Stoichiometry

Stoichiometry is the process of determining how much product is made or how much reactant is needed during a chemical reaction. As we know, in chemical reactions **atoms are conserved**. We show this in a balanced chemical equation.

The balanced chemical equation tells us two things:

1. Reactants and products involved in the chemical change (rearrangement of atoms).
2. The ratio of particles involved. This ratio can be seen either as a ratio of individual particles or as a ratio of moles.

In lab, it is only practical to work with moles of substances rather than individual atoms or molecules, and so we interpret our equations as a ratio of moles, or a **mole ratio**.

Example: $2\ Mg(s) + O_2(g) \rightarrow 2\ MgO(s)$

For the reaction above, we would interpret the balanced chemical equation as:

For every 2 moles of Mg that reacts, 1 mole of O_2 is required and 2 moles of MgO are produced.

Thus, the mole ratio is: **2 moles Mg : 1 mole O_2 : 2 moles of MgO**

The mole ratio relationship can be used to make predictions about how much reactant is needed to make a specific amount of product or how much product can be made from the available amount of reactant.

Making Predictions

In every reaction, there are three stages to consider:

1. **Before:** amounts of each substance present before the reaction takes place.
2. **Change:** how much of each substance actually changes during the reaction.
3. **After:** amounts of each substance present after the reaction takes place.

These three stages will be organized into a Before-Change-After (BCA) table.

Stoichiometry: Limiting Reactant (when there are two given values)

1. A S'more is made by combining 2 graham crackers, 1 marshmallow, and 1 bar of chocolate. If you have the following ingredients available, how many S'mores can you make?
   8 graham crackers, 5 marshmallows, and 12 bars of chocolate

Equation:	2 graham crackers +	1 marshmallow +	1 chocolate →	1 S’more
Before:	8	5	12	0
Change:				
After:				

Which ingredient is used up first?____

Identify any ingredients that are left over.____

Limiting Reactant (Reagent) - ____

Excess Reactant (Reagent) - ____

2. If you have the following ingredients available, how many S'mores can you make?
   14 graham crackers, 6 marshmallows, and 8 bars of chocolate

Equation:	2 graham crackers +	1 marshmallow +	1 chocolate →	1 S’more
Before:				
Change:				
After:				

# of S’mores produced:____

Identify the limiting reactant.____

Identify the excess reactants.____

How much of each excess reactant remain?

3. Hydrogen and oxygen react to form water according to the equation below. 4.0 moles of hydrogen and 4.0 moles of oxygen are mixed together and allowed to react.

$$2\ H_2(g)\ +\ O_2(g) \rightarrow 2\ H_2O(l)$$

a) Draw a particulate representation of the particles in the reaction container.

Before → After

i. How many moles of water are produced?

ii. Which reactant is completely used?

iii. Which reactant is in excess?

iv. How many moles of excess reactant remain after the reaction?

b) Construct a Before-Change-After Table for the reaction mixture.

i. How many moles of water are produced?

ii. Which reactant is completely used?

iii. Which reactant is in excess?

iv. How many moles of excess reactant remain after the reaction?

c) Based on the two methods above (particulate drawing and BCA table), what determines how much product is made from a particular reactant mixture?

4. Nitrogen gas and hydrogen gas react to form ammonia gas according to the equation below. 3 moles of nitrogen and 6 moles of hydrogen are placed into a reaction vessel and allowed to react.

$$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$$

a) Draw a particulate representation of the particles in the reaction container.

Before → After

i. How many moles of ammonia gas are produced?

ii. What is the limiting reactant?

iii. Which reactant is in excess?

iv. How many moles of excess reactant remain?

b) Construct a Before-Change-After Table for the reaction mixture.

i. How many moles of ammonia gas are produced?

ii. What is the limiting reactant?

iii. Which reactant is in excess?

iv. How many moles of excess reactant remain after the reaction?

c) How many liters of NH_3 gas are produced at STP from this reaction mixture?

