Balancing Chemical Equations

When chemists do experiments to see how chemicals react, they may be able to work out the products of the reaction precisely, but that still leaves them to determine one thing:

In what ratio do the reactants react, and in what ratio do they come out?

The ratio between each substance is important, as we want the reaction to work 100% efficiently and not have anything left over. You can then go to the measuring cylinders and make sure you measure your substances in the correct ratio. If you don't, then there will be extra substances left over, and this may slow the reaction down and make the product messy.

When we balance equations, we work out what these ratios need to be by looking at the reaction formula and from knowing the same atoms that go in must be the same that come out.

Step One – Observe the reaction

The compounds mixed together in a reaction are called **reactants**, and the compounds that emerge from the reaction are called **products**.

$$2Li + 2H_2O \rightarrow 2LiOH + H_2$$

Reactants   Products

In this step, you watch the reaction to see what happens, noting down the reactants and the products. This can be helped through knowing some of the different types of reactions possible, which will be outlined later.

Step Two – Write the correct formulae for reactants and products

In this step, write down the formula in words and then translate it into chemical symbols.

For example, when magnesium is exposed to oxygen, it burns into magnesium oxide. We can write the unbalanced reaction like this.

$Mg_{(s)} + O_{2\ (g)} \rightarrow MgO_{(s)}$

There are some important things to note:

- We need to write, next to each chemical symbol, what state of matter the compound takes. (s) is used for solid, (g) for gas, (l) for liquid and (aq) for aqueous, suspended/dissolved in water.
- When non-metals occur as a gas they don't appear as single atoms, rather they bind together with others of their kind. Nevertheless, we still refer to them confusingly by their element names.

Hydrogen appears as H_2, not H.
Oxygen appears as O_2, not O.
Nitrogen appears as N_2.
Iodine appears as I_2.
Phosphorous appears as P_4.
Sulphur appears as S_8.

Step Three – Balance the Equation

The basic principle of this step is that:

The same number of each atom that went into a reaction must come out.

This is one of the most important laws in chemistry. This is known as the conservation of mass, where in a chemical reaction, no individual atom is ever created or destroyed. This means, left must equal right.

$Mg + O_2 \rightarrow MgO$	Here is our previous, unbalanced equation. By counting the magnesium and oxygen, you notice that there's two oxygen atoms on the left, while there's only one on the right. **If there's not enough, add one more.**
$Mg + O_2 \rightarrow 2MgO$	We've added one more magnesium oxide on the right, *because we didn't have enough oxygen atoms*. Remember, we've doubled the **whole molecule**, not just magnesium. Now, we count. We're missing a magnesium atom on the left side! **If there's not enough, add one more.**
$2Mg + O_2 \rightarrow 2MgO$	We've added a 2 in front of magnesium on the left. When we count, we see: LHS: 2 magnesium atoms, 2 oxygen atoms RHS: 2 magnesium atoms, 2 oxygen atoms
$2Mg_{(s)} + O_{2\,(g)} \rightarrow 2MgO_{(s)}$	Now, just remember to place in the states. Magnesium and its oxide are solids, while oxygen is a gas.

We've balanced the equation! Let's have another example, a harder one, and start from step one.

Question:	Magnesium metal reacts with hydrochloric acid (hydrogen and chlorine) to produce hydrogen gas and magnesium chloride.	
Step Two	$Mg + …$	We need to write up the equation in word form first. Magnesium metal is simply Mg, while hydrochloric acid is composed of hydrogen and chloride.
	$Mg + HCl \rightarrow …$	We need to look at the valence of both H and Cl, to see if they join normally. H is +1, Cl is -1. They go well together! HCl is our second reactant. We go on to our products…
	$Mg + HCl \rightarrow H_2 + …$	Hydrogen is our first product. Remember, it likes to appear as H_2, not just H.
	$Mg + HCl \rightarrow H_2 + MgCl_2$	Lastly, we have magnesium chloride. Magnesium has a valence of +2, while chlorine only has a valence of -1. This means, we need to double our chlorine! Our magnesium chloride is $MgCl_2$.
Step Three	$Mg + 2HCl \rightarrow H_2 + MgCl_2$	Time to balance! We already know there's two things unbalanced – the hydrogen and the chlorine. We can start with the hydrogen – we haven't got enough so **we add one more** of the molecule.
	$Mg + 2HCl \rightarrow H_2 + MgCl_2$	Now, the hydrogen's balanced. Chlorine became balanced too, while we were balancing hydrogen. But, we're not complete yet…
	$Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2\,(g)} + MgCl_{2\,(s)}$	Write down the states! HCl is aqueous, and is dissolved in water.

