

Balanced chemical equations

This resource is part of the **Structure strips** series of resources, designed to support literacy in science teaching. More resources in this series can be found at: rsc.li/4aXYgzt.

Learning objectives

- 1 Explain why chemical equations need to be balanced.
- 2 Construct and interpret balanced symbol equations.
- 3 Show how the symbolic representation of a reaction links to observations made in the laboratory.
- 4 Integrate equations into written discussions and explanations.

Introduction

When we write about chemistry, we often use a type of 'shorthand' in the form of formulas and equations. While word equations can be used, symbol equations can give us more useful information about the reaction, particularly when the name of a substance doesn't make it obvious which elements it is made of (for example, methane is CH_4).

It is essential to balance symbol equations to ensure that they obey the law of conservation of mass. When we have an accurately constructed equation, it can help us make predictions about what we should observe and how much of each reactant we need for reactions to be efficient. Constructing and interpreting balanced chemical equations is a key skill which underpins all learning in chemistry.

Balanced symbol equations are a key example of the symbolic representation in Johnstone's triangle. Our Johnstone's triangle worksheets give learners the opportunity to reflect on how the symbolic representation relates to their observations of a chemical reaction (the macroscopic level): rsc.li/4dZ6pZ2. You can read more about how to use Johnstone's triangle in your teaching: rsc.li/3QbauIE.

Expert chemists move seamlessly between these two interpretations (symbolic and macroscopic). However, learners need to be taught how to include and refer to the symbolic representation when explaining observations and to use the symbolic representation as a tool to make predictions.

The first three sections of this structure strip check learners' understanding of the basic construction of symbol equations (learning objectives 1 and 2). The remainder of the exercise guides them to write about the links between equations and what they observe.

How to use structure strips

Structure strips are a type of scaffolding you can use to support learners to retrieve information independently. Use them to take an overview at the start of a topic, to activate prior knowledge, or to summarise learning at the end of a teaching topic. Visit rsc.li/4f33jAP for more ideas on how to use structure strips with your learners.

Structure strips have sections containing prompts, sized to suggest the amount that learners must write. Learners glue the strips into the margin of an exercise book and write their answers next to the sections, in full sentences or bullet points. When they have finished using the structure strip, they will have an A4 page set of notes and examples.

Scaffolding

Encourage learners to use the suggested key words in their answers. These key words link with our key terms support resources for quantitative chemistry: rsc.li/3Gi9HHN.

To further support learners, you can include additional prompts in the structure strip. If learners are struggling to engage with the task, supply them with sentence starters created from the example answers.

If learners find it tricky to decide which state symbol should go with each substance in prompt four, show them our 'Reactivity series of metals' practical video (rsc.li/4tswJPA): 00:36 – 06:49 alkali metals and water experiment (03:08 – 04:57 for sodium and water reaction only). If you don't want learners to see the word and symbol equations for the sodium and water reaction, stop the video at 04:45.

As learners grow in confidence, ask them to attempt the extended answer question first and then use the structure strip to improve or self-assess their answer.

Metacognition

This resource supports learners to develop their metacognitive skills in three key areas.

- **Planning:** the strips provide scaffolding to plan the written response. Learners will decide where to gather information from (textbooks, own notes, revision websites). Ask learners: is the source of information you are using reliable?
- **Monitoring:** learners are prompted by the questions in the structure strip and can check their own answer against the prompts. Ask learners: have you covered all of the prompts in the space provided? Do you need to change anything to complete the task?
- **Evaluation:** learners can self-assess or ask a peer to check their work against the answers. Ask learners: did you achieve what you meant to achieve? What will you do differently another time?

Example answers

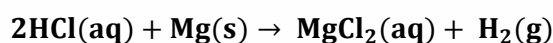
Structure strip Balanced chemical equations	Example answer
State the law of conservation of mass.	During a chemical reaction no atoms are created or destroyed. The total mass of chemicals after a reaction (the products) is the same as the total mass of chemicals at the start of the reaction (the reactants).
$\text{CH}_4 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ Explain how you know the above equation is unbalanced, and how to balance it.	There is one carbon atom, four hydrogen atoms and two oxygen atoms on the left of the arrow (reactants). On the right of the arrow (products), there is one carbon atom but only two hydrogen atoms and three oxygen atoms. The number of each type of atom is not the same, so the equation is unbalanced. To balance it, we need more hydrogen atoms on the right. We must add a two in front of the H_2O , giving four hydrogen atoms, but also four oxygen atoms. So, we also must add a two in front of O_2 on the left, to give a total of four oxygen atoms on each side.
This equation is balanced: $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$ Explain the meaning of the 2 in front of H_2O and the 2 within H_2O .	The large 2 in front of H_2O means that there are two molecules, or moles, of water. The small 2 after the H in H_2O means that there are two atoms of hydrogen in the molecule, giving a ratio of 2:1 hydrogen to oxygen atoms in the molecule.
Write out the four state symbols and give their meanings. Add state symbols to the equation above.	The state symbols are: s = solid, l = liquid, g = gas, aq = aqueous solution (dissolved in water) $2\text{Na(s)} + 2\text{H}_2\text{O(l)} \rightarrow 2\text{NaOH(aq)} + \text{H}_2\text{(g)}$
Define the term 'limiting reactant'.	The limiting reactant is completely used up in the reaction, so it limits the amounts of products that can be formed.
In the reaction between sodium and water, sodium is usually the limiting reactant. Explain what you observe that confirms this.	In the reaction, sodium is a solid which floats on the surface of the water and moves around as it reacts. There is fizzing because hydrogen gas is being made. The sodium gradually gets smaller and disappears and the fizzing stops. When the sodium has disappeared or has been used up, the reaction stops. All the sodium has gone but there is still water present.
Define the term 'excess reactant'.	The excess reactant is not used up in a chemical reaction. There is more of it than is needed to completely react with the other reactant.
When methane burns it is best if oxygen is in excess, so we have complete combustion (see equation above). Explain the differences if oxygen is the limiting reactant.	The products of the combustion of methane are carbon dioxide and water (see equation above). If there was not enough oxygen present, the combustion would be incomplete. So, instead of carbon dioxide, carbon monoxide and carbon would form. The flame would look yellow and leave a sooty deposit on glassware.

Extended answer question

Instruct learners to answer the question after they have attempted the structure strip. The structure strip activates the required knowledge which learners can then apply to the question.

Consider re-framing the context of this question to one that your learners are more familiar with, to empower them to unlock their existing science capital. Read more about science capital here: rsc.li/40FAMLP.

Example answers to extended answer question



During the reaction, we can see from the equation that hydrogen gas is produced, so we will observe fizzing. In addition, the solid magnesium turns into aqueous magnesium chloride, so the piece of magnesium will get smaller. These observations will be the same whether the magnesium is in excess or limiting.

When the magnesium is in excess, the acid will be used up first, so the fizzing will stop and a small piece of solid magnesium will be present. Whereas, if the magnesium is the limiting reactant, it will completely disappear and at the end there will be a clear, colourless solution.

We can test pH of the solution when the reaction finishes. If the magnesium is the limiting reactant, there will still be acid present so the solution will turn universal indicator red or orange. However, if the magnesium is in excess, all the acid should be used up, so the solution will turn universal indicator green.