Yield

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 yield of fertiliser: rsc.li/3YwGDT0.

Learning objectives

LO	Objective	Where assessed
1	Recognise that actual yield may be less than the yield that could theoretically be produced and that this can be shown quantitively by calculating the percentage yield.	Q1
2	Calculate the theoretical yield for a given reaction from the mass of a reactant and the balanced chemical equation.	Q2
3	Determine the location of product ions following the separation of an insoluble product.	Q3
4	Suggest a reason for a calculated percentage yield that is less than 100%	Q3

How to use this resource

This resource aims to develop learners' understanding of the idea of actual and theoretical yield.

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	

The questions encourage learners to think at the sub-microscopic level about the location of ions following the separation of an insoluble product and about why actual yield may not equal the theoretical yield. 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/4sqO6kb.

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 develops learners' understanding by connecting experimental observations and measurements (macroscopic understanding) to an explanation of why the actual yield of a chemical reaction may be less than the yield that could theoretically be produced. It then supports learners to calculate percentage yield. This question requires no familiarity with the concept of moles.

(a)

Observation	Substance
grey solid	**magnesium**
colourless gas	**oxygen**
white solid	**magnesium oxide**
white smoke	**magnesium oxide**

(b) 1.2 g
(c) The student had to occasionally lift the lid to allow oxygen (air) in.
(d) 1.7 g
(e)

Student	mass of crucible + magnesium oxide/g	Mass of magnesium oxide/g (actual yield)/g
B	51.8	**1.8**
C	51.5	**1.5**
D	51.6	**1.6**

(f) Student B

(g)

Student	Actual yield	Theoretical yield /g	Percentage yield
A	**1.7**	2	**85**
B	**1.8**	2	**90**
C	**1.5**	2	**75**
D	**1.6**	2	**80**

(h) No student was able to prevent some of the white smoke (magnesium chloride) escaping.

2. *Guidance note:* This question develops learners' understanding of how theoretical yield can be calculated by connecting the ratio from the balanced chemical equation (symbolic understanding) to number of moles (sub-microscopic understanding) that could theoretically be produced from a given number of moles of reactant. It supports learners to calculate theoretical from the given mass of a reactant (macroscopic understanding and reinforces the idea of percentage yield.

(a) Every two moles of **magnesium** react with one mole of oxygen to form **two** moles of magnesium oxide. This means that every mole of magnesium produces **one** mole of magnesium oxide.

(b) 24 g

(c) 24 + 16 = 40 g

(d)

mass of magnesium/g	number of moles of magnesium	Number of moles of magnesium oxide	Theoretical yield of magnesium oxide/g
24	1	1	40
2.4	**0.1**	**0.1**	**4**
0.24	**0.01**	**0.01**	**0.4**

(e) 0.075 moles

(f) 0.075 moles

(g) 3 g

(h) 87%

3. *Guidance note:* This question develops learners' understanding of yield by supporting them to identify the physical location (macroscopic understanding) of ions (sub-microscopic understanding) after the separation of an insoluble product through filtration. This question assumes familiarity with the terms filtrate and residue. The question then supports learners to connect calculation of theoretical yield from a balanced chemical equation (symbolic understanding) to an explanation of why the final percentage yield is not 100% (macroscopic understanding).

(a) A white precipitate will be formed/it will turn cloudy (white).

(b)

reactant or product	Ion 1	Ion 2
silver nitrate	$\mathbf{Ag^+}$	$\mathbf{NO_3^-}$
sodium chloride	$\mathbf{Na^+}$	$\mathbf{Cl^-}$
silver chloride	$\mathbf{Ag^+}$	$\mathbf{Cl^-}$
sodium nitrate	$\mathbf{Na^+}$	$\mathbf{NO_3^-}$

(c)

i. Ag^+:Residue

ii. Na^+:Filtrate

(d) In the dish

(e) Each mole of silver nitrate that is dissolved in the water reacts with **one** mole of sodium chloride that is also dissolved in water. This forms **one** mole of silver chloride and **one** mole of sodium nitrate dissolved in water.

(f) 170 g

(g) 143.5 g

(h) number of moles of silver nitrate = mass / mass of one mole

= 1.7 / 170

= 0.01 moles

This reacts with the same number of moles of silver chloride.

The mass of silver chloride that can theoretically be produced is the number of moles x mass of one mole

= 0.01 x 143.5

= 1.435 g

(i) 1.3 / 1.435 x100 = 91%

(j) Some of the silver chloride may not have been transferred from the filter paper to the dish.