Stoichiometry

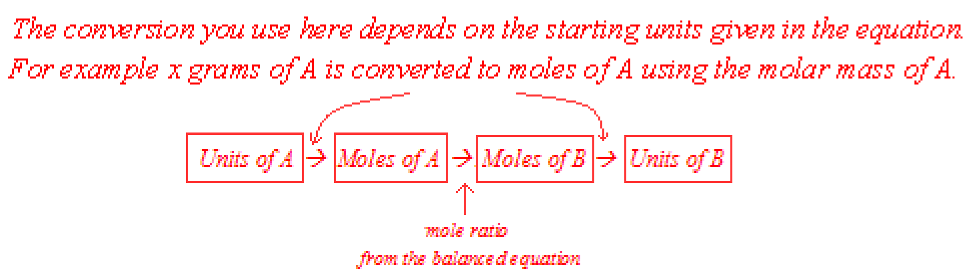
1. What is stoichiometry?

   This is when the BALANCED chemical reaction is used to determine proportions of chemicals involved in the reaction. The coefficients are viewed as mole counts.

2. What are the basic steps required for most stoichiometry calculations?

   The basic steps that you will follow for most of the stoichiometric problems are.

   1 – Make sure the reaction equation is balanced.
   2 – The "backbone" calculation
   You will be given information about substance A and need to answer a question about substance B. The "backbone" is the general method for how you proceed with these calculations.



3. Consider:

$$Al_{(s)} + NH_4ClO_{4(s)} \rightarrow Al_2O_{3\,(s)} + AlCl_{3\,(s)} + NO_{(g)} + H_2O_{(g)}$$

   What mass of ammonium perchlorate should be used for every kg of Al?

   Step 1 – Balance the equation. Often times the equation will be given to you balanced, but always double check.

$3Al_{(s)} + 3NH_4ClO_{4(s)} \rightarrow Al_2O_{3\,(s)} + AlCl_{3\,(s)} + 3\,NO_{(g)} + 6\,H_2O_{(g)}$

<u>Step 2</u> – Stoichiometry.

Perform the “backcbone” calculation….

$$\frac{1000g\ \cancel{Al}}{} \cdot \frac{1\ \cancel{mol\ Al}}{26.98\ \cancel{g\ Al}} \cdot \frac{3\ \cancel{mol\ NH_4ClO_4}}{3\ \cancel{mol\ Al}} \cdot \frac{117.50g\ \cancel{NH_4ClO_4}}{1\ \cancel{mol\ NH_4ClO_4}} \cdot \frac{1\ kg}{1000\cancel{g}}$$

$$= \boxed{4.355\ kg\ NH_4ClO_4}$$

As a matter of practice, you will report your answer in the same units you were given

4. Consider:

$$5\ CO_{2\,(g)} + 55\ NH_4^+{}_{(aq)} + 76\ O_{2\,(g)} \xrightarrow{\text{bacteria}} \underset{\text{bacterial tissue}}{C_5H_7O_{2\,(s)}} + 54\ NO_2^-{}_{(aq)} + 52\ H_2O_{(l)} + 109\ H^+_{(aq)}$$

How much bacterial tissue is produced in a treatment plant for every 1.0×10^4 kg of waste water containing 3.0% NH_4^+ by mass? Assume that 95% of the ammonium ions are consumed by bacteria.

The part of the waste water treated to produce bacterial tissue is NH_4^+. Thus only 3.0% of the mass of the water is involved in the reaction. So….

(10,000,000 total grams of waste water) (3.0%) = 300,000 g NH_4^+

Additionally, the reaction is only 95% efficient. This means that only 95% of the NH_4^+ will be consumed by the bacteria. Thus….

(300,000 g NH_4^+) (95%) = 285,000 g NH_4^+ treated.

$$285{,}000\ \text{g NH}_4^+ \times \frac{1\ \text{mol NH}_4^+}{18.05\ \text{g NH}_4^+} \times \frac{1\ \text{mol bacterial tissue}}{55\ \text{mol NH}_4^+} \times \frac{113.13\ \text{g bacterial tissue}}{1\ \text{mol bacterial tissue}} \times \frac{1\ \text{kg}}{1000\ \text{g}}$$

$$= \boxed{32\ \text{kg}}$$

5. What is a limiting reactant? How does it affect a reaction?

   Reactant/reagent used up first in a reaction. The limiting reactant puts a cap on the amount of product that can be produced.