Some Common Mistakes

You only ever put numbers before the molecules or atoms, never underneath them or between them, when balancing the equation. If you need one more Hydrogen atom on the right side of the above equation, you can't write H_2Cl, because it changes the type of the molecule! You can only double molecules – 2HCl is correct!

Types of Chemical Reactions

The next step, after knowing how to balance equations, is to learn what the common types of chemical reactions that can occur are. These reactions require energy. There are seven main reactions that we need to recognise.

1. Combustion
2. Corrosion
3. Precipitation
4. Neutralisation
5. Acids on metals
6. Acids on carbonates
7. Decomposition

We've already seen neutralisation on page 9, with the production of KCl.

Oxidation

Oxidation reactions are reactions where a substance combines with oxygen gas. Some create problems, others are useful. The first is a fast reaction, called **combustion**. Oxygen does not burn, but it allows other things to burn in it. Other elements, however, burn slowly, and undergo what is called **corrosion**. Lastly, living things use oxygen in **respiration** reactions.

Combustion

The reaction of a substance with air, at high temperatures, is called combustion. Atoms of the element being burned join up with oxygen atoms, and the burned substance is called a **fuel.** Combustion can easily be summarised by this formula:

$$Fuel + Oxygen \rightarrow Carbon\ dioxide + Water$$

For example, when methane burns in oxygen, this is what happens: **$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$**. The carbon from methane joins up with an oxygen atom to produce carbon dioxide, while the hydrogen and more oxygen join to make water.

Corrosion

Corrosion is the result of metals reacting with air, water or other substances in their surroundings. The metals that react are not very reactive, so this process is generally slow. Again, this is from contact with oxygen.

$$Metal + Oxygen \rightarrow Metal\ Oxide$$

Copper, for example, can become coated with a greenish compound. **$2Cu + O_2 \rightarrow 2CuO$**. Copper oxide is released.

Respiration
Living things use oxidation to break down food substances. In cells, oxygen from the air combine with the carbon and hydrogen from our food to release energy. For example, glucose reacts with oxygen.

$$Glucose + Oxygen \rightarrow Carbon\ Dioxide + Water$$

This can be written out as $\mathbf{C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O}$.

Reactions with Acids, Bases and Salts

Precipitation
Precipitation occurs when two soluble salt solutions are mixed and a new combination of metal and non-metal is produced, where one is insoluble.

$$Soluble\ salt + Soluble\ salt \rightarrow Insoluble\ salt + Soluble\ salt$$

For example, if we mix copper sulphate with sodium hydroxide, they react together to form copper hydroxide and sodium sulphate, where copper hydroxide is insoluble.

Neutralisation
The neutralisation reaction involves making the reactants neutral.

$$Acid + Base \rightarrow Salt + Water$$

Acid on Metals and Carbonates

Acid on Metal/Metal Oxide
Many metals react with acids, which also *neutralises* them. These metals join with the non-metal part of the acid. The hydrogen is let off as a gas.

$$Metal + Acid \rightarrow Salt + Hydrogen$$

For example, if you place zinc into sulphuric acid, it will bubble and release hydrogen gas.

If the metal is in the oxide form, then the oxygen joins in with the hydrogen to form water.

$$Metal\ Oxide + Acid \rightarrow Salt + Water$$

Acid on Carbonate
Carbonates are molecules containing CO_3. For example, calcium carbonate is $CaCO_3$. A carbonate fizzes (effervesces; releases a gas) when it reacts with an acid. The gas produced is CO_2.

$$Carbonate + Acid \rightarrow Salt + Water + Carbon\ Dioxide$$

Decomposition
This occurs when a compound is broken down into its separate elements. We can do this through heat or electricity.

$$Molecule \rightarrow Molecule\ part + Molecule\ part$$

Water can be broken down by passing electricity through it: $H_2O \rightarrow H_2 + O$