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# AS LEVEL

*Delivery Guide*

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H032

# ***CHEMISTRY A***

Theme: Atom economy and  
percentage yield

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Oxford Cambridge and RSA

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# Introduction

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: a clear outline of the content covered by the delivery guide;
- Thinking Conceptually: expert guidance on the key concepts involved, common difficulties students may have, approaches to teaching that can help students understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: a range of suggested teaching activities using a variety of themes so that different activities can be selected that best suit particular classes, learning styles or teaching approaches.

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## KEY



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# Curriculum Content

## 2.1.3

(h) calculations to determine:

- (i) the percentage yield of a reaction or related quantities
  - (ii) the atom economy of a reaction.
- (i) the techniques and procedures required during experiments requiring the measurement of mass, volumes of solutions and gas volumes.
- (j) the benefits for sustainability of developing chemical processes with a high atom economy.



# Thinking Conceptually

## Approaches to teaching the content

When starting to teach percentage yield you can split the topic into three parts. The first part needs to be balancing equations; students need to be able to create and balance chemical equations. Students will have covered this at GCSE, and it is usually refreshed at the beginning of Year 12. The second part of the topic is reacting masses; this has also been covered in the earlier part of the AS course, but students will need to be reminded of this. The final aspect of the topic is the calculating of the theoretical yield and the percentage yield itself.

Percentage yield = (actual yield  $\div$  theoretical yield)  $\times$  100.

Students may find it difficult to transfer skills they have learnt in Maths GCSE or A Level regarding percentages and as such may need reminding. Students who are unsure of calculating percentages should be led through worked examples at this point in order to understand fully what the equation is asking of them.

Atom economy is the molecular mass of the desired product  $\div$  the sum of molecular masses of all the products  $\times$  100. Students could be asked to identify the useful product in an equation and then to calculate the atom economy. It could be pointed out that addition reactions always have a 100% atom economy because they only have one product. Substitution reactions don't have 100% atom economy as there is more than one product.

## Common misconceptions or difficulties students may have

It is the calculation of the theoretical yield that students will find the most difficult. One approach to teaching theoretical yield is to remind students of the way that they calculated reacting masses earlier in the course.

- 1) work out the amount, in mol, of reactant;
- 2) look at the mole ratio and adjust according to the ratio;
- 3) convert the amount of product into a mass by multiplying by the molar mass.

The actual yield in grams can then be divided by the theoretical yield just calculated.

Several structured examples should be carried out at this point to allow students to clarify their understanding.

Atom economy gives information about the efficiency of the reaction whereas percentage yield gives information about how much product is made. They are different concepts, but students may not see them as such. The atom economy can be improved by finding a use for the 'waste' products; an example of this is that carbon dioxide, produced as a by-product of the petrochemical industry, can be used in fizzy drinks or as a substitute for hydrochloric or sulfuric acids in pH adjustment of waste water;  $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$ ;  $\text{H}_2\text{CO}_3 + 2\text{NaOH} \rightarrow \downarrow \text{Na}_2\text{CO}_3 + 2\text{H}_2\text{O}$ .




When discussing the question "which is more desirable: a high yield or a high atom economy?" the economics of disposing of a large amount of waste compared with a low percentage yield should be considered.



# Thinking Conceptually





## Conceptual links to other areas of the specification – useful ways to approach this topic to set students up for topics later in the course.

Reacting masses and balancing equations are concepts that are covered at the very beginning of the AS course. Candidates may be required to apply understanding of percentage yield and atom economy in any context, so it is sensible to revisit the concepts throughout the two year A Level course, for example in more complex organic reactions in Module 6.

Activities	Resources
<p><b>Calculating percentage yield</b> Provided by <a href="http://www.chemfiesta.com">www.chemfiesta.com</a>. <a href="http://misterguch.brinkster.net/PRA022.pdf">http://misterguch.brinkster.net/PRA022.pdf</a></p> <p>This is a worksheet with answers that would help students reinforce the calculations required for percentage yield.</p>	<p> Click here</p>
<p><b>Green chemistry, atom economy and sustainable development</b> Provided by the RSC. <a href="http://www.rsc.org/Education/Teachers/Resources/Inspirational/resources/6.6.1.pdf">http://www.rsc.org/Education/Teachers/Resources/Inspirational/resources/6.6.1.pdf</a></p> <p>An excellent resource that links yield, atom economy and sustainability into one well-structured worksheet. It provides descriptions and questions relating to each concept.</p>	<p> Click here</p>
<p>For students who are weak at balancing equations it may be worth starting with balancing equations. This resource will help with this.</p> <p><b>Balancing Chemical Equations</b> Provided by PHET at the University of Colorado. <a href="http://phet.colorado.edu/en/simulation/balancing-chemical-equations">http://phet.colorado.edu/en/simulation/balancing-chemical-equations</a></p> <p>This link is a Java applet that can be embedded into virtual learning environments if you so wish. It is a see-saw wherein students can move atoms and molecules around to ensure the see-saw balances, thus balancing the equation.</p>	<p> Click here</p>



