Chemical Equations and Stoichiometry

$MnO_2 + 4HCI \rightarrow MnCI_2 + 2H_2O + CI_2$

The quantitative information drawn from the above balanced chemical equation is

- The molar ratio in which the two reactants (MnO_2 and HCI) are reacting is 1 : 4.

- The molar ratio between two products can also be known i.e. moles of H_2O produced would be double the moles of $MnCI_2$ produced.
  Remember we can start the reaction with MnO_2 and HCI taken in any molar ratio, but the moles of two reacting will always be in the molar ratio of 1:4.
- The balanced chemical equation should follow the law of conservation of mass.

stoichiometric problems can be solved in just four

simple steps:

1. **Balance the equation.**
2. **Convert units of a given substance to moles.**
3. **Using the mole ratio, calculate the moles of substance yielded by the reaction.**
4. **Convert moles of wanted substance to desired units.**

https://www.youtube.com/watch?v=XnfATaoubzA
for calculation
https://www.youtube.com/watch?v=rESzyhPOJ7I

https://youtu.be/nZOVR8EMwRU

explains limiting reactant

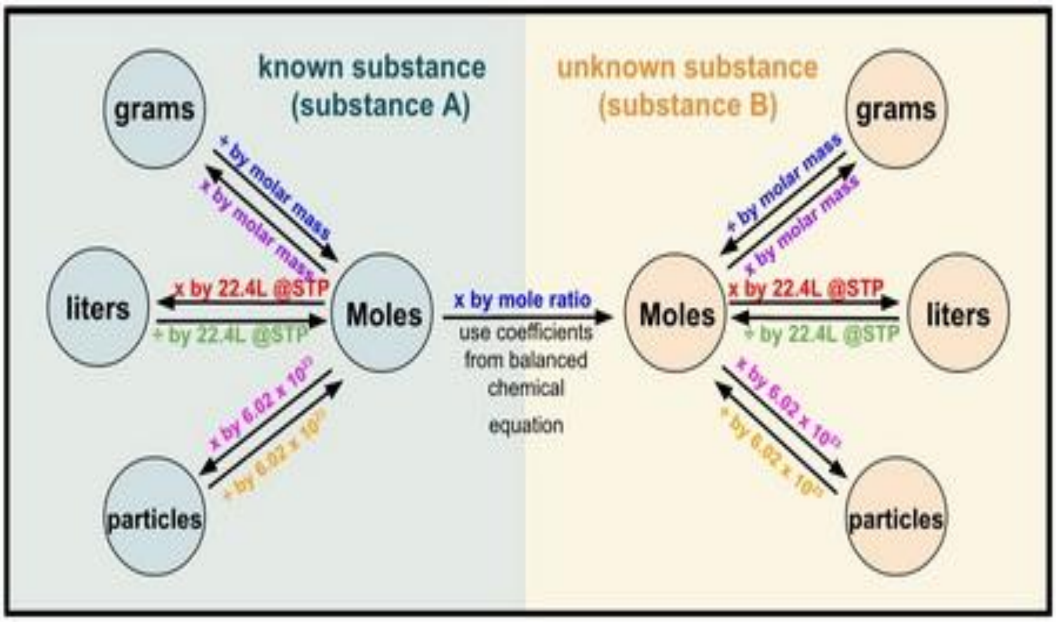
Some more links

https://www.youtube.com/

https://www.youtube.com/watch?v=Xu-rRFPR0hM

https://www.youtube.com/watch?v=S6

Graphic organizer : shows students how to solve stoichiometry problems using a graphic organizer.



this process includes writing a balanced equation, identifying the known and unknown substances, selecting the correct mole ratio, determining the path to a solution

