TEACHER NOTES

Reacting ratios: masses

This resource is from the **Johnstone's triangle** series, which can be viewed at: rsc.li/498JyaF. In this series you will also find our Johnstone's triangle worksheet which introduces the triangle in the context of extracting tin from tin oxide: rsc.li/4qq2DLK.

Learning objectives

LO	Objective	Where assessed
1	Describe what a balanced chemical equation means in terms of the ratio of reactant and product atoms or molecules.	Q1
2	Explain why the mass of carbon dioxide formed is not equal to the mass of carbon that reacts.	Q1
3	Calculate the mass of a given number of moles of carbon, oxygen and carbon dioxide.	Q2
4	Calculate the mass of product formed from a given mass of reactant using a chemical equation with a 1:1 ratio.	Q3
5	Calculate the mass of product formed from a given mass of a reactant using a chemical equation with a 1:2 ratio.	Q4

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 a balanced chemical equation and what this means at the sub-microscopic level in terms of the ratio of a very large number of number (measured in moles) of atoms or molecules reacting or being produced. The questions encourage learners to think about how the measured mass of reactants or products connects with the number of moles of atoms or molecules. The more secure mental models developed should help learners to understand calculations of the mass of product formed from a given mass of reactant using chemical equations with both a 1:1 and 1:2 ratio.

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 circulate examples of substances in the classroom, run a class practical of a chemical reaction or show a teacher demonstration of properties.

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 starts by developing learners' understanding of how a balanced chemical equation (symbolic understanding) shows the ratio in which atoms or molecules react and are produced (sub-microscopic understanding). Learners are then required to determine masses of reactants and products (macroscopic understanding) with the same number of atoms or molecules (sub-microscopic understanding). This supports learners to understand why 12 g of carbon does not produce 12 g of carbon dioxide.

(a) Each **atom** of carbon reacts with one **molecule** of oxygen to produce one **molecule** of carbon dioxide.

(b)

Number of carbon atoms	Number of oxygen molecules	Number of carbon dioxide molecules
1 million	**1 million**	**1 million**
1 billion	1 billion	**1 billion**
6.02×10^{23}	**6.02×10^{23}**	6.02×10^{23}

(c) An oxygen molecule is made up of two oxygen atoms so the RFM is 2 x 16 which equals 32.

(d) M_r of CO_2 is 12 + (2 x 16) = 44

(e)

	carbon	oxygen	carbon dioxide
Mass with an equal number of atoms/molecules	12 g	**32 g**	**44 g**

(f)

mass of carbon	mass of oxygen	mass of carbon dioxide
24 g	**64 g**	**88 g**
6 g	**16 g**	**22 g**
3 g	**8 g**	**11 g**

(g)
- i. 88 g
- ii. 3 g

(h) 12 g of carbon will produce the same number of carbon dioxide molecules as there are atoms in 12 g of carbon. A carbon dioxide molecule has more mass than a carbon atom so the mass of carbon dioxide produced is greater than 12 g.

2. *Guidance note*: This question develops learner's confidence in calculating the mass (macroscopic understanding) of different numbers of moles (sub-microscopic understanding) of carbon, oxygen and carbon dioxide.

(a)
- i. **32** g
- ii. **44** g

(b)
- i. **24** g
- ii. **3** x 12 g = **36** g
- iii. **10** x 12 g = **120** g

(c)
- i. **64** g
- ii. **3** x **32** g = **96** g
- iii. **10** x **32** g = **320** g

(d)
- i. **2** x **44** g = **88** g
- ii. **3** x **44** g = **132** g
- iii. **10** x **44** g = **440** g

3. *Guidance note*: This question develops learner's understanding of how the number of moles of a reactant may be determined (sub-microscopic understanding) from its mass (macroscopic understanding). The question then requires learners to use the ratio given by the balanced chemical equation (symbolic understanding) to determine the number of moles of product formed (sub-microscopic understanding). Learners must then calculate the mass of product formed (macroscopic understanding).

(a) Each mole of carbon atoms reacts with **one mole** of oxygen molecules to form **one mole** of carbon dioxide molecules.

(b) 12 g of carbon reacts with **32** g of oxygen to form **44** g of carbon dioxide.

(c)

carbon mass	carbon moles	carbon dioxide moles	carbon dioxide mass
12 g	1	1	44 g
24 g	2	**2**	**88 g**
6 g	**0.5**	**0.5**	**22 g**
20.4 g	**1.7**	**1.7**	**74.8 g**

(d) mass/A_r = moles s ∴ 20.4 /12 = 1.7 moles of carbon
moles x M_r = mass ∴ 1.7 x 44 = 74.8 g of carbon dioxide

(e) mass/A_r = moles s ∴ 28.8 / 12 = 2.4 moles of carbon
moles x M_r = mass ∴ 2.4 x 44 = 105.6 g of carbon dioxide

(f)

carbon dioxide mass	carbon dioxide moles	carbon moles	carbon mass
44 g	1	1	12 g
88 g	2	**2**	**24 g**
11 g	**0.25**	**0.25**	**3 g**
57.2 g	**1.3**	**1.3**	**15.6 g**

(g) mass/M_r = moles ∴ 57.2 / 44 = 1.3 moles of carbon dioxide
moles x A_r = mass ∴ 1.3 x 12 = 15.6 g of carbon

4. *Guidance notes*: The chemical reaction used in this question extends learners' understanding from the 1:1 ratio in question 3 to a 1:2 ratio.

(a) Each mole of methane **molecules** reacts with two moles of oxygen **molecules**. This produces **one** mole of carbon dioxide molecules and **two** moles of water molecules.

(b)

i. M_r of CH_4 = 12 + (4 x 1) = 16
ii. M_r of O_2 = 16 x 2 = 32
iii. M_r of CO_2 = 12 + (2 x 16) = 44
iv. M_r of H_2O = (2 x 1) + 16 = 18

(c)

Substance	methane CH_4	oxygen O_2	carbon dioxide CO_2	water H_2O
Number of moles	1	2	**1**	**2**
Mass	16 g	**2 x 32 = 64 g**	**44 g**	**2 x 18 = 36 g**

(d)

methane mass	methane moles	water moles	water mass
8 g	0.5	1	**18 g**
32 g	2	**4**	**72 g**
22.4 g	**1.4**	**2.8**	**50.4 g**