

Writing formulae and balancing equations

Chemistry grades 9-10 (GCSE · IGCSE · O Level · Class 9-10) · Lesson

Quick answer: A formula shows the ratio of atoms or ions in a substance, and for ionic compounds the charges must cancel. A balanced equation has the same number of atoms of each element on both sides, achieved only by changing coefficients. An ionic equation shows just the ions that react, leaving out spectator ions.

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How do you write a formula from ions?

An ionic compound is neutral overall, so the positive and negative charges must cancel. Find the smallest numbers of each ion that make the total charge zero.

Definition

A **chemical formula** shows which elements are in a substance and in what ratio. In an ionic formula the total positive charge equals the total negative charge.

Charge	Positive ions	Negative ions
1	H ⁺ , Na ⁺ , K ⁺ , Ag ⁺ , NH ₄ ⁺	Cl ⁻ , Br ⁻ , OH ⁻ , NO ₃ ⁻
2	Mg ²⁺ , Ca ²⁺ , Zn ²⁺ , Cu ²⁺ , Fe ²⁺	O ²⁻ , S ²⁻ , SO ₄ ²⁻ , CO ₃ ²⁻
3	Al ³⁺ , Fe ³⁺	PO ₄ ³⁻

Transition metals such as iron and copper can form more than one ion, so the Roman numeral in a name, as in copper(II), tells you the charge.



The charge numbers swap and become subscripts: $2 \times (3+) = 6+$ and $3 \times (2-) = 6-$

The criss-cross method: swap the charge numbers and use them as subscripts, then cancel any common factor.

Put brackets around a compound ion when you need more than one of it: write Ca(NO₃)₂, never

CaNO_{32} . Use no brackets for a single compound ion, as in CaCO_3 .

Worked example

Write the formula of iron(III) sulfate.

Iron(III) is Fe^{3+} and sulfate is SO_4^{2-} . The lowest common multiple of 3 and 2 is 6, so 2 Fe^{3+} give 6+ and 3 SO_4^{2-} give 6–.

Answer: $\text{Fe}_2(\text{SO}_4)_3$.

What do state symbols mean?

State symbols follow a formula in brackets and show the physical state at the conditions of the reaction.

Symbol	Meaning	Example
(s)	solid	Mg(s)
(l)	liquid	$\text{H}_2\text{O(l)}$
(g)	gas	$\text{CO}_2\text{(g)}$
(aq)	dissolved in water	NaCl(aq)

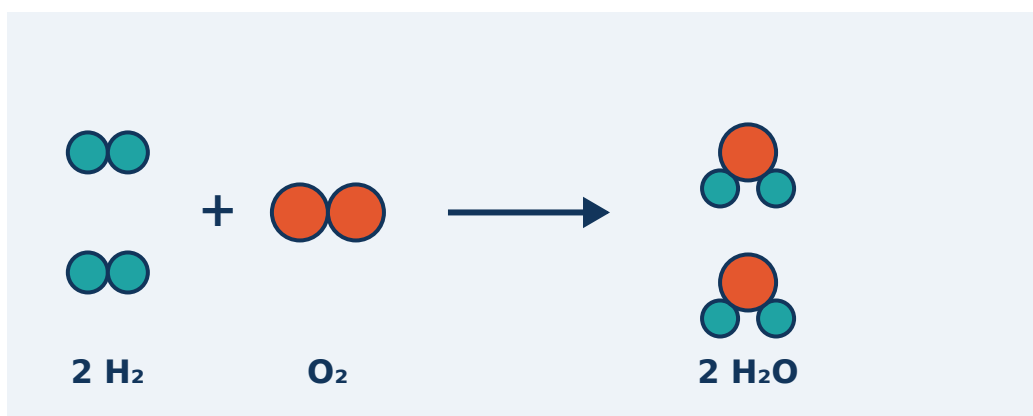
State symbols matter: a precipitate is written (s) even though it forms in a solution, and water formed in a reaction is usually written (l). Without them an equation does not tell the whole story.

How do you balance a chemical equation?

Atoms are never created or destroyed, so every element must have the same number of atoms on each side. Follow these steps:

1. Write the correct formula for every reactant and product.
2. Count the atoms of each element on both sides.
3. Put whole-number coefficients in front of formulae until the counts match.
4. Check the counts again, then add state symbols.

Treat a compound ion such as SO_4^{2-} as one unit if it appears unchanged on both sides. This makes counting quicker and reduces errors in long equations.



$2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$: four hydrogen atoms and two oxygen atoms on each side.