# Thinking Conceptually

Activities	Resources
<p>For reacting masses you could reinforce this concept practically by using these practicals.</p> <p><b>A demonstration of the reduction of copper (II) oxide using hydrogen gas</b> Provided by the Nuffield Foundation.</p> <p><a href="http://www.nuffieldfoundation.org/practical-chemistry/reaction-hydrogen-and-oxygen-reacting-masses">http://www.nuffieldfoundation.org/practical-chemistry/reaction-hydrogen-and-oxygen-reacting-masses</a></p> <p>It allows the calculation of hydrogen in the water produced. A complicated demonstration that some centres may not be able to carry out.</p> <p><b>Determination of Relative Atomic Mass</b> Provided by the Nuffield Foundation.</p> <p><a href="http://www.nuffieldfoundation.org/practical-chemistry/determination-relative-atomic-mass">http://www.nuffieldfoundation.org/practical-chemistry/determination-relative-atomic-mass</a></p> <p>This allows the calculation of a relative atomic mass; by doing so you are calculating the reacting masses of the reactants in order to calculate the atomic mass.</p>	<p> Click here</p> <p> Click here</p>
<p>Or, if you would rather not use a practical approach, a paper-based route could be used.</p> <p><b>Reacting Masses</b> Provided by Creative Chemistry.</p> <p><a href="http://www.creative-chemistry.org.uk/gcse/documents/Module7/N-m07-13.pdf">http://www.creative-chemistry.org.uk/gcse/documents/Module7/N-m07-13.pdf</a></p> <p>This is a structured work sheet that allows students to calculate reacting masses.</p>	<p> Click here</p>
<p><b>Stoichiometry</b> Provided by Crash Course Chemistry (YouTube).</p> <p><a href="https://www.youtube.com/watch?v=UL1jmJaUkaQ&amp;list=PL8dPuualjXtPHzzYuWy6fYEaX9mQQ8oGr">https://www.youtube.com/watch?v=UL1jmJaUkaQ&amp;list=PL8dPuualjXtPHzzYuWy6fYEaX9mQQ8oGr</a></p> <p>This is short video introduction to the stoichiometry of reactions in a very student-orientated way.</p>	<p> Click here</p>





# Thinking Contextually

The ideal context within which to base percentage yield is organic chemistry – this can be covered when carrying out a synthesis of an organic product such as aspirin or when oxidising a primary alcohol, and then also carrying out a percentage yield. Percentage yield could be incorporated into equilibrium when explaining le Chatelier's principle and the effects of changing temperature and concentration on the yield of a product – the best context would be the Haber Process.

Atom economy could be introduced at every point of the organic module; there could be discussions about how different reactions give different types of atom economy and how atom economy could be improved.

A good discussion point is the synthesis of ibuprofen and how it was initially a multi-step synthesis with a lot of waste, after which a different synthetic route was devised which improved the atom economy and enabled the drug to be cheaply available. Most students will be aware of ibuprofen and there is an interesting website here <http://www.rsc.org/learn-chemistry/resources/chemistry-in-your-cupboard/nurofen/7> which explains the history of its development.





This is a good example provided by the RSC: <http://www.ch.ic.ac.uk/marshall/416/Ibuprofen2.pdf>. This is a structured worksheet which incorporates percentage yield and atom economy based around the synthesis of ibuprofen. It will need to be differentiated according to ability of the students – parts could be taken away or added, and it could also be used as a stretch and challenge activity.

▶ Click here

▶ Click here



# Thinking Contextually

Activities	Resources
<p><b>Calculating Percentage yield</b> Provided by <a href="http://www.4college.co.uk">www.4college.co.uk</a>.</p> <p><a href="http://www.4college.co.uk/a/Md/yield.php">http://www.4college.co.uk/a/Md/yield.php</a></p> <p>This is another example of a resource that could be used to calculate percentage yield. It provides a step-by-step demonstration of the calculation.</p>	<p></p>
<p><b>Atom economy</b> Provided by Aus-e-tute.</p> <p><a href="http://www.usetute.com.au/atomeconomy.html">http://www.usetute.com.au/atomeconomy.html</a></p> <p>This is an online tutorial which runs through the calculation of atom economy. It could perhaps form part of a student revision site in a virtual learning environment.</p>	<p></p>
<p><b>The difference between percentage yield and atom economy</b> Provided by YouTube.</p> <p><a href="https://www.youtube.com/watch?v=9YpT-QGTrWw">https://www.youtube.com/watch?v=9YpT-QGTrWw</a></p> <p>This is a little animation that lasts 10 seconds showing the difference between percentage yield and atom economy – the percentage yield picture shows that a high yield could lead to more waste and so a poor atom economy; whereas the atom economy shows no waste, but not necessarily a high yield. Maybe it could be embedded into a PowerPoint as a starter or a talking point. A possible starter could include “Why would a high yield not be good for the environment?”</p>	<p></p>
<p><b>Making a fertiliser</b> Provided by RSC.org</p> <p><a href="http://www.rsc.org/learn-chemistry/resource/res00000475/making-a-fertiliser">http://www.rsc.org/learn-chemistry/resource/res00000475/making-a-fertiliser</a></p> <p>This practical is an example of an activity that could be adapted so the students calculate either atom economy or percentage yield – or both. There are many practicals that could be adapted in this way.</p>	<p></p>





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