

Nanomaterials and the nanoscale: structure strip

This resource accompanies the article **Small wonders** in *Education in Chemistry* which provides context for the many and varied uses of nanomaterials and can be read at: rsc.li/46OCU5l

Learning objectives

- 1 Explore the topic of nanomaterials and the nanoscale.
- 2 Understand how to calculate orders of magnitude and surface area to volume ratio.
- 3 Practise drafting extended responses.

When your learners have finished using the structure strip they should have an A4 page set of notes and examples.

Introduction

Nanomaterials are becoming more and more important in everyday life and in scientific research. In this activity, your learners will develop their skills in reading and writing about nanomaterials and the nanoscale.

How to use structure strips

Structure strips are a type of scaffolding that support learners to write independently. You can use them in lots of ways: to take an overview at the start of the topic, to activate prior knowledge or to summarise a set of objectives.

Your learners should glue their structure strip into the margin of an exercise book or a piece of paper. The strips have sections containing prompts which are sized to show the amount learners must write. Learners write their answers next to the sections, in full sentences.

Question

Get your learners to answer the question after they have completed the structure strip. The structure strip activates the required knowledge which learners can then apply to the following question.

'Gold nanoparticles can be used as catalysts. They cost £120 for a 25 cm³ bottle as a suspension. A lab orders bottles of 30 nm and 80 nm gold nanoparticles. Evaluate the use of these two sizes of nanoparticles including appropriate calculations.'

Scaffolding

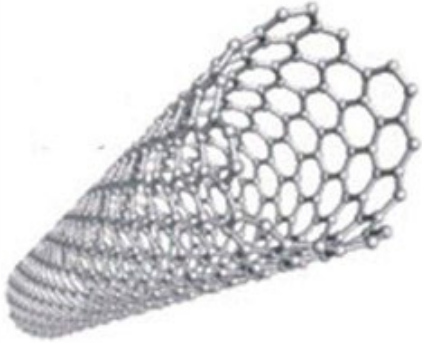
For learners who need support, you can include a list of key words or additional prompts in the structure strip. As learners grow in confidence, they will be able to answer the question without the structure strip or attempt the question first and then use the structure strip to improve or self-assess their answer.

Answers

Structure strip

The answers to structure strip questions can be written as bullet points or prose.

| Nanomaterials and the nanoscale | |
|---|---|
| Explain the term 'nanometre'. | A nanometre is a very small unit of length, much smaller than a metre, cm or mm. It is 1×10^{-9} m which is 0.000000001 m. |
| Define the term nanoscience and compare nanoparticles to coarse particles and fine particles. | <p>Nanoscience is the study of structures that are between 1 and 100 nanometres (nm) in size.</p> <p>Nanoparticles are typically made up of 1–100 atoms and have a size of 1–100 nm.</p> <p>Fine particles (sometimes called particulate matter) are bigger, they have a size of 100 to 2500 nm.</p> <p>Coarse particles are bigger again, 2500 to 10,000 nm.</p> |
| Give some uses of nanoparticles in everyday life and research. | Nanoparticles are used as catalysts, in medical treatment, cosmetics and electronics. In everyday life they are used as sunscreens which block harmful UV light from the skin. Sunscreen contains zinc oxide. When it is used as fine particles it appears white on the skin but when zinc oxide nanoparticles are used the sunscreen isn't visible on the skin. |
| A gold atom has a diameter of 0.14 nm. Calculate what size gold nanoparticle is 10 times and 100 times larger than a gold atom. | <p>0.14 nm gold atom.</p> <p>Ten times larger would be $0.14 \times 10 = 1.4$ nm.</p> <p>One hundred times larger would be $0.14 \times 100 = 10.4$ nm.</p> <p>These would still be considered to be on the nanoscale as they are between 1–100 nm diameter.</p> |
| Show, using an example, how to calculate the surface area (SA):volume (V) ratio of a cube shaped nanoparticle. | <p>A cube has six sides. For a cube with sides of 0.2 nm:</p> <p>Surface area of each side = $0.2 \text{ nm} \times 0.2 \text{ nm} = 0.04 \text{ nm}^2$.</p> <p>Six sides so $6 \times 0.04 \text{ nm}^2 = 0.24 \text{ nm}^2$.</p> <p>The volume of a cube can be calculated by cubing its sides (length x width x depth) which are all the same for a cube.</p> |

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| <p>Explain why SA:V ratio is an important property.</p> | <p>For a side of 0.2 nm:</p> <p>Volume = 0.2 nm x 0.2 nm x 0.2 nm = 0.2³ = 0.008 nm³.</p> <p>SA:V ratio = 0.24:0.008 = 0.24/0.008 = 30:1.</p> <p>Surface area to volume ratio is a property which can tell us how much reactive surface there is compared to the volume of the substance. A large surface area to volume ratio is preferred (eg for catalysts) as smaller amounts can be used. This is important as catalysts can be expensive.</p> |
| <p>Describe the structure and bonding of a carbon nanotube. You may support your answer with a sketch.</p> <ul style="list-style-type: none"> • What are the properties of carbon nanotubes and how are they related to their structure and bonding? • Where do they sit on the nanoscale? | <div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> <p>Carbon nanotubes are nanomaterials made from a single sheet of graphene rolled up to create a tube. Nanotubes are very long compared to their width. They have high length to diameter ratios. Each carbon atom in the graphene sheet is covalently bonded to 3 other carbon atoms. This leaves one of the 4 outer shell electrons free.</p> <p>Carbon nanotubes are strong (especially tensile strength where they resist being stretched). This is due to the strong covalent bonds between the carbon atoms. They are good conductors of electricity because the spare electron per carbon atom can be delocalised across the structure.</p> <p>Carbon nanotubes are nanomaterials. They have diameters between 0.4 and 40 nm and lengths from about 100 nm to a few millimetres.</p> </div> </div> |

Extended response question

Indicative content:

- Both bottles of gold nanoparticles cost the same.
- Calculation: order of magnitude.
The 80 nm particles are $80/30 = 2.7$ times bigger than the 30 nm particles.
- Calculation: Surface area to volume ratio (see structure strip answers).
Learners can use a spherical nanoparticle or a cubic nanoparticle for their calculation.
- The 30 nm nanoparticles have a higher surface area to volume ratio so you would need less of them to get the same activity as a catalyst.
- If less is needed, then the risks associated with the use of the gold nanoparticles would also be reduced.

- However, catalysts can be very specific so the 30 nm nanoparticles might not work in all the applications the lab needs.

Extension

- Selectivity for only the desired product.
- Efficiency of the catalyst (how much it speeds up the reaction, whether it gets poisoned easily).
- The ability to work in particular conditions for the reaction eg the solvent, temperature.
- Environmental impact.
- Risks/hazards.