How many grams of calcium phosphate are required to give 5.00 g of phosphorus?

3.78 Acrylonitrile, C_3H_3N, is the starting material for the production of a kind of synthetic fiber (acrylics). It can be made from propylene, C_3H_6, by reaction with nitric oxide, NO.

$$4C_3H_6(g) + 6NO(g) \longrightarrow 4C_3H_3N(g) + 6H_2O(g) + N_2(g)$$

How many grams of acrylonitrile are obtained from 651 kg of propylene and excess NO?

3.80 Solutions of sodium hypochlorite, NaClO, are sold as a bleach (such as Clorox). They are prepared by the reaction of chlorine with sodium hydroxide.

If chlorine gas, Cl_2, is bubbled into a solution containing 61.1 g NaOH, how many grams of Cl_2 will eventually react?

3.82 Copper metal reacts with nitric acid. Assume that the reaction is

$$3Cu(s) + 8HNO_3(aq) \longrightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

If 5.92 g $Cu(NO_3)_2$ is eventually obtained, how many grams of nitric oxide, NO, would have formed also, according to the preceding equation?

3.77 Tungsten metal, W, is used to make incandescent bulb filaments. The metal is produced from the yellow tungsten(VI) oxide, WO_3, by reaction with hydrogen.

How many grams of tungsten can be obtained from 4.81 kg of hydrogen with excess tungsten(VI) oxide?

3.79 The following reaction is used to make carbon tetrachloride, CCl_4, a solvent and starting material for the manufacture of fluorocarbon refrigerants and aerosol propellants.

$$CS_2(g) + 3Cl_2(g) \longrightarrow CCl_4(g) + S_2Cl_2(g)$$

Calculate the number of grams of carbon disulfide, CS_2, needed for a laboratory-scale reaction with 62.7 g of chlorine, Cl_2.

3.81 When dinitrogen pentoxide, N_2O_5, a white solid, is heated, it decomposes to nitrogen dioxide and oxygen.

$$2N_2O_5(s) \xrightarrow{\Delta} 4NO_2(g) + O_2(g)$$

If a sample of N_2O_5 produces 1.315 g O_2, how many grams of NO_2 are formed?

LIMITING REACTANT; THEORETICAL AND PERCENTAGE YIELD

3.83 Potassium superoxide, KO_2, is used in rebreathing gas masks to generate oxygen.

$$4KO_2(s) + 2H_2O(l) \longrightarrow 4KOH(s) + 3O_2(g)$$

If a reaction vessel contains 0.25 mol KO_2 and 0.15 mol H_2O, what is the limiting reactant? How many moles of oxygen can be produced?

3.84 Large quantities of ammonia are burned in the presence of a platinum catalyst to give nitric oxide, as the first step in the preparation of nitric acid.

$$4NH_3(g) + 5O_2(g) \xrightarrow{Pt} 4NO(g) + 6H_2O(g)$$

Suppose a vessel contains 0.120 mol NH_3 and 0.140 mol O_2. Which is the limiting reactant? How many moles of NO could be obtained?

3.86 Carbon disulfide, CS_2, burns in oxygen. Complete combustion gives the reaction

$$CS_2(g) + 3O_2(g) \longrightarrow CO_2(g) + 2SO_2(g)$$

Calculate the grams of sulfur dioxide, SO_2, produced when a mixture of 30.0 g of carbon disulfide and 35.0 g of oxygen reacts. Which reactant remains unconsumed at the end of combustion? How many grams remain?

3.88 Hydrogen cyanide, HCN, is prepared from ammonia, oxygen, and natural gas (CH_4) by the following process:

$$2NH_3(g) + 3O_2(g) + 2CH_4(g) \xrightarrow{Pt} 2HCN(g) + 6H_2O(g$$

Hydrogen cyanide is used to prepare sodium cyanide, which is used in part to obtain gold from gold-containing rock. If a reaction vessel contains 11.5 g NH_3, 10.0 g O_2, and 10.5 g CH_4, what is the maximum mass in grams of hydrogen cyanide that could be made, assuming the reaction goes to completion as written?

3.90 Methyl salicylate (oil of wintergreen) is prepared by heating salicylic acid, $C_7H_6O_3$, with methanol, CH_3OH.

$$C_7H_6O_3 + CH_3OH \longrightarrow C_8H_8O_3 + H_2O$$

In an experiment, 1.50 g of salicylic acid is reacted with 11.20 g of methanol. The yield of methyl salicylate, $C_8H_8O_3$, is 1.31 g. What is the percentage yield?

Challenge Problems

3.113 An alloy of iron (54.7%), nickel (45.0%), and manganese (0.3%) has a density of 8.17 g/cm^3. How many iron atoms are there in a block of alloy measuring 10.0 cm × 20.0 cm × 15.0 cm?

3.108 A mixture of Fe_2O_3 and FeO was found to contain 72.00% Fe by mass. What is the mass of Fe_2O_3 in 0.500 g of this mixture?

3.110 Penicillin V was treated chemically to convert sulfur to barium sulfate, $BaSO_4$. An 8.19-mg sample of penicillin V gave 5.46 mg $BaSO_4$. What is the percentage of sulfur in penicillin V? If there is one sulfur atom in the molecule, what is the molecular weight?

3.112 1.92 g M^+ ion reacts with 0.158 mol X^- ion to produce a compound, MX_2, which is 86.8% X by mass. What are the identities of M^+ and X^-?

Thermo Problems

6.5 Suppose heat flows into a vessel containing a gas. As the heat flows into the gas, what happens to the gas molecules? What happens to the internal energy of the gas?

