EXAMPLE: **If 56.8 g of $FeCl_2$, 14.0 g of KNO_3 and 40.0 g of HCl are mixed and allowed to react according to the equation**

$$3\ FeCl_2 + KNO_3 + 4\ HCl \longrightarrow 3\ FeCl_3 + NO + 2\ H_2O + KCl$$

a) which chemical is the LIMITING reactant?

Arbitrarily find the mass of NO which can be produced by each of the three reactants.

$$\text{mass of NO (based on } FeCl_2) = 56.8\ g\ FeCl_2 \times \frac{1\ mol\ FeCl_2}{126.8\ g\ FeCl_2} \times \frac{1\ mol\ NO}{3\ mol\ FeCl_2} \times \frac{30.0\ g\ NO}{1\ mol\ NO}$$
$$= \mathbf{4.48\ g}$$

$$\text{mass of NO (based on } KNO_3) = 14.0\ g\ KNO_3 \times \frac{1\ mol\ KNO_3}{101.1\ g\ KNO_3} \times \frac{1\ mol\ NO}{1\ mol\ KNO_3} \times \frac{30.0\ g\ NO}{1\ mol\ NO}$$
$$= \mathbf{4.15\ g}$$

$$\text{mass of NO (based on HCl)} = 40.0\ g\ HCl \times \frac{1\ mol\ HCl}{36.5\ g\ HCl} \times \frac{1\ mol\ NO}{4\ mol\ HCl} \times \frac{30.0\ g\ NO}{1\ mol\ NO} = \mathbf{8.22\ g}$$

Since the KNO_3 produces the **least** amount of NO, KNO_3 is the **LIMITING REACTANT.** Therefore, **both** $FeCl_2$ and HCl are **IN EXCESS.**

b) how many grams of each "excess reactant" are actually present in excess?

First find the mass of $FeCl_2$ and HCl which actually react, **arbitrarily based on the mass of the limiting reactant KNO_3.** Then calculate the mass of each reactant left over. (The mass of NO or any other product could have been used instead of the mass of KNO_3.)

$$\text{mass of } FeCl_2 \text{ (used)} = 14.0\ g\ KNO_3 \times \frac{1\ mol\ KNO_3}{101.1\ g\ KNO_3} \times \frac{3\ mol\ FeCl_2}{1\ mol\ KNO_3} \times \frac{126.8\ g\ FeCl_2}{1\ mol\ FeCl_2}$$
$$= 52.7\ g$$

mass of $FeCl_2$ in excess = 56.8 – 52.7 = **4.1 g**

$$\text{mass of HCl (used)} = 14.0\ g\ KNO_3 \times \frac{1\ mol\ KNO_3}{101.1\ g\ KNO_3} \times \frac{4\ mol\ HCl}{1\ mol\ KNO_3} \times \frac{36.5\ g\ HCl}{1\ mol\ HCl} = 20.2\ g$$

mass of HCl in excess = 40.0 – 20.2 = **19.8 g**

EXERCISES:

26. What mass of CS_2 is produced when 17.5 g of C are reacted with 39.5 g of SO_2 according to the equation

$$5\ C + 2\ SO_2 \longrightarrow CS_2 + 4\ CO\ ?$$

What mass of the excess reactant will be left over?

27. What mass of NO is produced when 87.0 g of Cu are reacted with 225 g of HNO_3 according to the equation

$$3\ Cu + 8\ HNO_3 \longrightarrow 3\ Cu(NO_3)_2 + 2\ NO + 4\ H_2O\ ?$$

What mass of the excess reactant will be left over?

28. What mass of P_4 is produced when 41.5 g of $Ca_3(PO_4)_2$, 26.5 g of SiO_2 and 7.80 g of C are reacted according to the equation

$$2\ Ca_3(PO_4)_2 + 6\ SiO_2 + 10\ C \longrightarrow P_4 + 6\ CaSiO_3 + 10\ CO\ ?$$

How many grams of each excess reactant will remain unreacted?

29. What mass of Br_2 is produced when 25.0 g of $K_2Cr_2O_7$, 55.0 g of KBr and 60.0 g of H_2SO_4 are reacted according to the equation

$$K_2Cr_2O_7 + 6\ KBr + 7\ H_2SO_4 \longrightarrow 4\ K_2SO_4 + Cr_2(SO_4)_3 + 3\ Br_2 + 7\ H_2O\ ?$$

How many grams of each excess reactant will remain unreacted?

30. What volume of $CO_2(g)$ at STP can be made when 0.0250 L of $C_5H_{12}(l)$ (density = 626.0 g/L), is reacted with 40.0 L of $O_2(g)$at STP, according to the equation

$$C_5H_{12}(l) + 8\ O_2(g) \longrightarrow 5\ CO_2(g) + 6\ H_2O(l)\ ?$$

31. If 50.0 mL of 0.100 M HCl is allowed to react with 30.0 mL of 0.200 M NaOH according to the reaction

$$HCl + NaOH \longrightarrow NaCl + H_2O,$$

which reactant is in excess?

32. If 0.250 g of $Ba(OH)_2$ is mixed with 15.0 mL of 0.125 M HBr, what mass of $BaBr_2$ can be formed?

$$Ba(OH)_2 + 2\ HBr \longrightarrow BaBr_2 + 2\ H_2O$$

VII.5. EXTENSION : PERCENTAGE YIELD AND PERCENTAGE PURITY

Sometimes 100% of the expected amount of products cannot be obtained from a reaction. The term "Percentage Yield" is used to describe the amount of product actually obtained as a percentage of the expected amount. There are two major reasons for this reduced yield of products.

i) The reactants may not all react. This can occur either because:
   - not all of the pure material actually reacts, or
   - the reactants may be less than 100% pure.

ii) Some of the products are lost during procedures such as solvent extraction, filtration and crystallization, which are needed to physically separate and purify the products.

If you know the expected amount of a product based on a stoichiometry calculation and measure the actual mass of product formed, you can calculate the **PERCENTAGE YIELD** of the reaction as follows.

$$\text{PERCENTAGE YIELD} = \frac{\text{mass of product obtained}}{\text{mass of product expected}} \times 100\%$$

Another way in which less than the "expected" amount of a product is produced is to start with reactants which are less than 100% pure. In this case, the **PERCENTAGE PURITY** of the REACTANT is calculated as follows.

$$\text{PERCENTAGE PURITY} = \frac{\text{mass of pure reactant}}{\text{mass of impure reactant}} \times 100\%$$