Chapter 3
Stoichiometry - Equations

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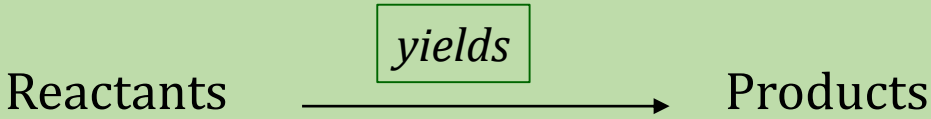
Stoichiometry

- **Stoichiometry** helps us to find out
  - How much starting material is required to produce a certain amount of product
  - The amount of product that can be produced from a certain amount of starting material.
  - How will the reaction be affected if there is more than one starting material (limiting reagent)?
  - Will there be any starting material left over?
  - How efficient is the process (% yield)?
- A **chemical reaction** is representation of chemicals in a reaction.
  - A reaction is written in chemical symbols so that it is clear how many atoms are being used.
  - A chemical reaction where reactants are written on the left and products on the right with an arrow (yield) to show progress of reaction.



Chemical Equations

Reactants ⟶ Products

Here is an example:

$$C + O_2 \longrightarrow CO_2$$

- The law of conservation of mass has to be obeyed.
- The number of atoms on the reactant side should be equal to the atoms on the right side.
- Number of C atoms is one on both sides and number of oxygen atoms is two.
- They are not in their original form (chemical change) but all atoms are accounted for.
- This equation is balanced. If atoms are not accounted for then we have to balance the chemical equation.

Balancing Chemical Equations

For example, the reaction of sodium with chlorine produced sodium chloride.

- First, we determine the correct formula for each compound.
  - Sodium is Na; Chlorine is Cl_2; Sodium chloride is NaCl.
- Second, we write the reaction: $Na + Cl_2 \rightarrow NaCl$
- Third, we check the number of each atom on each side of the equation.
- The equation shows two Cl atoms on the reactant side and only one Cl atom on the product side. To balance the Cl atoms, we insert a coefficient of "2" before NaCl on the product side.

$$Na + Cl_2 \rightarrow 2NaCl$$

- Now the Na are not balanced: there is one on the reactant side and there are two on the product side. To balance Na, we insert the coefficient "2" before Na on the reactant side.

$$2Na + Cl_2 \rightarrow 2NaCl$$

Word Equation to Symbol Equation

- It is common to write equations in word format that have to be then converted into a proper chemical equation using chemical symbols, like shown in the previous slide.
- Hints to writing equations:
  - Metals are always monoatomic, e.g. potassium (K), tin (Sn)
  - Some elements exist only as diatomic gases, e.g. chlorine (Cl_2), oxygen (O_2), hydrogen (H_2). In an chemical reaction, this has to be remembered.
  - All compounds should be written with proper mol ratios e.g. sodium chloride (NaCl), calcium chloride ($CaCl_2$), magnesium oxide (MgO). Be good in nomenclature.
  - Read from the problem what are the products and what are the reactants.

Example: Write the equation for magnesium reacting with nitrogen to give magnesium nitride.

1) Symbols for all chemicals: Mg, N_2, Mg_3N_2.

2) Write the equation: what are the reactants? Mg and N_2

Magnesium + nitrogen $\rightarrow$ magnesium nitride

$Mg + N_2 \rightarrow Mg_3N_2$

3) Now balance the equation: leave Mg for last because it is by itself.

$Mg + 2N_2 \rightarrow 2Mg_3N_2$

Finally balance Mg:

$6\ Mg + 2\ N_2 \rightarrow 2Mg_3N_2$

Balance the following equation: $CS_2 + O_2 \rightarrow CO_2 + SO_2$

Tally the number of each atom on each side:

C	1 on reactant side; 1 on product side
S	2 on reactant side; 1 on product side
O	2 on reactant side; 4 on product side

Begin by inserting the coefficient "2" before SO_2 on the product side. We leave O_2 until later because it is an element.

$$CS_2 + O_2 \rightarrow CO_2 + 2SO_2$$

Tally the atoms again:

C	1 on reactant side; 1 on product side
S	2 on reactant side; 2 on product side
O	2 on reactant side; 6 on product side

Insert a "3" before O_2:

$$CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$$

Tally the atoms again:

C	1 on reactant side; 1 on product side
S	2 on reactant side; 2 on product side
O	6 on reactant side; 6 on product side

Balance the following equation: $NH_3 + O_2 \rightarrow NO + H_2O$

1) Tally the number of each atom on each side:
N 1 on reactant side; 1 on product side
H 3 on reactant side; 2 on product side
O 2 on reactant side; 2 on product side

2) Begin by inserting the coefficient "2" before NH_3 on the reactant side and the coefficient "3" before H_2O on the product side. We leave O_2 until later because it is an element.

$$2NH_3 + O_2 \rightarrow NO + 3H_2O$$

3) Tally the atoms again:
N 2 on reactant side; 1 on product side
H 6 on reactant side; 6 on product side
O 2 on reactant side; 4 on product side

4) To balance N, insert a "2" before NO:

$$2NH_3 + O_2 \rightarrow 2NO + 3H_2O$$

5) Tally the atoms again:
N 2 on reactant side; 2 on product side
H 6 on reactant side; 6 on product side
O 2 on reactant side; 5 on product side

6) Since Since this gives us an odd number oxygens, we double the coefficients on NH_3, NO, and H_2O and to balance O, insert a "5" before O_2.

7) Tally the atoms again to double check:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

N 4 on reactant side; 4 on product side
H 12 on reactant side; 12 on product side
O 10 on reactant side; 10 on product side

The reaction is now balanced!

Types of Reactions

- **Synthesis** (combination): two substances combine to form one.

  $2\mathrm{Na}(s) + \mathrm{Cl}_2(g) \rightarrow 2\mathrm{NaCl}(s)$

- **Double Displacement**: A reaction in which two elements displaces two elements.

  $\mathrm{AgNO}_3(aq) + \mathrm{NaCl}(aq) \rightarrow \mathrm{AgCl}(s) + \mathrm{NaNO}_3(aq)$

- **Single displacement**: A reaction where one element displaces one other element.

  $\mathrm{Zn}(s) + \mathrm{CuSO}_4(aq) \rightarrow \mathrm{ZnSO}_4(aq) + \mathrm{Cu}(s)$

- **Decomposition**: A reaction in which a single compound reacts to give two or more substances.

  $2\mathrm{HgO}(s) \rightarrow 2\mathrm{Hg}(l) + \mathrm{O}_2(g)$

(g) – gas; (l) – liquid; (s) – solid; (aq) – dissolved in water

Review

- Chemical equations
  - Reactants
  - Products
  - State symbols
  - Balancing
- Writing chemical equation from word equations
- Types of reactions
  - Synthesis
  - Double displacement
  - Single displacement
  - Decomposition