6. What clue indicates that you are dealing with a limiting reactant stoichiometry calculation?

   If you are given information that would allow you to calculate for the moles of more than one reactant.

7. Consider:

$$\underset{\text{chlorobenzene}}{2\ C_6H_5Cl} + \underset{\text{chloral}}{C_2HOCl_3} \rightarrow \underset{\text{DDT}}{C_{14}H_9Cl_5} + H_2O$$

   1142 g of chlorobenzene is reacted with 485 g of chloral.

   a. What mass of DDT is formed?

      You actually have to do part b before a. The first step is ALWAYS to figure out what the limiting reagent is. Never decide limiting reagent based on mass – many times it will work out but not always!

      There are a few ways to go about determining the limiting reactant. One of the favored methods is to determine which reactant produces the least amount of product (it does not matter which product you choose, just as long as you pick the same product for both calculations).

For this problem, the calculations are as follows…

$$1142\ \text{g}\ C_6H_5Cl \times \frac{1\ \text{mol}\ C_6H_5Cl}{112.56\ \text{g}\ C_6H_5Cl} \times \frac{1\ \text{mol DDT}}{2\ \text{mol}\ C_6H_5Cl} = 5.073\ \text{mol DDT}$$

$$485\ \text{g}\ C_2HOCl_3 \times \frac{1\ \text{mol}\ C_2HOCl_3}{147.38\ \text{g}\ C_2HOCl_3} \times \frac{1\ \text{mol DDT}}{1\ \text{mol}\ C_2HOCl_3} = 3.291\ \text{mol DDT}$$

Based on the resulting information chloral is the limiting reagent as produces the least amount of product. Therefore the mass of DDT formed is…

$$3.291\ \text{mol DDT} \times \frac{354.48\ \text{g DDT}}{1\ \text{mol DDT}} = \boxed{1{,}167\ \text{g DDT produced}}$$

b. What is the limiting reactant?

As determined in part a **chloral is the limiting reactant**.

c. How much reactant is left?

No chloral remains as it limited the reaction.

There is, however, some chlorobenzene remaining. As previously stated there are multiple methods to solving. One of the commonly used techniques is demonstrated below.

$$3.291\ \text{mol DDT} \times \frac{2\ \text{mol}\ C_6H_5Cl}{1\ \text{mol DDT}} \times \frac{112.56\ \text{g}\ C_6H_5Cl}{1\ \text{mol}\ C_6H_5Cl} = 740.9\ \text{g of}\ C_6H_5Cl\ \text{required to produce 3.291 moles of DDT}$$

$$1142\text{g}\ C_6H_5Cl\ \text{present} - 740.9\text{g}\ C_6H_5Cl\ \text{used} = \boxed{401\ \text{g}\ C_6H_5Cl\ \text{remaining}}$$

8. What is the percent yield?

In a perfect world calculated would be the same as lab results. However, due to a variety of factors, we will never get 100% of our calculated value. The percent yield tells us what percentage of the expected value was actually obtained.

a. What is the f

$$\frac{actual\ yield}{theoretical\ yield} \times 100 = \%\ yield$$

9. Consider:

$$P_{4\,(s)} + F_{2\,(g)} \rightarrow 4PF_{3\,(g)}$$

How many grams of F_2 are needed to produce 120.0g of PF_3 if the reaction has a 78.1% yield?

This question is a bit tricky in that they gave you the desired actual yield but when you are using stoichiometry you deal with theoretical values.

$$\frac{Actual\ Yield}{\%\ yield} \times 100 = Theoretical\ Yield$$

$$\frac{120.0g}{78.1\%} \times 100 = 154g\ PF_3$$

$$154g\ PF_3 \ \frac{1\ mol\ PF_3}{87.97\ g\ PF_3} \ \frac{6\ mol\ F_2}{4\ mol\ PF_3} \ \frac{38.00g\ F_2}{1\ mol\ F_2} = \boxed{99.8g\ F_2}$$ are needed to produce 120.0g of PF_3