Common mistake

Never change a subscript to balance an equation. Changing H_2O to H_2O_2 makes a different substance, hydrogen peroxide. Only the coefficient in front of a formula may change.

Worked example

Balance $\text{Al} + \text{O}_2 \rightarrow \text{Al}_2\text{O}_3$.

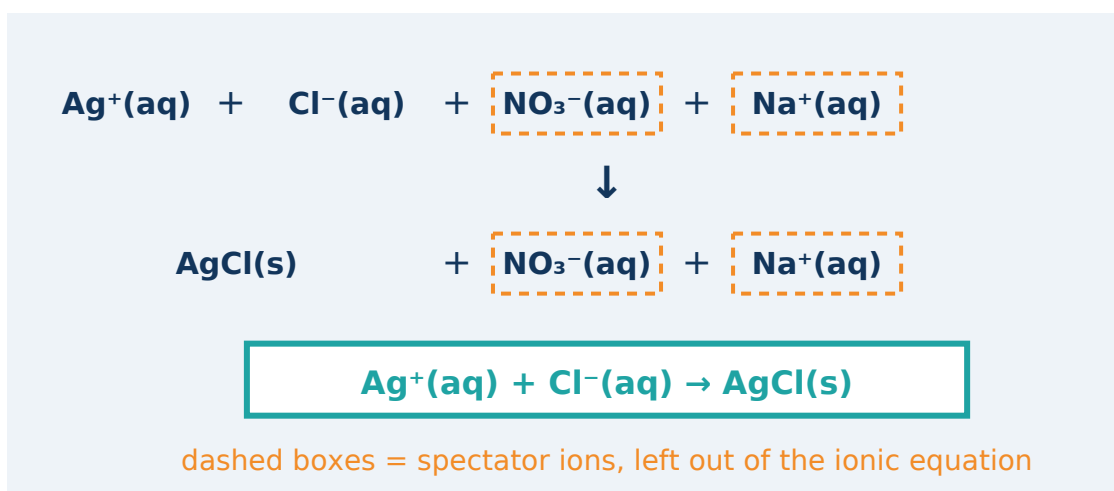
Oxygen is 2 on the left and 3 on the right, so use 6 as the common number: 3O_2 and $2\text{Al}_2\text{O}_3$. That gives 4 aluminium atoms on the right, so write 4Al .

Check: Al $4 = 4$ and O $6 = 6$.

Answer: $4\text{Al}(\text{s}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{Al}_2\text{O}_3(\text{s})$.

What is an ionic equation?

Many reactions in solution involve only some of the ions. An ionic equation shows only the ions that change. Ions that appear unchanged on both sides are *spectator ions* and are left out. The charge must balance as well as the atoms.



In this precipitation, silver and chloride ions join to form a solid.

Worked example

Write the ionic equation for $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$.

Write every dissolved compound as ions. The Na^+ and NO_3^- ions are the same on both

sides, so they are spectators.

Answer: $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$. The charge is zero on each side.

Lina's tip

Balance elements that appear in only one substance on each side first. Leave an element that stands alone, such as O_2 or H_2 , until last, because changing it does not disturb anything else.

Key points to remember

- Ionic formula: total positive charge = total negative charge (Al^{3+} and O^{2-} give Al_2O_3).
- State symbols: (s) solid, (l) liquid, (g) gas, (aq) dissolved in water.
- Balance an equation by changing coefficients only, never subscripts.
- Spectator ions appear unchanged on both sides and are omitted from the ionic equation.
- Atoms and charge must both balance in a correct ionic equation.

Writing formulae and balancing equations: frequently asked questions

How do you find the formula of an ionic compound?

Write each ion with its charge, then use the smallest numbers of each ion so that the positive and negative charges add up to zero. Use brackets around compound ions when more than one is needed.

Why can you not change subscripts when balancing?

A subscript is part of the identity of the substance. Changing H_2O to H_2O_2 gives hydrogen peroxide, a different compound, so only coefficients may be changed.

What does (aq) mean in an equation?

The symbol (aq) means aqueous, which shows that the substance is dissolved in water. A solid in a solution is written (s), as for a precipitate.

What are spectator ions?

Spectator ions are ions present in a reaction mixture that do not change. They appear on both sides of the full ionic equation, so they are cancelled to give the net ionic equation.

How do you check that an equation is balanced?

Count the atoms of every element on each side. If a polyatomic ion stays intact, you can count it as a unit. For ionic equations also check that the total charge is equal on both sides.