The Mole and Chemical Reactions: Stoichiometry

A balanced chemical equation indicates:
(i) which chemicals were used in the reaction, i.e. the reactants
(ii) which chemicals were produced in the reaction, i.e. the products
(iii) the type of the reaction which has occurred
(iv) the mole ration of the reactants to products in the reaction

A balanced chemical equation, thus, indicates the number of moles of each of the chemicals involved in the reaction, i.e. a balanced chemical equation will indicate quantitative relationships in chemical reactions.

Stoichiometry (***pronouced stoy-key-om-i-tree***) in its broadest sense includes all the quantitative relationships in chemical reactions. It has to do with how much of one substance will react with another. A chemical equation such as . . .

$$N_2 + 3\ H_{2(g)} \longrightarrow 2\ NH_{2(g)}$$

is a kind of chemical balance sheet; it states that one mole of nitrogen reacts with three moles of hydrogen to yield two moles of ammonia. The numbers 1,3 and 2 are called the stoichiometric coefficients. Such an equation is an essential starting point for many experiments and calculations; it tells us the proportions in which the substances react and in which the products are formed.

Worked Example

What mass of iodine will react completely with 10.0g of aluminum according to the following equation . . . $2Al_{(s)} + 3\ I_{2(s)} \longrightarrow 2\ Al\ I_{3(s)}$?

Solution

This problem involves several steps, each step is simple - plan a strategy. I suggest that you ask yourself the following three questions. . .

1. What do I know?
In this case the answer should be:
a) the equation for the reaction
b) the mass of the aluminum

2. What can I get from what I know
a) From the equation, I can find the mole ratio of reacting amounts.
b) From the mass of aluminum, I can calculate the amount of moles of Al provided that I look up the molar mass.

3. Can I now see how to get the final answer?
a) From the amount of Al and the mole ratio of reacting amounts, I can calculate the amount of moles of iodine.
b) From the amount of moles of iodine, I can get the mass, using the molar mass of $I_2(s)$.

Summary of Steps

1. Balanced equation
2. Grams to moles (*use molar mass)*
3. Moles to moles (*use stoichiometric coefficients from balanced equation)*
4. Moles to grams (*use molar mass)*

Solution to the above problem ...

What mass of iodine will react completely with 10.0 g of aluminum according to the following equation. . . 2 Al + 3 $I_{2(s)}$ ---------> 2 Al $I_{3(s)}$?

1. Balanced equation given. This equation tells us that 2 moles of Al react with 3 moles of I_2; so we can write the mole ratio as:

moles of Al : moles of I_2 = 2 : 3

2. Calculate the number of moles of Al in 10.0 g ...

$$\text{\# moles} = \frac{m}{Mr}$$
$$= \frac{10.0\text{g}}{27.0\text{g/mol}}$$
$$= 0.370 \text{ mol}$$

3. Calculate the number of moles of I_2 which reacts with this number of moles of Al by using the mole ratio. . .

$$\frac{\text{\# of moles of } I_2}{\text{\# of moles of Al}} = \frac{3}{2}$$

$$\text{\# of moles of } I_2 = \frac{3}{2} \times 0.370$$
$$= 0.555 \text{ mol}$$

4. Calculate the mass of I_2 from the number of moles of I_2 consumed by the reaction of 10.0 g of Al

m = # of moles x Mr
m = 0.555 mol x 254 g/mol
m = 141 g

Now try some similar problems for yourself :

1. Using the equation: $N_{2(g)} + 3\ H_{2(g)} \longrightarrow 2\ NH_{3(g)}$
a) How many moles of $NH_{3(g)}$ will be formed if (i) 5 mol of $N_{2(g)}$ react, (ii) 2 mol of $H_{2(g)}$.
b)How many grams of $H_{2(g)}$ are required to react with 4 mol of $N_{2(g)}$?
c) How many grams of $NH_{3(g)}$ will be produced by the reaction of 140 g of $N_{2(g)}$?
d) What mass of $H_{2(g)}$ will be consumed by the reaction of 140 g of $N_{2(g)}$?
e) If 55 g of $N_{2(g)}$ react, how many grams of $NH_{3(g)}$ will form?
f) If 45 g of $H_{2(g)}$ react, how many grams of $N_{2(g)}$ are required?

2. When magnesium metal burns in air, it combines with oxygen gas to form magnesium oxide.
a) Write a balanced equation for the above reaction.
b) How many moles of $O_{2(g)}$ are required to produce 10 mol of MgO?
c) How many mol of MgO is produced by the reaction of 130 g of Mg?
d) If 2.60 g of $O_{2(g)}$ react, how many moles of MgO will form?
e) What mass of $O_{2(g)}$ combines with 10.0 g of Mg in this reaction?
f) What mass of MgO will be produced by the reaction of 45.5 g of Mg?
g) If 3.60×10^{26} molecules of $O_{2(g)}$ are to react, how many moles of Mg are required?

3. Use the balanced equation to answer the following questions . . .

$$Al_2(SO_4)_3 + 3\ NH_3 + 6\ H_2O \longrightarrow 2\ Al(OH)_3 + 3\ (NH_4)_2SO_4$$

a) How many moles of H_2O are required to react with 2.50 moles of $Al_2(SO_4)_3$?
b) How many grams of $Al(OH)_3$ would be produced by the reaction of 5 moles of NH_3?
c) How many moles of $Al_2(SO_4)_3$ will be consumed when 200 g of $(NH_4)_2SO_4$ are produced?
d) How many grams of $Al(OH)_3$ will be produced if 25.0 g of H_2O react?
e) How many molecules of NH_3 are required to react with 50.0 g of $Al_2(SO_4)_3$?
f) If 4.50×10^{22} molecules of water react, how many grams of $Al(OH)_3$ will form?

4. Calculate the mass of O_2 required for the complete combustion of 1.2 kg of C_2H_5OH.