Notes Limiting Reactant and Percent Yield

Limiting Reactants

Once one of the reactants is used up, no more product can be produced and the reaction will stop. The ***limiting reactant*** is the reactant that is completely used up in the reaction and limits the amount of product that can be produced.

To determine the limiting reactant you will use a mole ratio of two reactants.

Silicon dioxide which is quartz is usually unreactive but will react with hydrogen fluoride.

$$SiO_{2(s)} + 4HF_{(g)} \longrightarrow SiF_{4(g)} + 2H_2O_{(L)}$$

If 6.0 mol of HF is added to 4.5 mol of SiO_2, which is the limiting reactant?

Steps to solving

1. State the given: 6.0 mol of HF
   4.5 mol of SiO_2
   State the unknown: limiting reactant
2. The mole ratio of HF to SiF_4 and the mole ratio of SiO_2 to SiF_2 will be needed.

$$\frac{6.0 \text{ mol HF}}{1} \times \frac{1 \text{mol } SiF_4}{4 \text{ mol HF}} = 1.5 \text{ mol } SiF_4$$

$$\frac{4.5 \text{ mol } SiO_2}{1} \times \frac{1 \text{mol } SiF_4}{1 \text{ mol } SiO_2} = 4.5 \text{ mol } SiF_4$$

Because 6.0 moles of HF can only make 1.5 moles of SiF_4, HF is the limiting reactant.

Practice Problems

25. The equation for the complete combustion of ethene (C_2H_4) is

$$C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(g)$$

If 2.70 mol C_2H_4 is reacted with 6.30 mol O_2, identify the limiting reagent.

26. Hydrogen gas can be produced by the reaction of magnesium metal with hydrochloric acid.

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$$

Identify the limiting reagent when 6.00 g HCl reacts with 5.00 g Mg. Ans: HCl

$$2.70 \text{mol } C_2H_4 \times \frac{2 \text{mol } CO_2}{1 \text{mol } C_2H_4} = 5.40 \text{mol } CO_2$$

$$6.30 \text{mol } O_2 \times \frac{2 \text{mol } CO_2}{3 \text{mol } O_2} = 4.02 \text{mol } CO_2$$

Which is limiting? O_2 but why?

Produces the least amount of CO_2

Try #26.

Percent Yield

The amounts of products calculated under ideal conditions represent theoretical yields. ***Theoretical yield*** is the maximum amount of product that can be produced from a given amount of reactant. Most chemical reactions actually produce less than what the theoretical yield states.

Why is this? There are many reasons, reactants may contain impurities that form byproducts and many reactions do not go to completion.

Ideal stoichiometric calculations can only predict what can be produced. The ***Actual yield*** is the measured amount of product that is obtained from doing the reaction in the lab. It is important to chemists and industries to know the efficiency of a reaction.

The efficiency is determined by ***Percentage yield*** which compares the ratio of actual yield to theoretical yield.

$$\text{percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Chlorobenzene, C_6H_5Cl is used in the production of asprin. To make chlorobenzene, benzen must be reacted with chlorine.

$$C_6H_{6(l)} + Cl_2 \longrightarrow C_6H_5Cl_{(l)} + HCl_{(g)}$$

When 36.8 g C_6H_6 react with an excess of Cl_2, the actual yield of C_6H_5Cl is 38.8 g. What is the percentage yield of C_6H_5Cl?

Steps to solving

1. State the given: 36.8 g of C_6H_6
   38.8 g C_6H_5Cl actual yield
   State the unknown: percentage yield of C_6H_5Cl
2. Molar mass of C_6H_6 and C_6H_5Cl is needed and the mole ratio of C_6H_6 and C_6H_5Cl is needed.

$$\frac{36.8\text{ g } C_6H_6}{1} \times \frac{1\text{ mol } C_6H_6}{78.12\text{ g } C_6H_6} \times \frac{1\text{ mol } C_6H_5Cl}{1\text{ mol } C_6H_6} \times \frac{112.56\text{ g } C_6H_5Cl}{1\text{ mol } C_6H_5Cl} =$$

$$= 53.0\text{ g } C_6H_5Cl \text{ (theoretical yield)}$$

$$\text{percentage yield} = \frac{38.8\text{ g}}{53.0\text{ g}} \times 100 = 73.2\%$$

Practice Problems

29. When 84.8 g of iron(III) oxide reacts with an excess of carbon monoxide, iron is produced.

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$$

What is the theoretical yield of iron?

30. When 5.00 g of copper reacts with excess silver nitrate, silver metal and copper(II) nitrate are produced. What is the theoretical yield of silver in this reaction?