Example 1

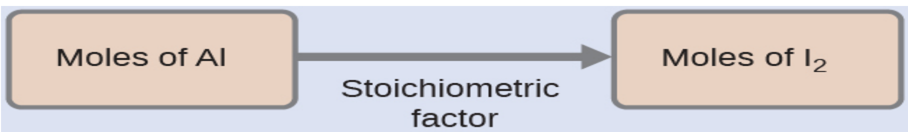
Moles of Reactant Required in a Reaction
How many moles of I_2 are required to react with 0.429 mol of Al according to the following equation

$$2Al + 3I_2 \text{-----------}\rightarrow 2AlI_3$$

Solution
Referring to the balanced chemical equation, the stoichiometric factor relating the two substances of interest is

$$\frac{3 \text{ mol } I_2}{2 \text{ mol Al}}.$$

The molar amount of iodine is derived by multiplying the provided molar amount of aluminum by this factor:



$$\text{mol } I_2 \quad 0.429 \text{ mol Al} \times \frac{3 \text{ mol } I_2}{2 \text{ mol Al}}$$

$$0.644 \text{ mol } I_2$$

Example 2

Number of Product Molecules Generated by a Reaction
How many carbon dioxide molecules are produced when 0.75 mol of propane is combusted according to this equation?

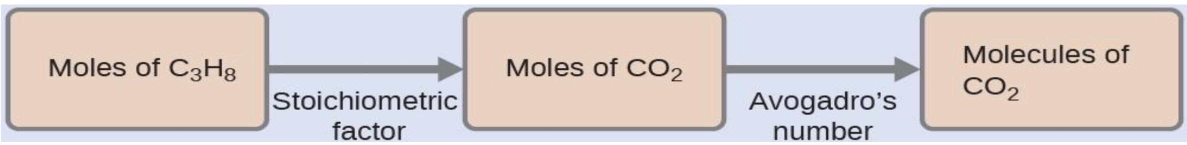
$$C_3H_8 + 5O2 \text{-----------} \rightarrow 3CO_2 + 4H_2O$$

Solution, though the absolute number of molecules is requested, not the number of moles of molecules. This will simply require use of the moles-to-numbers conversion factor, Avogadro's number.

The balanced equation shows that carbon dioxide is produced from propane in a 3:1 ratio:

$$\frac{3 \text{ mol } CO_2}{1 \text{ mol } C_3H_8}$$

Using this stoichiometric factor, the provided molar amount of propane, and Avogadro's number,



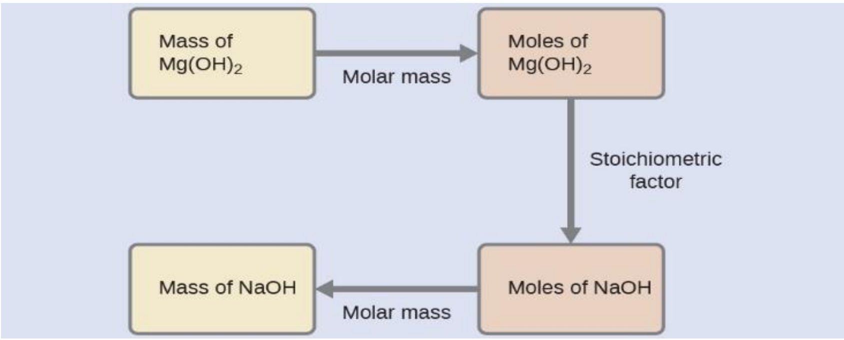
$$0.75 \text{ mol } C_3H_8 \times \frac{3 \text{ mol } CO_2}{1 \text{ mol } C_3H_8} \times \frac{6.022 \times 10^{23} \; CO_2 \text{ molecules}}{\text{mol } CO_2} = 1.4 \times 10^{24} CO_2 \text{ molecules}$$

Example 3

Relating Masses of Reactants and Products
What mass of sodium hydroxide, NaOH, would be required to produce 16 g of the antacid milk of magnesia [magnesium hydroxide, $Mg(OH)_2$] by the following reaction?

$$MgCl_2(aq)+2NaOH(aq)\text{------}\rightarrow Mg(OH)_2(s)+NaCl(aq)$$

Solution
we must derive an appropriate stoichiometric factor from the balanced chemical equation and use it to relate the amounts of the two substances of interest. In this case, however, masses (not molar amounts) are provided and requested, so additional steps of the sort learned in the previous chapter are required. The calculations required are outlined in this flowchart:



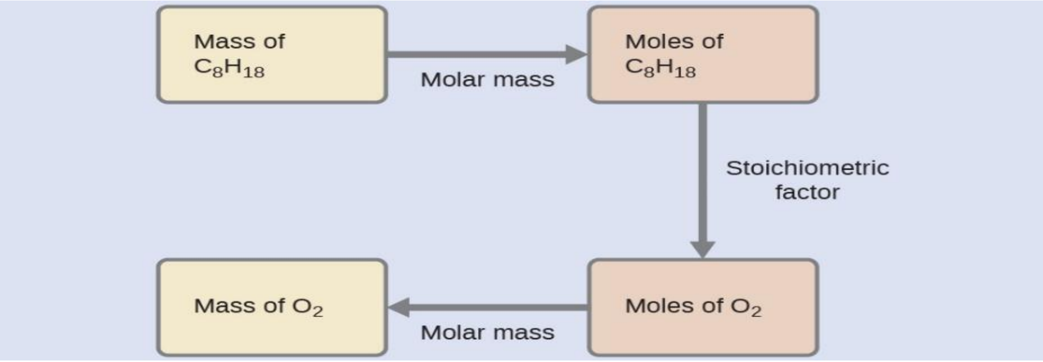
$$16\text{ g }Mg(OH)_2 \times \frac{1\text{ mol }Mg(OH)_2}{58.3\text{ g }Mg(OH)_2} \times \frac{2\text{ mol NaOH}}{1\text{ mol }Mg(OH)_2} \times \frac{40.0\text{ g NaOH}}{1\text{ mol NaOH}} = 22\text{ g NaOH}$$

Example 4

Relating Masses of Reactants
What mass of oxygen gas, O_2, from the air is consumed in the combustion of 702 g of octane, C_8H_{18}, one of the principal components of gasoline?

$$2C_8H_{18}+25O_2\text{--------}\rightarrow 16CO_2+18H_2O$$

Solution
The approach required here is the same as for the Example 3, differing only in that the provided and requested masses are both for reactant species.



$$702\ \text{g}\ C_8H_{18} \times \frac{1\ \text{mol}\ C_8H_{18}}{114.23\ \text{g}\ C_8H_{18}} \times \frac{25\ \text{mol}\ O_2}{2\ \text{mol}\ C_8H_{18}} \times \frac{32.00\ \text{g}\ O_2}{\text{mol}\ O_2} = 2.46 \times 10^3\ \text{g}\ O_2$$

Figure 3. Airbags deploy upon impact to minimize serious injuries to passengers. (credit: Jon Seidman)

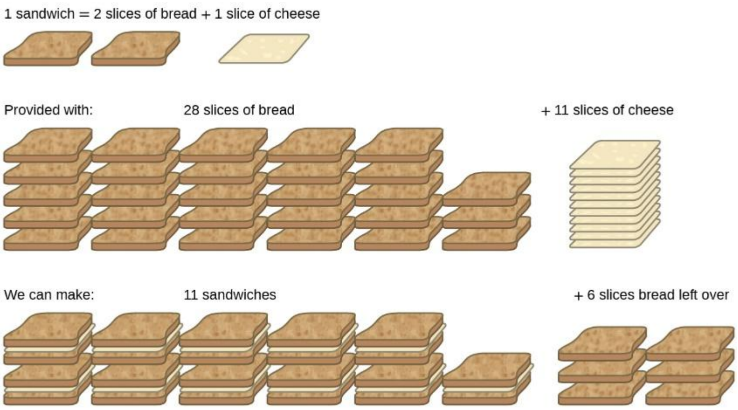
LIMITING REACTANT

Hands-On Manipulative Activity/ analogy method : students can use a hands-on manipulative (beads) to represent the stoichiometric relationships in a compound and in a balanced equation. They will determine the limiting reactant for a given amount of two reactants and they will identify the excess reactant.

Consider another food analogy, making grilled cheese sandwiches :

1slice of cheese+2slices of bread⟶1sandwich

Stoichiometric amounts of sandwich ingredients for this recipe are bread and cheese slices in a 2:1 ratio. Provided with 28 slices of bread and 11 slices of cheese, one may prepare 11 sandwiches per the provided recipe, using all the provided cheese and having six slices of bread left over. In this scenario, the number of sandwiches prepared has been *limited* by the number of cheese slices, and the bread slices have been provided in *excess*.



