Chapter 3 - Moles, Atoms, Mass Percents and Stoichiometry

Section 3 - Stoichiometry - Equations

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Introduction - Chemical Equations

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.

Reactants —*yields*→ Products

- The law of conservation of mass should be obeyed, which means the number of atoms on the reactant side should be equal to the atoms on the right side.

Here is an example:

$$C + O_2 \longrightarrow CO_2$$

- To check this, count the number of C and O atoms on each side: C is one atom both sides and number of O atoms is two.
- All atoms are accounted for no matter which state they are in.
- This equation is balanced. If atoms are not accounted for then we have to balance the chemical equation.

Types of Reactions

Before we get into balancing equations, lets see the different types of reactions in chemistry.

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

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

- **Double Displacement**: Two elements displaces two elements.

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

- **Single displacement**: One element displaces one other element.

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

- **Decomposition**: A single compound decomposes to give two or more substances.

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

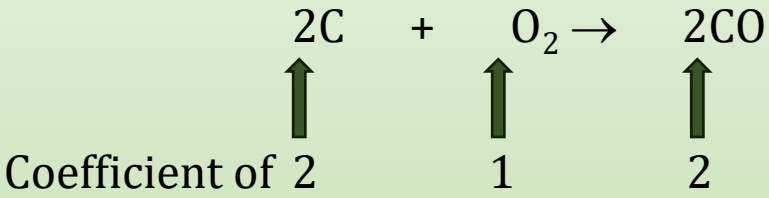
We show the different states of matter by using the symbols below.

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

Balancing Chemical Equations

The most important rule for balancing equations is that you can change only the coefficients of the chemical, not the formula.

Coefficient is the number we place in front of the chemical.



These coefficients can be translated into mols. We can read the equation as: 2 mols of carbon reacts with 1 mol of oxygen to give 2 mols of carbon monoxide.

In chemical equations you must remember to use O_2 for oxygen and not O. This goes for all the diatomic gases we have learned during nomenclature: chlorine, hydrogen etc.

Simple Balancing of Equation

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

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

**At this point it is not critical to write the states of the chemicals.*

Word Equation to Symbol Equation

In some cases, we write equations in word format that are then converted to chemical equation using chemical symbols, as shown in the previous slide.

Hints for 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).
- 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.
- The only time your equation will not balance is if any of the chemical formulas are incorrect.

Example: Writing a balanced equation

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.

$Mg + 2N_2 \rightarrow 2Mg_3N_2$

4) Finally balance Mg:

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

Example: Writing a balanced equation

Write the equation for the formation of calcium phosphate from calcium oxide and tetraphosphorous decaoxide.

1) Symbols for all chemicals: $Ca_3(PO_4)_2$, CaO and P_4O_{10}.

2) Write the equation: what are the reactants?

Calcium oxide + tetraphosphorous decaoxide → calcium phosphate

$CaO + P_4O_{10} \rightarrow Ca_3(PO_4)_2$

3) Now balance the equation:.

$CaO + P_4O_{10} \rightarrow Ca_3(PO_4)_2$

a) Balance P first because phosphate is a polyatomic ion)

P is 4 on left and 2 on the right so place 2 before $Ca_3(PO_4)_2$

$CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2$

b) Now Ca is 6 atoms on right so add 6 before CaO.

$6CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2$

c) Now see if O is balanced:

6 from CaO and 10 from P_4O_{10} = 16; and $(PO_4)_2$ is 8 and multiply by 2 = 16

$$6CaO + P_4O_{10} \rightarrow 2Ca_3(PO_4)_2$$

Solved Problem: Balancing equation

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 by itself.

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

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

Solved Problem: Balancing equation

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!

Review

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