Reaction Stoichiometry

The term ***stoichiometry*** *refers to the quantities study of relationships between reactants and products or within the reactants or within the products in a chemical reaction.* When chemical reaction is carried out in the laboratory, we would like to know "how much product(s) is being formed starting with specified amount(s) of reactant(s)" or vice versa. Answer to this question lies in the stoichiometry. Before you indulge yourself into stoichiometry, there is one stringent requirement that must be satisfied; you must have a balanced chemical equation. If it is not balanced, you must first balance it and then carry out the stoichiometry. Also you need to remember how to convert mole into mass or mass into mole using the definition of mole, which is,

$$\text{mole} = \frac{\text{mass(g)}}{\text{molar mass(g / mol)}}$$

There are two ways of interpreting any chemical equation that are in terms of molecules or in terms of moles. For example, consider the combustion of methane gas (cooking gas). The chemical equation for this reaction is,

$$CH_4\,(g) + 2O_2\,(g) \rightarrow CO_2\,(g) + 2H_2O\,(g)$$

We can say that 1 molecule of $CH_4(g)$ combines with 2 molecules of $O_2(g)$ to produce 1 molecules of $CO_2(g)$ and 2 molecules of $H_2O(g)$ or we can also say that 1 mole of $CH_4(g)$ combines with 2 moles of $O_2(g)$ to produce 1 mole of $CO_2(g)$ and 2 moles of $H_2O(g)$:

$CH_4\,(g)$	+	$2O_2\,(g)$	→	$CO_2\,(g)$	+	$2H_2O\,(g)$
1 molecule	+	2 molecules	→	1 molecule	+	2 molecules
1 mole	+	2 mole	→	1 mole	+	2 mole

The second way of interpretation is preferable because it is the proper and modern way. Then we can relate one substance to another as follows.

$$1\text{ mol } CH_4\,(g) = 2\text{ mol } O_2\,(g) = 1\text{ mol } CO_2\,(g) = 2\text{ mol } H_2O\,(g)$$

Stoichiometry

In general, there are four kinds of problems:

- mole-mole problem – the problem is stated in terms of mole and the answer is sought in terms of mole .
- mass-mass problem – the problem is stated in terms of mass and the answer is sought in terms of mass.
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Only the first two kinds are discussed below.

Mole-mole problem

Plants make food through the process known as the photosynthesis that involve the reaction of carbon dioxide (CO_2) from the air with water (H_2O) from the ground to produce glucose ($C_6H_{12}O_6$) and oxygen gas (O_2) in presence of sunlight. This process is very complex and the simplified reaction is given below.

$$6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$$

If 7.5 moles of CO_2 react completely with enough H_2O, how many moles of glucose are produced?

Answer

The problem is stated in mole of CO_2 and the answer is sought in moles of $C_6H_{12}O_6$. This means that we need to relate only CO_2 and $C_6H_{12}O_6$. Other substances do not enter into the calculation at all. From the above equation we see that

$$6\ \text{mol}\ CO_2 = 1\ \text{mol}\ C_6H_{12}O_6$$

Then we set up the following ratio.

$$\text{mol}\,C_6H_{12}O_6 = 7.5\,\text{mol}\,CO_2 \text{x} \frac{1\,\text{mol}\,C_6H_{12}O_6}{6\,\text{mol}\,CO_2} = 1.25\,\text{mol}\,C_6H_{12}O_6$$

Mass-mass problem

Using the photosynthesis equation given above, find the number of grams of O_2 produced when 100 g of H_2O are completely reacted with unlimited amount of CO_2.

Answer

This is the mass-mass problem because grams of H_2O are given and the answer is sought in grams of O_2. To calculate the grams of O_2, first we calculate the moles of H_2O from the given mass of H_2O, then convert the moles of H_2O to moles of O_2, and then convert the moles of O_2 to mass of O_2.

$$\text{mass}\ H_2O \rightarrow \text{mol}\ H_2O \rightarrow \text{mol}\ O_2 \rightarrow \text{mass}\ O_2$$

First we convert 100g of H_2O to moles of H_2O using the molar mass of H_2O as the conversion factor.

$$\text{mol}\,H_2O = 100\,\text{g}\,H_2O\,\text{x}\,\frac{1\,\text{mol}}{18\,\text{g}\,H_2O} = 5.55\,\text{mol}\,H_2O$$

Next, we calculate the number of moles of O_2 produced using the fact that

6 mol H_2O = 6 mol O_2.

Hence,

$$\text{mol}\,O_2 = 5.55\,\text{mol}\,H_2O\,\text{x}\,\frac{6\,\text{mol}\,O_2}{6\,\text{mol}\,H_2O} = 5.55\,\text{mol}\,O_2$$

Finally, we calculate the mass of O_2 produced in grams using the molar mass O_2 as the conversion factor.

$$\text{gram}\,O_2 = 5.55\,\text{mol}\,O_2\,\text{x}\,\frac{32.0\,\text{g}}{1\,\text{mol}} = 177.70\,\text{g}\,O_2$$

The above three steps can be combined into a single step. Try it!

You do not need to know other two types of calculations!!