Chemistry Lecture #58: Stoichiometric Mass-to-Mass Conversion

Stoichiometry is the calculation of relative quantities of reactants and products in chemical reactions. Stoichiometric calculations often try to determine how much product can be made from a given amount of reactant.

To illustrate the meaning of stoichiometry, suppose we have a formula for making a cake. The formula is

3 apples + 4 eggs ⟹ 1 cake

How many cakes can be made from 6 apples?

apples ⟹ cakes

$$\frac{6 \text{ apples}}{1} \times \frac{1 \text{ cake}}{3 \text{ apples}} = 2 \text{ cakes}$$

Now instead of using a baking formula to calculate the number of cakes you can make, let's take a chemical reaction and calculate the amount of product you can make.

$4\ Al + 3\ O_2 \Longrightarrow 2\ Al_2O_3$

How many grams of Al_2O_3 can be made from 12.0 g of Al?

We'll use the following steps to solve mass-to-mass problems:

1. Identify the known and unknown compounds.
2. Find the molar mass of the known and unknown compounds.
3. Set up fractions, solve by factor-labeling

Memorize:

g known ⇨ moles known ⇨ moles unknown ⇨ g unknown

$4\ Al + 3\ O_2 \Rightarrow 2\ Al_2O_3$

How many grams of Al_2O_3 can be made from 12.0 g of Al?

12.0 g known ? g unknown

$4\ Al + 3\ O_2 \Rightarrow 2\ Al_2O_3$

1 mole Al = 27.0 g 1 mole Al_2O_3 = 102 g

g known ⇨ moles known ⇨ moles unknown ⇨ g unknown

$$\frac{12.0\text{ g Al}}{1} \times \frac{\text{mole Al}}{27.0\text{ g Al}} \times \frac{2\text{ mole } Al_2O_3}{4\text{ mole Al}} \times \frac{102\text{ g } Al_2O_3}{\text{mole } Al_2O_3} = 22.7\text{ g } Al_2O_3$$

Thus, from 12.0 g of Al, we can obtain 22.7 g of Al_2O_3.

$3\ Mg + 2\ CrCl_3 \rightarrow 2\ Cr + 3MgCl_2$

How many grams of $CrCl_3$ are needed to make 0.840 g of $MgCl_2$?

Solution

Notice that this problem does not ask for the amount of product ($MgCl_2$); this is given to us. Instead, it asks for the amount of starting material, $CrCl_3$. $MgCl_2$ is the known and $CrCl_3$ is the unknown.

$$\underset{\text{?g unknown}}{3\ Mg + 2\ CrCl_3} \rightarrow \underset{\text{0.840 g known}}{2\ Cr + 3MgCl_2}$$

$CrCl_3$ = 159 g/mole $\qquad$ $MgCl_2$ = 95.3 g/mole

g known → moles known → moles unknown → g unknown

$$\frac{0.840\ g\ MgCl_2}{1} \times \frac{mole\ MgCl_2}{95.3\ g\ MgCl_2} \times \frac{2\ mole\ CrCl_3}{3\ mole\ MgCl_2} \times \frac{159\ g\ CrCl_3}{mole\ CrCl_3}$$

$$= 0.934\ g\ CrCl_3$$

$2H_2O \rightarrow 2H_2 + O_2$

A sample of H_2O is broken into its elements and yields 4.70 g of H_2. How many grams of O_2 are also produced?

Solution

Notice that the known, H_2 and the unknown, O_2, are both products. It is also possible to have problems where both the known and unknown are reactants.

4.70 g known ? g uknown

$2H_2O \rightarrow 2H_2 + O_2$

H_2 = 2.02 g/mole O_2 = 32.0 g/mole

g known → moles known → moles unknown → g unknown

$$\frac{4.70 \text{ g } H_2}{1} \times \frac{\text{mole } H_2}{2.02 \text{ g } H_2} \times \frac{\text{mole } O_2}{2 \text{ moles } H_2} \times \frac{32.0 \text{ g } O_2}{\text{mole } O_2}$$

$$= 37.2 \text{ g } O_2$$