Limiting Reagent Calculations

When chemicals are mixed together under the appropriate conditions, a chemical reaction is started. The reaction will start when one of the reactants is completely used up. The reactant that is totally consumed, thereby stopping the reaction is called the **limiting reactant** or limiting **reagent.** The other reactant(s) are the excess reagent(s).

The amount of the limiting reactant will determine how much of the other reactant(s) react and how much of each product is formed. When the limiting reactant is used up, no more product can be formed - limiting reagent in a chemical reaction is completely used up.

Excess reagent is present in a quantity greater than that required to react completely with another reactant.

So far, in aH the calculations performed only the amount of one of the reactant has been given, and this reactant was assumed to be the limiting reactant. When the amount of two or more reactants are given, special procedures for limiting reactant calculations must be performed.

The concept of the limiting regent is analogous to the relationship between men and women at a dance. If there are fifteen boys and only ten girls, then only ten girl/boy pairs can be on the dance floor at any given moment..

$$1 \text{ boy} + 1 \text{girl} \longrightarrow 1 \text{ couple}$$

Five boys will be left without partners. The number of girls thus limits the number of boys that can dance, and there is an excess of boys

A variety of problems can be solved in the context of the limiting reactant concept. These include determinations of which reactant is the limiting reactant, and how much product is formed, and how much of the excess reactant does not react.

Procedures for solving limiting reactant problems must always be used when the amounts of two or more reactants are given in the statement of the problem.

Once a limiting reactant is identified, all further calculations are based on the amount of limiting reactant given in the statement of the problem.

Example
sulphur hexafluoride, SF_6, a colourless, odourless, and extremely stable compound formed by burning sulphur in an atmosphere of fluorine

$$S_{(1)} + 3\,F_{2(g)} \longrightarrow SF_{6(g)}$$

This equation tells us that 1 mol of S reacts with 3 mol of F_2 to produce 1 mol of $5F_6$.
Now, suppose that 4 mol of S are added to 20 mol of F_2.
From the balanced equation: $S : F_2 = I : 3$
$x : 4 = 12 : 3$
But, there are 20 mol of F_2 available, more than what is needed to completely react with S.
Thus the S must be the limiting reagent and F_2 the excess reagent. The amount of SF_6 that can be produced depends only on how much S was originally present.

In stoichiometric calculations involving limiting reagents, the first step is to decide which reactant is the limiting reagent. Once the limiting reagent has been identified, the rest of the problem can be solved as explained in stoichiometric calculations.

Sample Problem

Given the following reaction...

$$NH_{3(g)} + HCl_{(g)} \longrightarrow NH_4Cl_{(s)}$$

If you are given 1.00 g of NH_3 and 1.00 g HCl, determine:
a) which is the limiting reagent, b) which is the excess reagent, c) how much of the excess reagent is left over, and d) how much NH_4Cl is produced?

Solution

Step I **Determine the number of mols of each reagent**

Since we cannot tell by inspection which of the two reactants is the limiting reagent, we have to proceed by first converting their masses into number of mols.
Number of mol of NH_3 = mass / molar mass = 1.00 g /17.00 g mol^{-1}
Number of mol of HCl = mass / molar mass = 1.00 g /36.45 g mol^{-1}

Step II **Find the limiting reagent**

From the balanced equation we see that:
I mol NH_3 reacts with 1 mol HCl
.: 0.0274 mol of HCl will react with 0.0274 mol NH_3
Since, there are *0.0558* mol of NH_3 available, and only 0.0274 mol of NH_3 are required for reaction, thus NH_3 is in excess.
Hence, the number of NH_3 in excess = 0.0558 - 0.0274 mo1

Step Ill **Find the amount of product**

The amount of NH_4Cl produced is determined by the amount of limiting reagent present.
Since the mol ratio of HCl : NH_4CI = 1 : 1 = 0.0274
Thus, we write mass of NH_4Cl = 0.0274 mol x molar mass of NH_4Cl
= 0.0274 mol x 53.49 moI g-' = 1.47 g

Answers to the Problem

a) HCl is the limiting reagent
b) NH_3 is the excess reagent
c) NH_3 is in excess by 0.0284 mol
d) mass of NH_4Cl obtained = 1.47 g
e) NH_3 is in excess by 0.0284 mol

Now, try the following problems...

1. Nitric oxide, NO, reacts instantly with $O_{2(g)}$ to give $NO_{2(g)}$...

$$2\ NO_{(g)} + O_{2(g)} \longrightarrow 2\ NO_{2(g)}$$

In one experiment 0.886 mol of NO is mixed with 0.503 mol of 0_2. Calculate which of the two reactants is the limiting reagent. Calculate the mass of $NO_{2(g)}$ produced and the mass of excess reagent remaining.

2. The reaction between Al and Fe_2O_3 can generate temperatures approaching 3000 ^{0}C and is used in welding metals: $2\ Al + Fe_2O_3 \longrightarrow A1_20_3 + 2\ Fe$

In one process 124 g of Al are reacted with 601 g of Fe_2O_3.

(a) Calculate the mass of $A1_20_3$ formed. (b) How much of the excess reagent is left at the end of the reaction.

3. Titanium is a strong lightweight, corrosion-resistant metal that is used in rockets, and jet engines. It is prepared by the reaction of $TiCl_4$ with Mg at 1150 ^{0}C:

$$TiC1_{4(g)} + 2\ Mg_{(l)} \longrightarrow Ti_{(s)} + 2\ MgCl_{2(1)}$$

In a certain operation 3.54 x io~ g of $TiCl_4$ are reacted with 1.13 x io~ g of Mg. Calculate the mass of Ti obtained and the mass of the excess reagent remaining.

4. Propane, C_3H_8, is a component of natural gas and is used in domestic cooking and heating...

$$C_3H_8 + O_2 \longrightarrow CO_2 + H_2O$$

a)Balance the equation

b) 8.8 g of C_3H_8 undergo combustion in 2.2 g $O_{2(g)}$

(i) what mass of $C0_2$ is produced? (ii) what mass of H_20 is formed.

5.What mass of $A1_20_3$ can be produced when a mixture of 1.00 g of Al and 1.00 g of 0_2 is ignited:

$$4Al + 3O_2 \longrightarrow 2\ A1_2O_3$$

6. What mass of CaF_2 can be obtained by igniting 10.25 g of Ca in 15.55 g of phosphorus...

$$6\ Ca + P_4 \longrightarrow 2\ Ca_3P_2$$