Limiting Reactants

Limiting reactants in the *real* world.

You drop a piece of zinc into a beaker of hydrochloric acid. It begins to bubble furiously, but eventually it stops. You drop another piece of zinc into the acid. The bubbling begins anew, but again it stops. This time, you add more hydrochloric acid. Nothing happens. Obviously, each time the reaction stopped it was because you ran out of zinc. There was always plenty of hydrochloric acid. In fact, there was an excess of the acid. Zinc, on the other hand, was a limiting reactant. The reactant that is consumed first limits the amount of product that is produced, and is called a limiting reactant. The balanced equation predicts the amounts of reactants needed to completely consume each other (stoichiometric quantities). If any of the reactants is in excess, the other(s) is (are) limiting reactants.

In stoichiometry problems where the amount of only one of the reactants is given, it is assumed either that there are stoichiometric amounts of all the reactants and products, or, at the very least, that all of the reactant for which the amount is specified is consumed because it is the limiting reactant. For problems in which the amount of more than one reactant is specified, you need to consider that there may be a limiting reactant. If there is a limiting reactant, you need to know which one it is and use it for your calculations, because excess, unconsumed reactants do NOT produce any product.

To identify the limiting reactant: [1] Write a balanced equation; [2] Calculate the number of moles of each of the reactants present; and [3] Divide the number of moles of each reactant by its stoichiometric coefficient. The smallest number corresponds to the limiting reactant. Once the limiting reactant is identified, stoichiometry problems are done as usual using the amount of the limiting reactant.

Sample Problem

How much ammonia is formed from 25.0 kg of nitrogen and 5.00 kg of hydrogen? How much material is unreacted?

Step 1: Write the balanced equation

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

Step 2: Calculate the number of moles of each of the reactants present.

$$\left(25.0kg_{N_2}\right)\left(\frac{1000g}{1kg}\right)\left(\frac{1mol_{N_2}}{28.0g_{N_2}}\right) = 8.93\times10^2\,mol_{N_2} \qquad \left(5.00kg_{H_2}\right)\left(\frac{1000g}{1kg}\right)\left(\frac{1mol_{H_2}}{2.02g_{H_2}}\right) = 2.48\times10^3\,mol_{H_2}$$

Step 3: Divide the number of moles of each reactant by its stoichiometric coefficient. The smallest number corresponds to the limiting reactant.

$$\frac{8.93\times10^2\,mol_{N_2}}{1} = 8.93\times10^2\,mol_{N_2} \qquad \frac{2.48\times10^3\,mol_{H_2}}{3} = 8.25\times10^2\,mol_{H_2}$$

H_2 is limiting

Step 4: Use the limiting reactant to complete the calculation.

$$\left(2.48\times10^3\,mol_{H_2}\right)\left(\frac{2mol_{NH_3}}{3mol_{H_2}}\right)\left(\frac{17.0g_{NH_3}}{1mol_{NH_3}}\right)\left(\frac{1kg}{1000g}\right) = 28.1kg_{NH_3}$$

Step 5: Calculate the amount of unreacted material by calculating the stoichiometric amount that reacted and subtracting it from the initial amount.

$$\left(2.48\times10^3\,mol_{H_2}\right)\left(\frac{1mol_{N_2}}{3mol_{H_2}}\right)\left(\frac{28.0g_{N_2}}{1mol_{N_2}}\right)\left(\frac{1kg}{1000g}\right) = 23.1kg_{N_2}$$

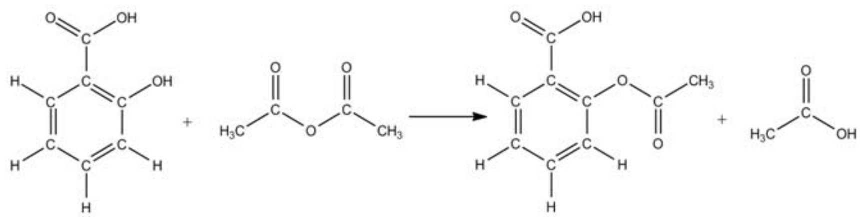
$$25.0kg_{N_2} - 23.1kg_{N_2} = 1.9kg_{N_2}$$

(CONTINUED ON THE NEXT PAGE)

Answer the questions below based on the preceding example. (*NOTE*: Equations provided may not be balanced.)

1. How much pure iron can be extracted from 250. kg of iron III oxide when it reacts with 148 kg of carbon monoxide? What is in excess, and by how much? [$Fe_2O_3 + CO \rightarrow Fe + CO_2$]

2. Salicylic acid ($C_7H_6O_3$) reacts with acetic anhydride ($C_4H_6O_3$) to form aspirin ($C_9H_8O_4$) and acetic acid ($C_2H_4O_2$). How much aspirin forms from 25.0 g of salicylic acid and 25.0 g of acetic anhydride? What is in excess, and by how much?
   [$C_7H_6O_3 + C_4H_6O_3 \rightarrow C_9H_8O_4 + C_2H_4O_2$].



3. How much copper will precipitate when 10.0 g of granular zinc are added to solution containing 16.0 g of aqueous copper II sulfate? What is in excess, and by how much? [$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$]