Atoms, elements and compounds

4.1.1.1 · Atomic structure and the periodic table · revision notes

The basic language of chemistry: atoms, elements and compounds, chemical symbols and formulae, and how to write word equations and balanced symbol equations. It is tested all through both papers, often as tick-box, 'name the compound' and 'balance the equation' questions. Higher tier students must also write half equations and ionic equations.

Key facts

- Atom: the smallest part of an element that can exist
- Element: contains only one sort of atom
- Compound: two or more elements chemically combined in fixed proportions
- A compound can only be separated into its elements by chemical reactions
- -ide: usually just the two elements named, e.g. NaCl sodium chloride (hydroxide, OH^-, is an exception)
- -ate: oxygen is also present, e.g. $CaCO_3$ calcium carbonate
- Balanced equation: same number of each type of atom on both sides
- Elements made of two-atom molecules: H_2, N_2, O_2, F_2, Cl_2, Br_2, I_2
- Grade 8+ only Half equation: $Mg \rightarrow Mg^{2+} + 2e^-$

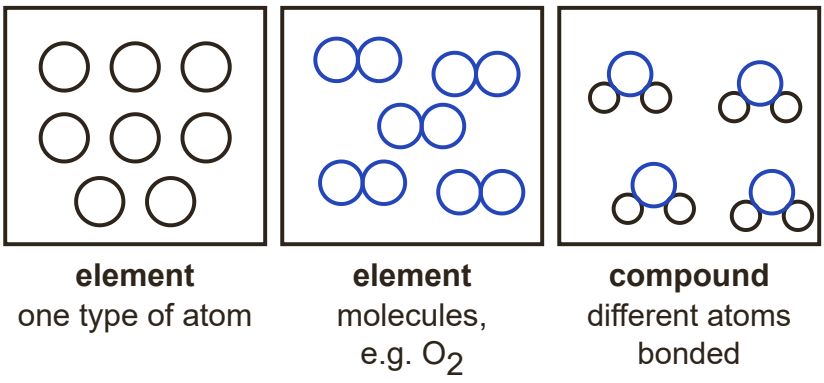
Notes

Atoms and elements

- All substances are made of **atoms**. An atom is the smallest part of an element that can exist.
- An **element** contains only one sort of atom. There are about 100 different elements, all listed in the periodic table.
- Each element has a **chemical symbol**: one capital letter, sometimes followed by one lower-case letter, e.g. C (carbon), Cl (chlorine), Cu (copper).
- Some elements exist as molecules of two atoms, e.g. H_2, N_2, O_2 and Cl_2. They are still elements, because all the atoms are the same.

Compounds

- A **compound** contains two or more elements **chemically combined in fixed proportions**. Water is always H_2O: two hydrogen atoms for every oxygen atom.

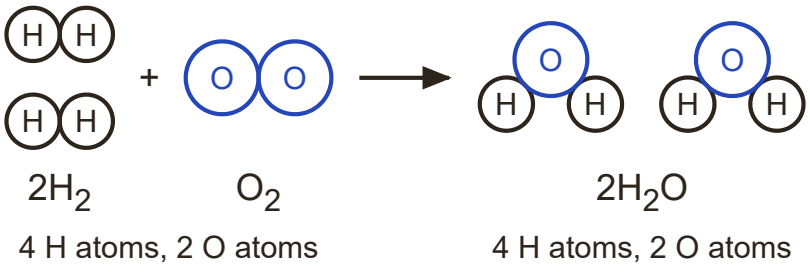


Each circle is an atom. A compound has two or more different atoms chemically combined.

- Compounds are made from elements by **chemical reactions**. A reaction always makes at least one new substance and often has an energy change you can detect, e.g. the mixture gets hot.
- A compound can only be separated into its elements by another chemical reaction, not by physical processes such as filtering or distilling.
- Naming: a metal with one non-metal ends in **-ide** (MgO, magnesium oxide). An ending of **-ate** means oxygen is also present ($CuSO_4$, copper sulfate; KNO_3, potassium nitrate).

Formulae and equations

- A formula shows which elements are in a substance and the ratio of their atoms. In $2H_2O$ the large 2 means two molecules; the small 2 means two H atoms in each molecule.
- Everything inside brackets is multiplied by the number after them: $Ca(OH)_2$ contains 1 Ca, 2 O and 2 H.
- A **word equation** names the reactants and products: magnesium + oxygen → magnesium oxide.
- A **balanced symbol equation** has the same number of atoms of each element on both sides, because atoms are not made or destroyed in a reaction: $2Mg + O_2 \rightarrow 2MgO$.



Balanced: $2H_2 + O_2 \rightarrow 2H_2O$. The atoms are rearranged, not made or destroyed.

- To balance, change only the large numbers in front of formulae. Never change a small number in a formula: that would make it a different substance.

Half equations and ionic equations Grade 7+ only

- An **ionic equation** shows only the particles that change. Ions that are the same on both sides (**spectator ions**) are left out, e.g. for any acid and alkali: $H^+ + OH^- \rightarrow H_2O$.
- A **half equation** shows electrons being lost or gained by one substance: $Na \rightarrow Na^+ + e^-$, or $Cl_2 + 2e^- \rightarrow 2Cl^-$. Grade 8+ only
- In ionic and half equations the total charge must be the same on both sides, as well as the numbers of atoms.

