Part A: Review of Limiting Reactants

1) Aqueous sodium hydroxide reacts with aqueous phosphoric acid in a typical acid-base neutralization reaction.

   a) Write the balanced equation for the above reaction.

Imagine that you have 18.0 grams each of sodium hydroxide and phosphoric acid and want to figure out how much sodium phosphate you can make. Let's break it down into steps.

   b) Assuming that the 18.0 g of sodium hydroxide is the limiting reactant, how many grams of sodium phosphate can be made?

   c) Assuming that the 18.0 g of phosphoric acid is the limiting reactant, how many grams of sodium phosphate can be made?

   d) Given your answers to questions 1b) and 1c), what is the actual limiting reactant and what is the maximum mass, in g, of sodium phosphate that you make? Briefly explain your choice.

   e) If the actual yield of sodium phosphate is 22.8 g, what is the percent yield for this reaction?

Part B: Figuring Out How Much Excess Reactant Is Left Over

In addition to identifying the limiting reactant and the theoretical yield of product, it can be useful to know how much of the excess reactant is left over after all of the limiting reactant is used up.

2) In a CHM 1A laboratory experiment, a student prepares aspirin by the following reaction:

$$2\ C_7H_6O_3(s) + C_4H_6O_3(l) \rightarrow 2\ C_9H_8O_4(s) + H_2O(l)$$

salicylic acid *acetic anhydride* *asprin*

Imagine that the student mixes 20.0 grams each of salicylic acid and acetic anhydride. First, let's find out how much aspirin she can make.

a) Assuming that the 20.0 g of salicylic acid (molar mass = 138.1 g/mol) is the limiting reactant, how many grams of aspirin (molar mass = 180.2 g/mol) can be made?

b) Assuming that the 20.0 g of acetic anhydride (molar mass = 102.1 g/mol) is the limiting reactant, how many grams of aspirin (molar mass = 180.2 g/mol) can be made?

c) Based on your answers to questions 2a) and 2b), what is the limiting reactant and what is the theoretical yield of aspirin?

Based on your answers to questions 2a) and 2b) you should have found that the salicylic acid was the limiting reactant and that the acetic anhydride was the excess reactant. Therefore, after the reaction is complete, all of the salicylic acid would be gone, but there should be some acetic anhydride left over. Let's see if we can figure out how much of the acetic anhydride remains. There are several ways to do this; one way is to determine how much acetic anhydride is used up when reacting with 20.0 g of salicylic acid. We can then take the 20.0 g of acetic anhydride we started with and subtract the amount that was used up.

d) Calculate the mass, in g, of acetic anhydride that will react with the 20.0 g of salicylic acid.

e) Calculate the mass, in g, of acetic anhydride that remains by taking the original mass of acetic anhydride (20.0 g) and subtracting the amount that was used up (your answer to question 2d).

Part C: Extra Problems If You Have Time

3) Acrylonitrile, C_3H_3N is an important chemical use in making different plastics. Over 1.4 billion kg of acrylonitrile are produced each year in the United States alone by the following unbalanced reaction:

$$\_\_\_\_\_\_ C_3H_6\ (l) + \_\_\_\_\_\_ NH_3\ (g) + \_\_\_\_\_\_ O_2\ (g) \rightarrow \_\_\_\_\_\_ C_3H_3N\ (l) + \_\_\_\_\_\_ H_2O\ (g)$$

a) Balance the above reaction.

b) If a manufacture of plastics starts with 1.5×10^3 kg of C_3H_6, 6.8×10^2 kg of NH_3, and 1.9×10^3 kg of O_2, what is the theoretical yield, in kg, of acrylonitrile?

c) How many grams of each excess reactant remain after the reaction described in question 3b) is complete?

d) If the actual yield for the process described in question 3b) is 1.8×10^3 kg of acrylonitrile, what is the percent yield for the process?

4) Carborundum (silicon carbide, SiC) is an important industrial abrasive made by the high temperature reaction of SiO_2 with carbon according to the following unbalanced reaction:

$$\_\_\_\_\_\_ SiO_2(s) + \_\_\_\_\_\_ C(s) \rightarrow \_\_\_\_\_\_ SiC(s) + \_\_\_\_\_\_ CO(g)$$

a) Balance the above reaction.

b) Determine the limiting reactant and the theoretical yield of caborundum that can be made from a mixture of 500. g each of SiO_2 and C.

c) If the percent yield for this reaction is 93.5%, how much carborundum can be made from the starting materials described in question 4b)?

This next problem is not a limiting reactant problem, but it requires that you understand the concept of percent yield.

5) The ceramic silicon nitride (Si_3N_4) is used in automobile engines and as an insulator in manufacturing integrated circuits. It is made by heating solid silicon with nitrogen gas at temperatures between 1300 – 1400°C.

a) Write the balanced chemical equation for the synthesis of silicon nitride.

b) How many kg of silicon are needed to produce 1.00 kg of silicon nitride if the process is 89.0% efficient?