5. Methanol, CH_3OH, is formed by the reaction of hydrogen and carbon monoxide.

$$CO + 2\ H_2 \rightarrow CH_3OH$$

a) If 5.0 moles CO and 8.0 moles H_2 are present, how many moles of CH_3OH are formed?

b) What is the limiting reactant (reagent)?

c) What is the excess reactant (reagent)?

d) How many moles of the excess react remain unchanged (unreacted/left over)?

e) The same reaction is performed using different amounts of reactants. 15 grams of carbon monoxide and 5.1 grams of hydrogen are combined and allowed to react.

(i) What is the limiting reactant?

(ii) How many grams of product are formed?

(iii) How many grams of excess reactant are left over unreacted?

Stoichiometry with one given value

Sample Problem 1:

How many moles of H_2 are produced when 0.4 moles of CaH_2 react?

$$CaH_2 + 2\,H_2O \rightarrow Ca(OH)_2 + 2\,H_2$$

Before:

Change:

After:

Sample Problem 2:

$$3\,Li_2S + 2\,AlCl_3 \rightarrow 6\,LiCl + Al_2S_3$$

a) How many moles of LiCl and Al_2S_3 are made when 6.3 moles of Li_2S react?

b) How many moles of LiCl and Al_2S_3 are produced when 2.2 moles of $AlCl_3$ react?

Sample Problem 3:

$$Fe_2O_3 + 3\,C \rightarrow 2\,Fe + 3\,CO$$

a) How many moles of Fe_2O_3 and C are required to produce 9.0 moles of CO?

b) How many moles of Fe are made when 12 moles of C react?

Sample Problem 4:

How many grams of NH_3 will be produced when 4.2 moles of H_2 react?

$$N_2 + 3\,H_2 \rightarrow 2\,NH_3$$

Summary:

Limiting Reactant Practice Problems

1. $2\ Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$
    a) 6.0 mol of Na and 4.0 mol of Cl_2 are mixed. How many moles of NaCl in moles can be made from this mixture?
    b) What is the limiting reactant?
    c) What is the excess reactant?

2. $C_2H_4(g) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(g)$
    a) 2.7 mol of C_2H_4 is reacted with 6.3 mol of O_2, how many moles of water will be made?
    b) What is the limiting reactant?
    c) What is the excess reactant?

3. $2\ Cu(s) + S(s) \rightarrow Cu_2S(s)$
    a) If 80.00 grams of copper is reacted with 25.00 grams of sulfur, how many grams of product can be produced?
    b) What is the limiting reactant?
    c) What is the excess reactant?
    d) How many grams of the excess reactant are left over at the end of the reaction?

Stoichiometry Practice Problems

Practice Problem 1:

$$Ca(OH)_2 + 2\ HCl \rightarrow 2\ H_2O + CaCl_2$$

a) How many moles of $Ca(OH)_2$ are required to react with 6.4 moles of HCl?
b) How many moles of HCl are required to produce 3.5 moles of H_2O?
c) How many moles of $Ca(OH)_2$ are required to produce 12 moles of H_2O?

Practice Problem 2:

$$2\ C_2H_2 + 5\ O_2 \rightarrow 4\ CO_2 + 2\ H_2O$$

a) How many moles of O_2 are required to produce 8.2 moles of H_2O?
b) How many moles of H_2O are produced when 10.5 moles of O_2 react?
c) How many moles of C_2H_2 are required to produce 3.6 moles of H_2O?
d) How many molecules of CO_2 are produced when 7.4 moles of C_2H_2 burn completely in oxygen?

Practice Problem 3:

$$C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$$

a) If 12 moles of carbon dioxide are formed, how many moles of C_3H_8 (propane) were burned?
b) If 2.33 moles of C_3H_8 are burned, how many grams of CO_2 are made?
c) How many moles of oxygen are required to react with 3.01 moles of C_3H_8?
d) How many liters of CO_2 are produced when 4.2 moles of C_3H_8 burn in excess O_2 at STP?

Practice Problem 4:

$$2\ AgNO_3(aq) + MgBr_2(aq) \rightarrow 2\ AgBr(s) + Mg(NO_3)_2(aq)$$

a) How many moles of $MgBr_2$ are required to react completely with 3.55 moles of $AgNO_3$?
b) If 3.13 moles of $MgBr_2$ react completely with excess $AgNO_3$, how many grams of AgBr are formed?
c) To produce 1.98 moles of AgBr, how many grams of $MgBr_2$ are needed?