6.13 Define the heat capacity of a substance. Define the specific heat of a substance.

6.14 Describe a simple calorimeter. What measurements are needed to determine the heat of reaction?

6.27 A house has an attached wind turbine that supplies some of the electricity to the home. Describe the energy changes that occur when a light is turned on, assuming that the energy originates with the wind.

6.45 When white phosphorus burns in air, it produces phosphorus(V) oxide.

$$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(s);\ \Delta H = -2940\ \text{kJ}$$

What is ΔH for the following equation?

$$P_4O_{10}(s) \longrightarrow P_4(s) + 5O_2(g)$$

6.47 Phosphoric acid, H_3PO_4, can be prepared by the reaction of phosphorus(V) oxide, P_4O_{10}, with water.

$$\tfrac{1}{4}P_4O_{10}(s) + \tfrac{3}{2}H_2O(l) \longrightarrow H_3PO_4(aq);\ \Delta H = -113.2\ \text{kJ}$$

What is ΔH for the reaction involving 1 mol of P_4O_{10}?

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$$

6.50 Hydrogen, H_2, is used as a rocket fuel. The hydrogen is burned in oxygen to produce water vapor.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g);\ \Delta H = -484\ \text{kJ}$$

What is the enthalpy change per gram of hydrogen?

6.52 Hydrogen sulfide, H_2S, is a foul-smelling gas. It burns to form sulfur dioxide.

$$2H_2S(g) + 3O_2(g) \longrightarrow 2SO_2(g) + 2H_2O(g);\ \Delta H = -1037\ \text{kJ}$$

Calculate the enthalpy change to burn 26.7 g of hydrogen sulfide.

6.54 Ethanol, C_2H_5OH, is mixed with gasoline and sold as gasohol. Use the following to calculate the grams of ethanol needed to provide 293 kJ of heat.

$$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g);\ \Delta H = -1235\ \text{kJ}$$

6.56 An iron skillet weighing 1.63 kg is heated on a stove to 178°C. Suppose the skillet is cooled to room temperature, 21°C. How much heat energy (in joules) must be removed to effect this cooling? The specific heat of iron is 0.449 J/g · °C.

6.62 A sample of benzene, C_6H_6, weighing 3.51 g was burned in an excess of oxygen in a bomb calorimeter. The temperature of the calorimeter rose from 25.00°C to 37.18°C. If the heat capacity of the calorimeter and contents was 12.05 kJ/°C, what is the value of q for burning 1 mol of benzene at constant volume and 25.00°C? The reaction is

$$C_6H_6(l) + \tfrac{15}{2}O_2(g) \longrightarrow 6CO_2(g) + 3H_2O(l)$$

HESS'S LAW

6.63 Hydrazine, N_2H_4, is a colorless liquid used as a rocket fuel. What is the enthalpy change for the process in which hydrazine is formed from its elements?

$$N_2(g) + 2H_2(g) \longrightarrow N_2H_4(l)$$

Use the following reactions and enthalpy changes:

$$N_2H_4(l) + O_2(g) \longrightarrow N_2(g) + 2H_2O(l);\ \Delta H = -622.2\ \text{kJ}$$
$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(l);\ \Delta H = -285.8\ \text{kJ}$$

6.64 Hydrogen peroxide, H_2O_2, is a colorless liquid whose solutions are used as a bleach and an antiseptic. H_2O_2 can be prepared in a process whose overall change is

$$H_2(g) + O_2(g) \longrightarrow H_2O_2(l)$$

Calculate the enthalpy change using the following data:

$$H_2O_2(l) \longrightarrow H_2O(l) + \tfrac{1}{2}O_2(g);\ \Delta H = -98.0\ \text{kJ}$$
$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l);\ \Delta H = -571.6\ \text{kJ}$$

6.69 The cooling effect of alcohol on the skin is due to its evaporation. Calculate the heat of vaporization of ethanol (ethyl alcohol), C_2H_5OH.

$$C_2H_5OH(l) \longrightarrow C_2H_5OH(g);\ \Delta H^\circ = ?$$

6.72 Carbon disulfide is a colorless liquid. When pure, it is nearly odorless, but the commercial product smells vile. Carbon disulfide is used in the manufacture of rayon and cellophane. The liquid burns as follows:

$$CS_2(l) + 3O_2(g) \longrightarrow CO_2(g) + 2SO_2(g)$$

Calculate heat of formation

$CS_{2(l)} = 117$ $SO_{2(g)} = -296.8$

$CO_{2(g)} = -393.5$

6.91 A 50.0-g sample of water at 100.00°C was placed in an insulated cup. Then 25.3 g of zinc metal at 25.00°C was added to the water. The temperature of the water dropped to 96.68°C. What is the specific heat of zinc?

6.86 Calcium oxide (quicklime) reacts with water to produce calcium hydroxide (slaked lime).

$$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s);\ \Delta H = -65.2\ \text{kJ}$$

The heat released by this reaction is sufficient to ignite paper. How much heat is released when 24.5 g of calcium oxide reacts?

6.88 Acetic acid, $HC_2H_3O_2$, is the sour constituent of vinegar (*acetum* is Latin for "vinegar"). In an experiment, 3.58 g of acetic acid was burned.

$$HC_2H_3O_2(l) + 2O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(l)$$

If 52.0 kJ of heat evolved, what is ΔH per mole of acetic acid?

6.116 How much heat is released when a mixture containing 10.0 g CS_2 and 10.0 g Cl_2 reacts by the equation

$$CS_2(g) + 3Cl_2(g) \longrightarrow S_2Cl_2(g) + CCl_4(g);\ \Delta H^\circ = -232\ \text{kJ}$$