

Limiting Reagent Calculations

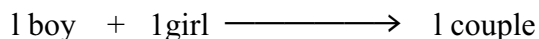
When chemicals are mixed together under the appropriate conditions, a chemical reaction is started. The reaction will start when one of the reactants is completely used up. The reactant that is totally consumed, thereby stopping the reaction is called the **limiting reagent** or limiting reagent. The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

The amount of the limiting reagent will determine how much of the other reactant(s) react and how much of each product is formed. When the limiting reagent 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 all the calculations performed only the amount of one of the reactants has been given, and this reactant was assumed to be the limiting reagent. When the amount of two or more reactants are given, special procedures for limiting reagent calculations must be performed.

The concept of the limiting reagent 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..



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 reagent concept. These include determinations of which reactant is the limiting reagent, and how much product is formed, and how much of the excess reagent does not react.

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

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

Example

sulphur hexafluoride, SF₆, a colourless, odourless, and extremely stable compound formed by burning sulphur in an atmosphere of fluorine



This equation tells us that 1 mol of S reacts with 3 mol of F₂ to produce 1 mol of SF₆.

Now, suppose that 4 mol of S are added to 20 mol of F₂.

From the balanced equation: S : F₂ = 1 : 3
 x : 4 = 12 : 3

But, there are 20 mol of F₂ available, more than what is needed to completely react with S.

Thus the S must be the limiting reagent and F₂ the excess reagent. The amount of SF₆ 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...



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.

$$\text{Number of mol of NH}_3 = \text{mass} / \text{molar mass} = 1.00 \text{ g} / 17.00 \text{ g mol}^{-1}$$

$$\text{Number of mol of HCl} = \text{mass} / \text{molar mass} = 1.00 \text{ g} / 36.45 \text{ g mol}^{-1}$$

Step II

Find the limiting reagent

From the balanced equation we see that:

1 mol NH_3 reacts with 1 mol HCl

\therefore 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.

$$\text{Hence, the number of NH}_3 \text{ in excess} = 0.0558 - 0.0274 \text{ mol}$$

Step III

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 $\text{HCl} : \text{NH}_4\text{Cl} = 1 : 1 = 0.0274$

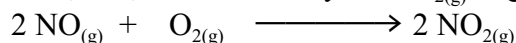
$$\begin{aligned} \text{Thus, we write mass of NH}_4\text{Cl} &= 0.0274 \text{ mol} \times \text{molar mass of NH}_4\text{Cl} \\ &= 0.0274 \text{ mol} \times 53.49 \text{ mol g}^{-1} = 1.47 \text{ g} \end{aligned}$$

Answers to the Problem

- HCl is the limiting reagent
- NH_3 is the excess reagent
- NH_3 is in excess by 0.0284 mol
- mass of NH_4Cl obtained = 1.47 g
- 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)}...



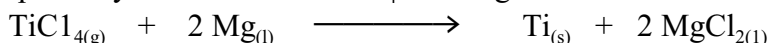
In one experiment 0.886 mol of NO is mixed with 0.503 mol of O₂. Calculate which of the two reactants is the limiting reagent. Calculate the mass of NO_{2(g)} produced and the mass of excess reagent remaining.

2. The reaction between Al and Fe₂O₃ can generate temperatures approaching 3000 °C and is used in welding metals: $2 \text{Al} + \text{Fe}_2\text{O}_3 \longrightarrow \text{Al}_2\text{O}_3 + 2 \text{Fe}$

In one process 124 g of Al are reacted with 601 g of Fe₂O₃.

(a) Calculate the mass of Al₂O₃ formed. (b) How much of the excess reagent is left at the end of the reaction.

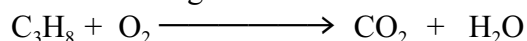
3. Titanium is a strong lightweight, corrosion-resistant metal that is used in rockets, and jet engines. It is prepared by the reaction of TiCl₄ with Mg at 1150 °C:



In a certain operation 3.54 x 10³ g of TiCl₄ are reacted with 1.13 x 10³ g of Mg.

Calculate the mass of Ti obtained and the mass of the excess reagent remaining.

4. Propane, C₃H₈, is a component of natural gas and is used in domestic cooking and heating...

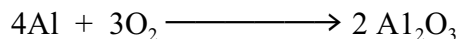


a) Balance the equation

b) 8.8 g of C₃H₈ undergo combustion in 2.2 g O_{2(g)}

(i) what mass of CO₂ is produced? (ii) what mass of H₂O is formed.

5. What mass of Al₂O₃ can be produced when a mixture of 1.00 g of Al and 1.00 g of O₂ is ignited:



6. What mass of CaF₂ can be obtained by igniting 10.25 g of Ca in 15.55 g of phosphorus...

