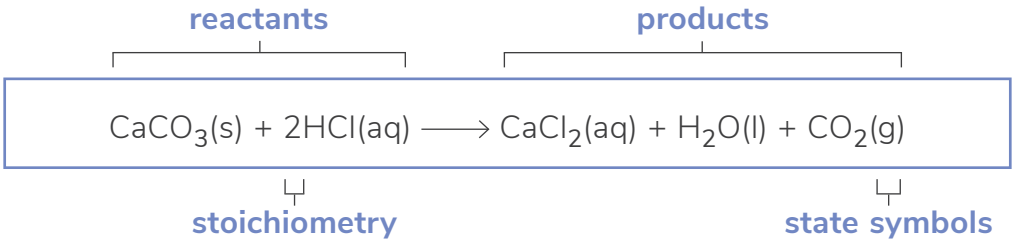
Writing Balanced Equations

Balanced chemical equations provide a lot of useful information about chemical reactions.

The reaction between solid calcium carbonate, $CaCO_3$, and a solution of hydrochloric acid, HCl, produces a solution of calcium chloride, $CaCl_2$, water, H_2O, and carbon dioxide gas, CO_2. This reaction can be represented by the following equation:



This is known as a **full equation** because it shows the full chemical formula of all of the **reactants** (on the left–hand side) and all of the **products** (on the right–hand side).

The arrow in the equation represents the transformation that occurs during the chemical reaction.

The numbers in front of the formulae of the reactants and products in a balanced equation represent the **stoichiometry** of the reaction. This is the ratio in which reactants react with each other and products are produced. In the example above, one mole of calcium carbonate would react completely with two moles of hydrochloric acid to produce one mole of calcium chloride, one mole of water and one mole of carbon dioxide.

Finally, **state symbols** indicate the physical state of reactants and products during the chemical reaction: (s) represents a solid, (l) represents a liquid, (g) represents a gas and (aq) represents an aqueous solution (a compound dissolved in water).

Balancing Equations

Atoms are not lost or gained in chemical reactions; they are simply rearranged to form different substances. Therefore, the total number of each type of atom represented on the left–hand side of an equation must equal the total number of each type of atom represented on the right–hand side of an equation. In the full equation above, the number of atoms of each element is the same on both sides of the equation, so the equation is balanced.

Element	Number of Atoms of Element in Reactants	Number of Atoms of Element in Products
calcium, Ca	1	1
carbon, C	1	1
oxygen, O	3	3
hydrogen, H	2	2
chlorine, Cl	2	2

If the equation is not balanced, you must change the stoichiometric ratios in the equation until it is balanced.

Example

Write a balanced full equation for the reaction between sodium metal and oxygen to produce sodium oxide.

Step 1

First, use the periodic table and your knowledge of chemical formulae, structure and bonding to deduce the chemical formulae of the reactants and products. You can assume that all substances are in their standard states unless otherwise stated.

Formulae of Reactants

sodium Na(s)

oxygen $O_2(g)$

Formula of Product

sodium oxide $Na_2O(s)$

(Sodium oxide is an ionic compound containing Na^+ and O^{2-} ions.)

$Na(s) + O_2(g) \longrightarrow Na_2O(s)$

Step 2

Check the number of each type of atom on each side of the equation.

Element	Number of Atoms of Element in Reactants	Number of Atoms of Element in Products
sodium, Na	1	2
oxygen, O	2	1

The equation is **not** balanced.

Step 3

To balance this equation there must be two oxygen atoms present on the right–hand side. So, there must be two molecules of Na_2O. This also changes the number of sodium atoms that are present on this side of the equation.

$Na(s) + O_2(g) \longrightarrow$ **2**$Na_2O(s)$

Element	Number of Atoms of Element in Reactants	Number of Atoms of Element in Products
sodium, Na	1	**4**
oxygen, O	2	**2**

Four atoms of sodium are now needed on the left–hand side of the equation.

4$Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$

Element	Number of Atoms of Element in Reactants	Number of Atoms of Element in Products
sodium, Na	**4**	4
oxygen, O	2	2

The equation is now balanced: **$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$**

Ionic Equations

In some reactions, there are ions present that do not take part in the overall reaction. These are known as **spectator ions** (ions that have the same formula, charge and physical state on both sides of the equation).

An **ionic equation** can be used to show only the ions that take part in the reaction.

The steps to writing an ionic equation are outlined below.

Step 1

Start with the full balanced equation for the reaction.

$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$

Step 2

Identify any ions that are present in each reactant and product.

Reactant/Product	Ions Present
$CaCO_3(s)$	$Ca^{2+}(s)$ and $CO_3^{2-}(s)$
$HCl(aq)$	$H^+(aq)$ and $Cl^-(aq)$
$CaCl_2(aq)$	$Ca^{2+}(aq)$ and $Cl^-(aq)$
$H_2O(l)$	none (covalent compound)
$CO_2(g)$	none (covalent compound)

Step 3

Write the equation out showing all ions that are present.

$Ca^{2+}(s) + CO_3^{2-}(s) + 2H^+(aq) + 2Cl^-(aq) \longrightarrow Ca^{2+}(aq) + 2Cl^-(aq) + H_2O(l) + CO_2(g)$

Step 4

Identify the spectator ions.

These are ions that have not taken part in the overall reaction and remain unchanged. The spectator ions can be cancelled out of the equation.

$Ca^{2+}(s) + CO_3^{2-}(s) + 2H^+(aq) + \mathbf{2Cl^-(aq)} \longrightarrow Ca^{2+}(aq) + \mathbf{2Cl^-(aq)} + H_2O(l) + CO_2(g)$

Step 5

Rewrite the equation without the spectator ions.

At this stage you can write the full chemical formula for compounds where all ions are still present in the equation.

$CaCO_3(s) + 2H^+(aq) \longrightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$

Example

Write a balanced ionic equation for the reaction between potassium iodide solution and silver nitrate solution to form a precipitate of silver iodide and soluble potassium nitrate.

Step 1

Formulae of Reactants

potassium iodide $KI(aq)$

silver nitrate $AgNO_3(aq)$

Formulae of Products

silver iodide $AgI(s)$

potassium nitrate $KNO_3(aq)$

Balanced full equation:

$KI(aq) + AgNO_3(aq) \longrightarrow AgI(s) + KNO_3(aq)$

Step 2

Ions present:

Reactant/Product	Ions Present
$KI(aq)$	$K^+(aq)$ and $I^-(aq)$
$AgNO_3(aq)$	$Ag^+(aq)$ and $NO_3^-(aq)$
$AgI(s)$	$Ag^+(s)$ and $I^-(s)$
$KNO_3(aq)$	$K^+(aq)$ and $NO_3^-(aq)$

Step 3

Equation with ions:

$K^+(aq) + I^-(aq) + Ag^+(aq) + NO_3^-(aq) \longrightarrow Ag^+(s) + I^-(s) + K^+(aq) + NO_3^-(aq)$

Step 4

Identify the spectator ions and cancel them out.

~~$K^+(aq)$~~ $+ I^-(aq) + Ag^+(aq) +$ ~~$NO_3^-(aq)$~~ $\longrightarrow Ag^+(s) + I^-(s) +$ ~~$K^+(aq)$~~ $+$ ~~$NO_3^-(aq)$~~

Step 5

Balanced ionic equation:

$I^-(aq) + Ag^+(aq) \longrightarrow AgI(s)$