

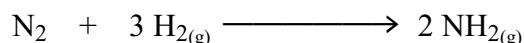
# The Mole and Chemical Reactions: Stoichiometry

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 . . .



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 . . .  $2\text{Al}_{(\text{s})} + 3 \text{I}_{2(\text{s})} \longrightarrow 2 \text{Al I}_{3(\text{s})} ?$

## 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  $\text{I}_2(\text{s})$ .

## 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. . .  $2 \text{ Al} + 3 \text{ I}_{2(s)} \text{ -----} \rightarrow 2 \text{ Al I}_{3(s)} ?$

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

$$\text{moles of Al} : \text{moles of I}_2 = 2 : 3$$

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

$$\begin{aligned} \# \text{ moles} &= \frac{m}{M_r} \\ &= \frac{10.0\text{g}}{27.0\text{g/mol}} \\ &= 0.370 \text{ mol} \end{aligned}$$

3. Calculate the number of moles of I<sub>2</sub> which reacts with this number of moles of Al by using the mole ratio. . .

$$\begin{aligned} \frac{\# \text{ of moles of I}_2}{\# \text{ of moles of Al}} &= \frac{3}{2} \\ \# \text{ of moles of I}_2 &= \frac{3}{2} \times 0.370 \\ &= 0.555 \text{ mol} \end{aligned}$$

4. Calculate the mass of I<sub>2</sub> from the number of moles of I<sub>2</sub> consumed by the reaction of 10.0 g of Al

$$\begin{aligned} m &= \# \text{ of moles} \times M_r \\ m &= 0.555 \text{ mol} \times 254 \text{ g/mol} \\ m &= 141 \text{ g} \end{aligned}$$

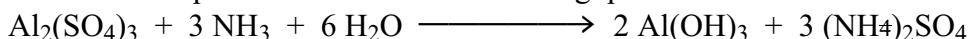
### Now try some similar problems for yourself :

1. Using the equation:  $\text{N}_{2(g)} + 3 \text{H}_{2(g)} \longrightarrow 2 \text{NH}_{3(g)}$
- How many moles of  $\text{NH}_{3(g)}$  will be formed if (i) 5 mol of  $\text{N}_{2(g)}$  react, (ii) 2 mol of  $\text{H}_{2(g)}$ .
  - How many grams of  $\text{H}_{2(g)}$  are required to react with 4 mol of  $\text{N}_{2(g)}$ ?
  - How many grams of  $\text{NH}_{3(g)}$  will be produced by the reaction of 140 g of  $\text{N}_{2(g)}$ ?
  - What mass of  $\text{H}_{2(g)}$  will be consumed by the reaction of 140 g of  $\text{N}_{2(g)}$ ?
  - If 55 g of  $\text{N}_{2(g)}$  react, how many grams of  $\text{NH}_{3(g)}$  will form?
  - If 45 g of  $\text{H}_{2(g)}$  react, how many grams of  $\text{N}_{2(g)}$  are required?

2. When magnesium metal burns in air, it combines with oxygen gas to form magnesium oxide.

- Write a balanced equation for the above reaction.
- How many moles of  $\text{O}_{2(g)}$  are required to produce 10 mol of  $\text{MgO}$ ?
- How many mol of  $\text{MgO}$  is produced by the reaction of 130 g of  $\text{Mg}$ ?
- If 2.60 g of  $\text{O}_{2(g)}$  react, how many moles of  $\text{MgO}$  will form?
- What mass of  $\text{O}_{2(g)}$  combines with 10.0 g of  $\text{Mg}$  in this reaction?
- What mass of  $\text{MgO}$  will be produced by the reaction of 45.5 g of  $\text{Mg}$ ?
- If  $3.60 \times 10^{26}$  molecules of  $\text{O}_{2(g)}$  are to react, how many moles of  $\text{Mg}$  are required?

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



- How many moles of  $\text{H}_2\text{O}$  are required to react with 2.50 moles of  $\text{Al}_2(\text{SO}_4)_3$ ?
- How many grams of  $\text{Al}(\text{OH})_3$  would be produced by the reaction of 5 moles of  $\text{NH}_3$ ?
- How many moles of  $\text{Al}_2(\text{SO}_4)_3$  will be consumed when 200 g of  $(\text{NH}_4)_2\text{SO}_4$  are produced?
- How many grams of  $\text{Al}(\text{OH})_3$  will be produced if 25.0 g of  $\text{H}_2\text{O}$  react?
- How many molecules of  $\text{NH}_3$  are required to react with 50.0 g of  $\text{Al}_2(\text{SO}_4)_3$ ?
- If  $4.50 \times 10^{22}$  molecules of water react, how many grams of  $\text{Al}(\text{OH})_3$  will form?

4. Calculate the mass of  $\text{O}_2$  required for the complete combustion of 1.2 kg of  $\text{C}_2\text{H}_5\text{OH}$ .