Interpreting chemical equations

This resource is from the **Johnstone's triangle** series, which can be viewed at: rsc.li/43jMfSn. In this series you will also find our Johnstone's triangle worksheet which introduces the triangle in the context of the equation for the reaction between hydrogen and oxygen: rsc.li/4sCRfNI.

Learning objectives

LO	Objective	Where assessed
1	Link the formula and state symbol of reactants and products to observations of a chemical reaction.	Q1
2	Describe what a balanced chemical equation represents in terms of individual atoms and molecules.	Q2
3	Describe what a balanced chemical equation represents in terms of a large number of atoms and molecules.	Q3, Q4
4	Recognise that a chemical equation can be used to work out the mass of product that could be produced from the given mass of reactant.	Q5

How to use this resource

When to use?	Introduce	**Develop**	**Revise**	Assess
	Use after initial teaching or discussion of this topic to develop ideas further. You can also use as a revision activity.			
Group size?	**Independent**	**Small group**	**Whole class**	**Homework**
	Suitable for independent work either in class or at home. Or use the questions for group or class discussions.			
How long?			15–30 mins	

This resource aims to develop learners' understanding of how balanced chemical equations provide information such as the state of reactants and products and the ratio in which atoms and molecules react or are formed. The questions also encourage learners to think how a balanced chemical equation can be used to determine the mass of substances that react and those that are formed. As a result, learners should develop more secure mental models to support their thinking about this topic.

Johnstone's triangle

Johnstone's triangle is a model of the three different conceptual levels in chemistry: macroscopic, sub-microscopic and symbolic. You can use Johnstone's triangle to build a secure understanding of chemical ideas for your learners.

Find further reading about Johnstone's triangle and how to use it in your teaching at rsc.li/4f9xaqV.

Johnstone's triangle and this resource

The icons in the margin indicate which level of understanding each question is developing to help prompt learners in their thinking.

Macroscopic: what we can see. Think about the properties that we can observe, measure and record.

Sub-microscopic: smaller than we can see. Think about the particle or atomic level.

Symbolic: representations. Think about how we represent chemical ideas including symbols and diagrams.

The levels are interrelated, for example, learners need visual representation of the sub-microscopic in order to develop mental models of the particle or atomic level. Our approach has been to apply icons to questions based on what the learners should be thinking about.

Questions may be marked with two or all three icons, indicating that learners will be thinking at more than one level. However, individual parts of the question may require learners to think about only one or two specific levels at a time.

Support

This worksheet is ramped so that the earlier questions are more accessible. The activity becomes more challenging in the later questions. You can give extra explanations for the more challenging questions. If completing as an in-class activity it is best to pause and check understanding at intervals, as often one question builds on the previous one.

It is useful for learners to observe macroscopic properties first-hand. You could run a class practical of relevant chemical reactions or carry out a teacher demonstration. It is important that learners can observe the detail of the reactions so a visualiser or camera may be useful. Ensure to look up the full instructions and health and safety guidance before running a practical or demonstration.

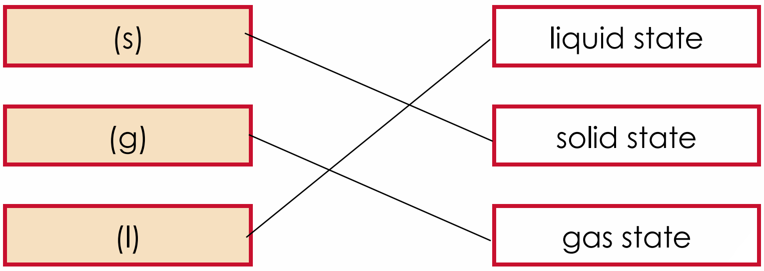
Give learners physical models to use and manipulate, such as a Molymod kits or counters.

Additional support may be needed for any learners still lacking in confidence in the required symbolic representation, for example by sharing and explaining a diagram or a simulation that can show movement of the particles.

Answers

1. *Guidance note:* This question develops learners' understanding of state symbols (symbolic understanding) and how the product of a chemical reaction that is in the gas state may or may not be observed (macroscopic understanding).

(a)



(b) The bubbles should be labelled.
(c) The carbon dioxide is in the gas state and is not visible.

2. *Guidance note:* This question develops learners' understanding of what a chemical equation (symbolic understanding) shows in terms of how many individual atoms or molecules react with or are produced from one atom or molecule of reactant (sub-microscopic understanding). This question deliberately focuses on individual atoms and molecules (an approach often used when balancing equations) before the consideration of ratio of a large number of atoms and molecules in the next question. Please note that examples where reactants or products are ionic compounds are explored in the developing understanding resource **Interpreting chemical equations: ionic compounds** (rsc.li/3LePXb6).

(a)
- i. S
- ii. O_2
- iii. SO_2

(b)
- i. One atom of carbon reacts with one molecule of oxygen to produce one molecule of carbon dioxide.
- ii. One molecule of methane reacts with two molecules of oxygen to product one molecule of carbon dioxide and two molecules of water.

3. *Guidance note:* This question develops learners' understanding of how a balanced chemical equation (symbolic understanding) shows the ratio of atoms and molecules reacting and being produced (sub-microscopic understanding). The question does not explicitly refer to the term ratio (although this could be used if students are familiar with the concept). Instead, a sentence structure is used to convey the concept e.g. each atom of carbon reacts with one molecule of oxygen.

(a) Left: oxygen, middle: carbon dioxide, right: carbon

(b)

Number of carbon atoms	Number of oxygen molecules	Number of carbon dioxide molecules
1	1	1
2	**2**	**2**
100	**100**	**100**
1 billion	**1 billion**	**1 billion**

(c) 1 billion carbon atoms cannot make 2 billion carbon dioxide molecules because 2 million carbon dioxide molecules need 2 billion carbon atoms.

4. *Guidance note:* This question develops further learners' understanding of how a balanced chemical equation (symbolic understanding) shows the ratio in which atoms and molecules react and are produced. The concept of ratio is modelled through the use of a table showing the ratio of actual numbers, from very small to 1 billion. This aims to pave the way for the concept of reacting ratios in terms of moles.

(a)

i. Gas

ii. Gas

iii. Gas

(b) Water is not in the liquid state because the temperature caused by the reaction is above the boiling point of water.

(c) Each molecule of methane reacts with **two** molecules of oxygen forming **one** molecule of carbon dioxide and **two** molecules of water.

(d)

Number of methane molecules	Number of oxygen molecules	Number of carbon dioxide molecules	Number of water molecules
1	2	1	2
2	4	**2**	**4**
10	**20**	**10**	**20**
1 billion	**2 billion**	**1 billion**	**2 billion**

5. *Guidance note*: This question develops learners' understanding of how a balanced chemical equation (symbolic understanding) shows the ratio of the number of moles of reacting and produced atoms and molecules (sub-microscopic). Students are then supported to connect this to the mass of substance reacting or being produced (macroscopic). Please note that if students are not required to learn about moles, this question could be omitted.

(a)
  i. One mole
  ii. Two moles

(b) Water forms from the combination of oxygen with the hydrogen atoms from the methane molecules.

(c) 32 g

(d) 88 g

(e)
  i. Two moles of water: 36 g
  ii. Four moles of water: 72 g

(f) 88 g (two moles of methane produce two moles of carbon dioxide)

(g) 72 g (two moles of methane produce four moles of water)