Limiting and excess reactants

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 excess copper oxide: rsc.li/49rruZz.

Learning objectives

LO	Objective	Where assessed
1	Recognise in an everyday situation why not having enough of one ingredient can limit the quantity of the final product that can be made.	Q1
2	Identify a reactant that is in excess.	Q2
3	Identify the excess and limiting reactants of different chemical reactions using evidence from observations and state symbols.	Q3
4	Use particle diagrams to determine the limiting reactant.	Q4
5	Suggest why copper carbonate is added in excess when making the salt copper sulfate.	Q4

How to use this resource

This resource aims to develop learners' understanding of limiting and excess reactants.

<table>
<tr><td rowspan="2">When to use?</td><td>Introduce</td><td>Develop</td><td>Revise</td><td>Assess</td></tr>
<tr><td colspan="4">Use after initial teaching or discussion of this topic to develop ideas further. You can also use as a revision activity.</td></tr>
<tr><td rowspan="2">Group size?</td><td>Independent</td><td>Small group</td><td>Whole class</td><td>Homework</td></tr>
<tr><td colspan="4">Suitable for independent work either in class or at home. Or use the questions for group or class discussions.</td></tr>
<tr><td>How long?</td><td colspan="2"></td><td colspan="2">15–30 mins</td></tr>
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The questions encourage learners to think about how observations (macroscopic understanding), state symbols in a chemical equation (symbolic understanding) and the number of reacting atoms and molecules (sub-microscopic understanding) can be used to determine the limiting reactant and excess reactants. 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/4qFzRGx.

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.

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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.

For question four consider giving learners a physical model e.g. 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 the basic concept of limiting and excess ingredients when making an overall product. The question uses the everyday example of scoops of ice cream and cones rather than chemical reactions to make the idea as accessible as possible.

(a) Five
(b) Four
(c) 100
(d) Cones
(e) 100 scoops
(f) Ice cream
(g) 50 cones

2. *Guidance note:* This question develops learners' understanding of how observation of a chemical reaction (macroscopic understanding) can be used to determine the excess and limiting reactant. The question also builds leaners' understanding of how an indicator (macroscopic understanding) may be used to show that an acid is in excess.

(a) Magnesium and hydrochloric acid
(b) Magnesium chloride solution
(c) The other product (hydrogen) is in the gas state and so has left the tube.
(d) Hydrochloric acid
(e) There was more hydrochloric acid at the start than was needed to react with the amount of magnesium. The reaction ended when all the magnesium had reacted which means that the unreacted hydrochloric acid was left.
(f) Magnesium can be seen at the end of the reaction which shows that magnesium was the reactant which is in excess.

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3. *Guidance note:* This question develops learners' understanding of observation of a chemical reaction (macroscopic understanding) and state symbols from a balanced chemical equation (symbolic understanding) can help determine the limiting and excess reactants. The question also builds learners' understanding of the use of an indicator (macroscopic understanding) to distinguish whether an acid or alkali is in excess.

(a) Observation shows that a solid is present at the end of the chemical reaction. The state symbols show that the solid reactant is calcium carbonate so this is in excess.

(b) Excess reactant: $CuO(s)$. Limiting reactant: $H_2SO_4(aq)$

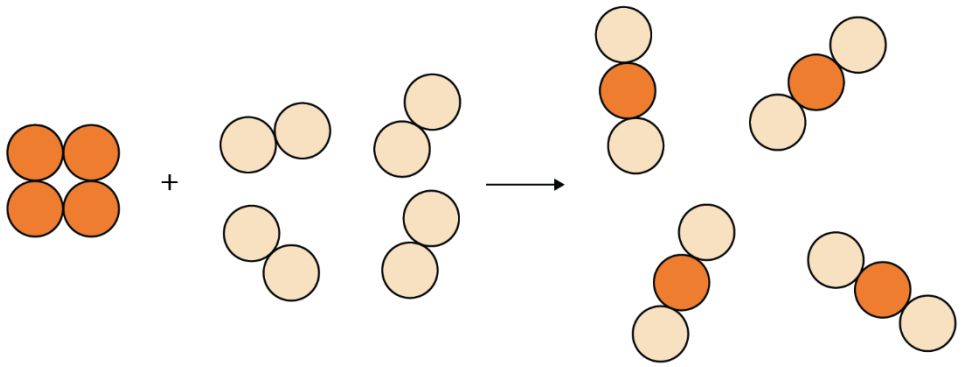
(c) Both reactants are aqueous so you cannot see which is in excess. Litmus can show if there is an acid or alkali left at the end of the reaction.

(d) The excess reactant is an acid.

(e) Excess reactant: hydrochloric acid.
Limiting reactant: sodium hydroxide solution

4. *Guidance note:* This question develops learners' understanding of how the ratio shown in a balanced chemical equation (symbolic understanding) and particle diagrams (sub-microscopic diagram) can be used to explain which reactant is the limiting reactant and which is in excess. Please note that to determine this from given masses of reactants quantitative methods are required. These are explored in the 'Limiting and excess reactants: quantitative' resource, available from rsc.li/4pmKCw8.

(a)



(b) Six molecules of carbon dioxide can be made.

(c) Some oxygen molecules were not used. This means that carbon limited the number of carbon dioxide molecules that were made so carbon is the limiting reactant.

(d) When carbon burns the oxygen comes from the air. This means that there are a very large number of oxygen molecules so, unless the supply of air is restricted in some way, oxygen will be in excess.

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5. *Guidance note:* This question develops learners' understanding of why limiting and excess reactants are important to consider when making a salt. It develops understanding of how a chemical reaction only shows the products of a chemical reaction and not an excess reactant (symbolic understanding). It builds understanding of why a solid excess reactant is used and how this can be removed to leave the desired product (macroscopic understanding). If learners have not yet covered methods of making salts, then this question could be omitted. Note: in part c it is also important to add excess copper carbonate from a safety perspective so that all the sulfuric acid has reacted before heating.

(a) Copper sulfate, water and sulfuric acid. (Carbon dioxide gas will escape.)
(b) Sulfuric acid
(c) The formula for sulfuric acid is not on the right of the chemical equation because it is not a product of the reaction. It is still a reactant.
(d) Copper carbonate
(e) Green powder (solid)
(f) Excess copper carbonate can be removed by filtering. Sulfuric acid passes through filter paper so it cannot be removed in this way.
(g) Copper carbonate is added in excess to make sure that all the sulfuric acid is reacted producing as much copper sulfate as possible. It also means that the copper sulfate crystals produced are a pure as possible.

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