Identifying the Limiting Reactant

Example 1

Silicon nitride is a very hard, high-temperature-resistant ceramic used as a component of turbine blades in jet engines. It is prepared according to the following equation:

$$3Si(s)+2N_{2(}g)\longrightarrow Si_3N_4(s)$$

Which is the limiting reactant when 2.00 g of Si and 1.50 g of N_2 react?

Solution

Compute the provided molar amounts of reactants, and then compare these amounts to the balanced equation to identify the limiting reactant.

$$\text{mol Si} = 2.00\ \cancel{\text{g Si}} \times \frac{1\ \text{mol Si}}{28.09\ \cancel{\text{g Si}}} = 0.0712\ \text{mol Si}$$

$$\text{mol N}_2 = 1.50\ \cancel{\text{g N}_2} \times \frac{1\ \text{mol N}_2}{28.09\ \cancel{\text{g N}_2}} = 0.0535\ \text{mol N}_2$$

The provided Si:N_2 molar ratio is:

$$\frac{0.0712\ \text{mol Si}}{0.0535\ \text{mol N}_2} = \frac{1.33\ \text{mol Si}}{1\text{mol N}_2}$$

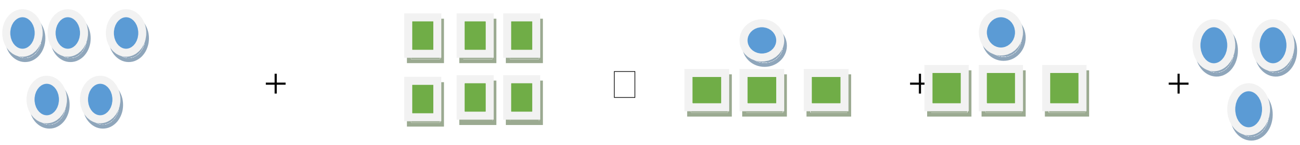
The stoichiometric Si:N_2 ratio is:

$$\frac{3\ \text{mol Si}}{2\ \text{mol N}_2} = \frac{1.5\ \text{mol Si}}{1\ \text{mol N}_2}$$

Comparing these ratios shows that Si is provided in a less-than-stoichiometric amount, and so is the limiting reactant.

Example 2

Nitrogen reacts with hydrogen to form ammonia. Represent each nitrogen atom by a circle and each hydrogen atom by a square. Starting with SIX molecules of both nitrogen and hydrogen, show pictorially what you have after the reaction is completed.



Nitrogen hydrogen ammonia excess nitrogen

Thus we can conclude that

The reactant which is completely consumed when a reaction goes to completion and which decides the yield of the product is called limiting reagent.

Practice Problems: Stoichiometry coefficient

Q1 Problem: Given the following equation at STP:

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

Determine what volume of $H_2(g)$ is needed to produce 224 L of $NH_3(g)$.

Q2 How many atoms of oxygen do I need in order to get 18 g of ice?

Given the following reaction:

$$2H_2S(g) + O_2(g) \rightarrow SO_2(g) + 2H_2O(s)$$

Q3 Problem : $2Al + 3Cl_2 \rightarrow 2AlCl_3$
When 80 grams of aluminum is reacted with excess chlorine gas, how many formula units of $AlCl_3$ are produced?

Q4 Problem : $Sb_2S_3(s) + 3Fe(s) \rightarrow 2Sb(s) + 3FeS(s)$

If 3.87×10^{23} particles of $Sb_2S_3(s)$ are reacted with excess Fe(s), what mass of FeS(s) is produced?

Q5. **Problem :** $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$

At STP, what volume of $H_2(g)$ is needed to react completely with 8.02×10^{23} molecules of $CO(g)$?

Practice Problems: Limiting Reagents

1. Take the reaction: $NH_3 + O_2 \rightarrow NO + H_2O$. In an experiment, 3.25 g of NH_3 are allowed to react with 3.50 g of O_2.

   a. Which reactant is the limiting reagent?

   b. How many grams of NO are formed?

   c. How much of the excess reactant remains after the reaction?

2. If 4.95 g of ethylene (C_2H_4) are combusted with 3.25 g of oxygen.

   a. What is the limiting reagent?

   b. How many grams of CO_2 are formed?