How to answer each type of question

Identify elements and compounds, and explain why

1 to 2 marks | Grade 3

1. Element: only one type of atom (single atoms, or molecules such as O_2).
2. Compound: two or more different types of atom bonded together.
3. To explain 'why it is a compound', give both ideas: different elements, and chemically combined.

Example. The formulae of four substances are: N_2, NaF, Fe, SO_2
(a) Give the formulae of the **two** elements.
(b) SO_2 is a compound. Explain why.

Model answer.

(a) N_2 and Fe (1)
(both needed)
(b) It contains two different elements, sulfur and oxygen (1), which are chemically combined / bonded together (1).

Name a compound or write a word equation

1 mark | Grade 4

1. Name the metal first, unchanged.
2. Change the non-metal ending to -ide, or use the -ate name for a group containing oxygen (sulfate, carbonate, nitrate).
3. In a word equation, use an arrow (→), never an equals sign.

Example. (a) Potassium reacts with bromine to form potassium bromide. Write a word equation for the reaction.
(b) Name the compound with the formula $MgSO_4$.

Model answer.

(a) potassium + bromine → potassium bromide (1)
(b) magnesium sulfate (1)

Balance a symbol equation

1 mark | Grade 5

1. Count the atoms of each element on each side.
2. Balance one element at a time, starting with one that appears in only one substance on each side.
3. Leave elements that are on their own (e.g. O_2) until last.
4. Recount every element at the end.

Example. Balance the equation for the reaction of aluminium with oxygen.
....Al + ...O_2 → ....Al_2O_3

Model answer.

$4Al + 3O_2 \rightarrow 2Al_2O_3$ (1)

Check: Al 4 on each side; O 6 on each side.

Write an ionic equation or half equation

1 to 3 marks | Grade 8

1. Split soluble ionic compounds into their ions.
2. Cross out the ions that appear unchanged on both sides (spectator ions).
3. For a half equation, add electrons (e^-) to the side that makes the charges balance.
4. Check both atoms and charges balance.

Example. Chlorine reacts with potassium iodide solution:
$Cl_2 + 2KI \rightarrow 2KCl + I_2$
(a) Write the ionic equation for this reaction.
(b) Complete the half equation for the iodide ions: $2I^- \rightarrow I_2$ + ...

Model answer.

(a) $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$: correct particles (1), balanced (1). The K^+ ions are spectator ions, so they are left out.

(b) $2e^-$ (1)

Don't lose marks

- Changing the small numbers in a formula (e.g. writing H_2O_2 for water) to balance an equation. This changes the substance.
- Naming NaCl 'sodium chlorine'. The compound is sodium chlori**de**.
- Saying a compound contains elements that are 'mixed'. They are chemically combined (bonded).
- Wrong capital letters: CO (carbon monoxide) and Co (cobalt) are different substances.
- Using = instead of → in an equation.

More tips

Memory tricks

- Symbols: one capital letter, then at most one lower-case letter. Co is cobalt; CO is carbon monoxide.
- Two-atom elements: 'HON plus the halogens': H_2, O_2, N_2 and all of Group 7 (F_2, Cl_2, Br_2, I_2).
- When balancing, write a tally of each element under both sides and update it every time you change a number.
- Charge check for half equations: add up the charges on each side; they must match.

Exam technique

- To explain why a substance is a compound, use both key phrases: 'two or more different elements' and 'chemically combined'.
- Copy formulae from the question exactly as they are printed; don't change them to make balancing easier.
- Balancing questions are usually 1 mark for the whole equation, so check every element before you move on.
- Higher tier: in an ionic or half equation, check that the total charge is the same on both sides.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Tell elements from compounds using formulae**
An element's formula has one symbol (Fe, O_2); a compound's formula has two or more different symbols (CO_2, NaCl).

Grade 3 — **Recall symbols of the first 20 elements**
Also the Group 1 and Group 7 elements and others in the course, with the correct capital and lower-case letters.

Grade 4 — **Name compounds from their formulae**
A metal with a non-metal ends in -ide (NaCl, sodium chloride); -ate means oxygen is also present ($CaCO_3$, calcium carbonate).

Grade 4 — **Count the atoms in a formula**
In $Ca(OH)_2$ the 2 multiplies everything in the brackets: 1 Ca, 2 O and 2 H, so 5 atoms.

Grade 4 — **Balance symbol equations**
Change only the large numbers in front of formulae until every element has the same number of atoms on each side.

Grade 5 — **Write word equations for reactions**
Reactants on the left, products on the right, joined by an arrow, e.g. magnesium + oxygen → magnesium oxide.

Grade 7 — **Write ionic equations (Higher tier)**
Show only the particles that change and leave out spectator ions, e.g. $H^+ + OH^- \rightarrow H_2O$.

Grade 8 — **Write half equations (Higher tier)**
Show the electrons lost or gained by one substance, with atoms and charges balanced, e.g. $Cl_2 + 2e^- \rightarrow 2Cl^-$.

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