STOICHIOMETRY PROBLEMS

Most stoichiometry problems follow a set strategy which revolves around the mole. This strategy is:

Quantity A ⟶ Mols A ⟶ Mols B ⟶ Quantity B

You will be using this strategy or some portion of it most of the time. We'll look at each step of this strategy and then combine these steps for more complicated problems.

Converting Quantity A to Mols A

The more ways you can find the mols of a substance, the easier stoichiometry problems will become. Many times the units will help you get to your goal. Take for instance converting the mass of a substance to mols. You will need a "conversion factor" which will contain both mass and mol units. If you think about it, the molar mass just happens to have these units. Now it's just a matter of getting the units to cancel to achieve the "conversion". Let's look at an example where you are given 25.0g of $CaCO_3$ and want to find how many mols of $CaCO_3$ are present. First calculate the molar mass of $CaCO_3$:

1 Ca = 40.08g/mol x 1 = 40.08g/mol

1 C = 12.01g/mol x 1 = 12.01g/mol

3 O = 16.00g/mol x 3 = 48.00g/mol

40.08g/mol + 12.01g/mol + 48.00g/mol = 100.09g/mol $CaCO_3$

The molar mass should be calculated to at least the same number of significant figures as the quantity you need to convert. I generally like to go one significant figure beyond the number I need. Next, use the molar mass to convert the 25.0g mass of $CaCO_3$ to mols $CaCO_3$. Let the units help you decide whether to multiply or divide by the molar mass:

$$25.0\text{gCACO}_3 \times \frac{1 molCaCO_3}{100.09 gCaCO_3} = 0.250\text{molCaCO}_3$$

Notice how the gram units cancel, leaving you with mols.

Converting mols into grams

This conversion may be accomplished by a similar calculation as the conversion of grams to mols. Intuitively, you should realize that the same conversion factor will be used--the molar mass. As before, let the units help you decide whether you need to multiply or divide by the molar mass. Given 0.750 mol $CaCO_3$, the number of grams of $CaCO_3$ would be calculated as:

$$0.750\text{ mol CaCO}_3 \times \frac{100.09\text{ g CaCO}_3}{1\text{ mol CaCO}_3} = 75.1\text{ g CaCO}_3$$

STOICHIOMETRY PROBLEMS

Mol A to Mol B Conversions

Once the mols of a quantity is known, a valid stoichiometric comparison may be made. The mol quantity is a scaled up version of what is happening on the molecular level. From mols you may go to the number of grams of a substance (as you did on the previous page), go to number of molecules using Avogadro's number, or go to mols of another substance based on how these two substances relate in a balanced chemical equation. Let's first look at how you can convert from mols of one substance to mols of another substance.

Suppose you had 0.100 mol of sodium carbonate and wanted to know how many mols of sodium ions are present. The chemical formula for sodium carbonate is Na_2CO_3. This means one mole of sodium carbonate contains 2 mols of sodium, 1 mol of carbon and 3 mols of oxygen. In this case, we need to compare the mols of sodium carbonate and mols of sodium ions. Again, we will let the units help us set up the problem:

$$0.100 \text{ mol } Na_2CO_3 \times \frac{2 \text{ mol } Na^+}{1 \text{ mol } Na_2CO_3}$$

Notice how the units cancel. Also, in this case, we were able to due a stoichiometric comparison within the same compound. In other cases, a reaction may be involved and a comparison of two different compounds is necessary. Given a balanced chemical reaction, the stoichiometric coefficients relate the mols reactants and products. Let's look at a typical reaction:

$$2\ KClO_3 \longrightarrow 2\ KCl + 3\ O_2$$

In this reaction, 2 mols of potassium chlorate ($KClO_3$) will decompose into 2 mols of potassium chloride (KCl) and 3 mols of oxygen (O_2). If you were given 0.400 mol of $KClO_3$, and wanted to know how many mols of O_2 will form, use the stoichiometric coefficients to set up a mol ratio in which mols of $KClO_3$ will cancel and mols of O_2 remain:

$$0.400 \text{ mol } KClO_3 \times \frac{3 \text{ mol } O_2}{2 \text{ mol } KClO_3} = 0.600 \text{ mol } O_2$$

From mols you may also find the number of particles by using Avogadro's number. These particles may be atoms, ions, or molecules. The key word here is particles. That should tip you off that Avogadro's number will be used. Avogadro's number, 6.02×10^{23}, represents how many particles are found in 1 mol, so it may be used to convert mols of a substance to particles or the number of particles to mols. Using the above example, let's calculate how many molecules of oxygen were formed:

$$0.600 \text{ mol } O_2 \times \frac{6.02 \times 10^{23} \text{ molecules } O_2}{1 \text{ mol } O_2} = 3.61 \times 10^{23}\ O_2 \text{ molecules}$$

STOICHIOMETRY PROBLEMS

Using the entire strategy

Now that you know how to convert grams to mols, mols A to mols B, and mols to grams, you can utilize the entire strategy, Quantity A --> mols A --> mols B --> Quantity B to work a typical stoichiometry problem encountered in which the theoretical yield of a substance is calculated. The theoretical yield represents the maximum amount of a product that may be produced from a given set of reactants. Here's a typical problem:

If ammonia, NH3, is burned in air, the following reaction takes place:

$$4\ NH_3 + 3\ O_2 \longrightarrow 2\ N_2 + 6H_2O$$

Given that you started with 51.0g of NH_3, how many g of water will be produced?

The overall strategy will be to convert the grams of ammonia to mols of ammonia (Quantity A to mols A), then convert the mols of ammonia to mols of water (mols A to mols B), and then finally convert the mols of water to grams of water (mols B to Quantity B):

$$51.0\ g\ NH_3 \times \frac{1\ mol\ NH_3}{17.0\ g\ NH_3} \times \frac{6\ mol\ H_2O}{4\ mol\ NH_3} \times \frac{18.0\ g\ H_2O}{1\ mol\ H_2O} = 81.0\ g\ H_2O$$

$$\text{Quantity A} \longrightarrow \text{mol A} \longrightarrow \text{mol B} \longrightarrow \text{Quantity B}$$

The first step was to convert Quantity A to mols A -- grams of ammonia to mols of ammonia. Next the mols A was converted to mols B -- mols of ammonia was converted to mols water. Finally, mols B was converted to Quantity B -- mols water was converted to grams water. The 81.0g H_2O produced represents the theoretical yield --the maximum amount of water which can be produced.

In the above problem, we assumed that we had more than enough oxygen to completely consume the ammonia. This assumption may be made when no information is given about the amount of oxygen present during the reaction. In a limiting reagent problem, initial quantities of both reactants are given, and it is not possible to tell which reactant will be used up first. If you need help with limiting reactant problems, please see the specific handout which deals with this topic.