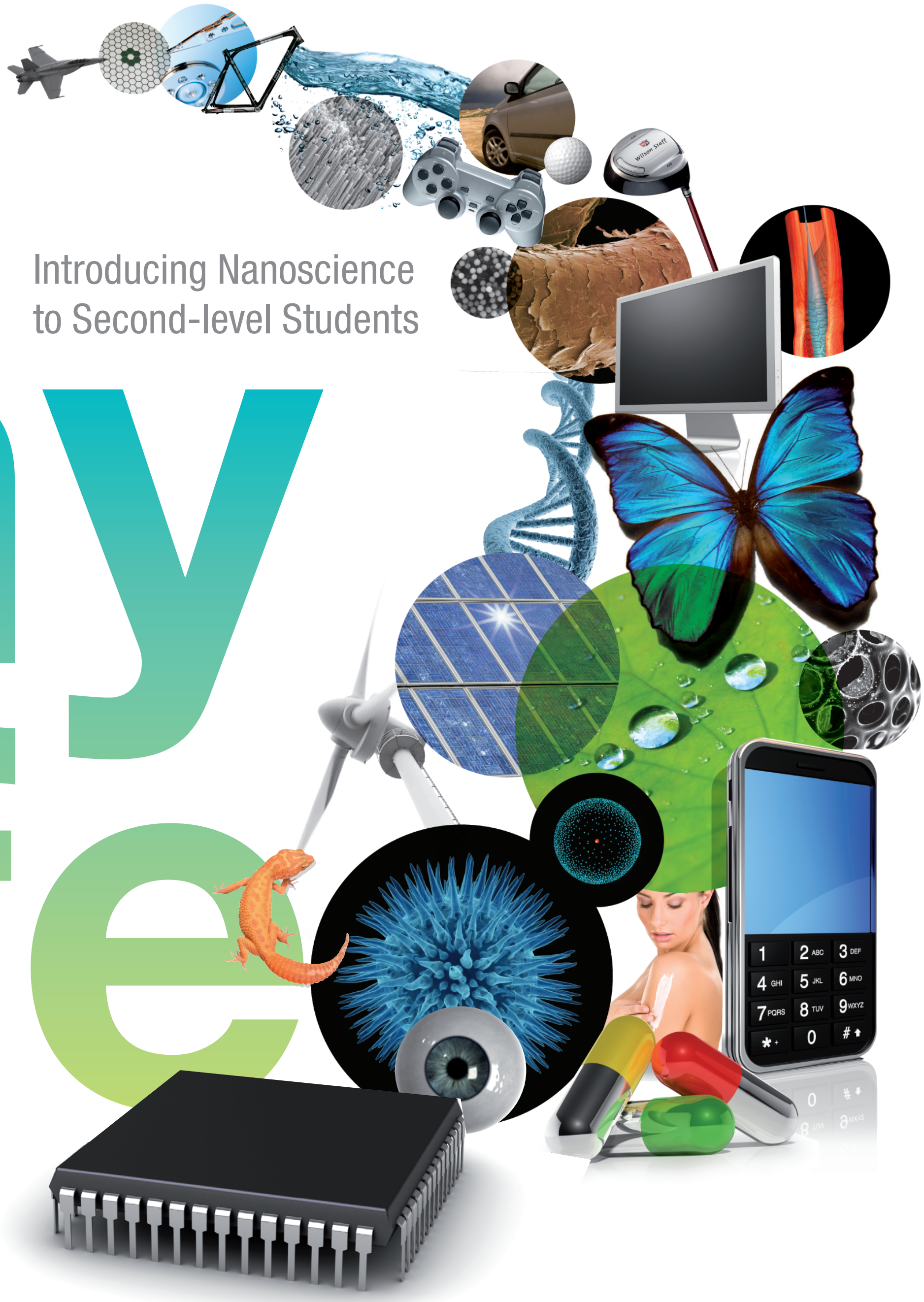
CRANN

nano in my life

Introducing Nanoscience to Second-level Students



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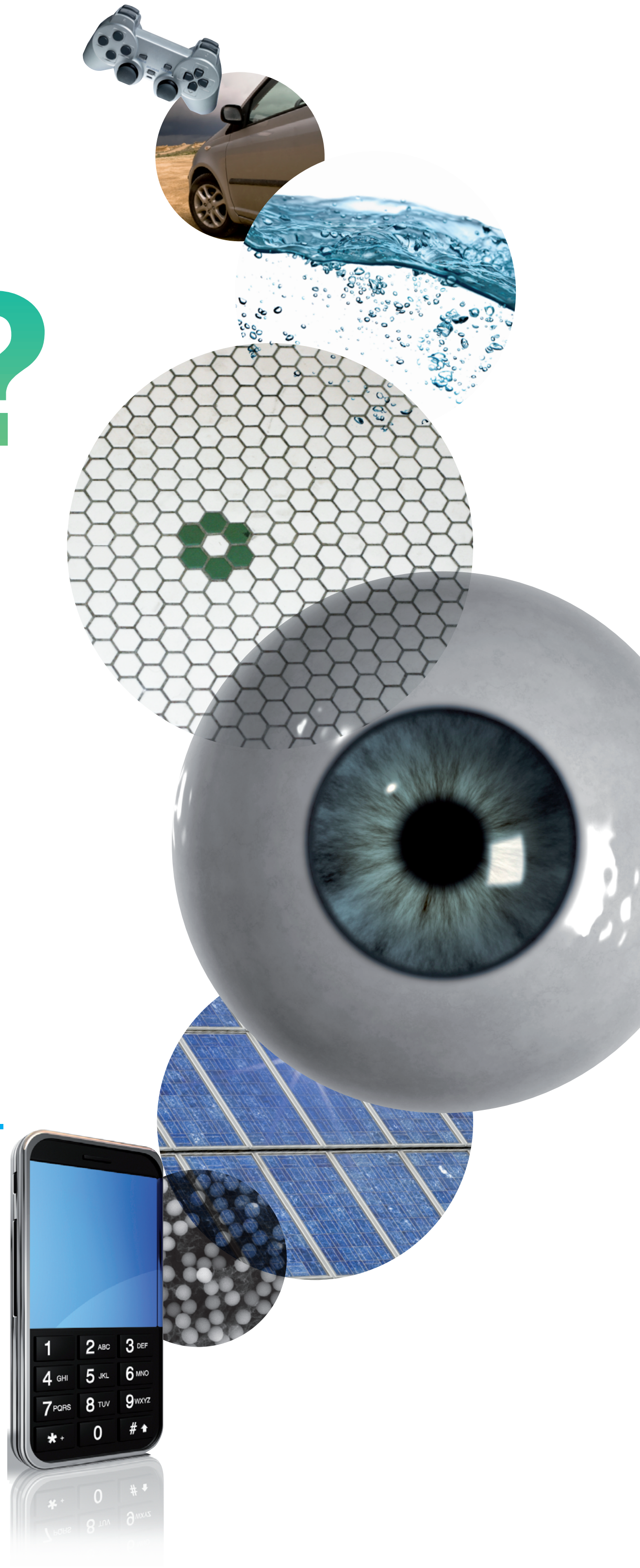
what is nano science?



This module serves as an introduction to nanoscience and nanotechnology. Nanoscience is becoming increasingly more prevalent in both society and industry. As a result, it is important to make pupils aware of what it is and how it can impact their lives. To enable discussion about nanoscience, pupils will first be introduced to the nanoscale. At the nanoscale, properties of materials differ from those of the same bulk material. In this module, these interesting effects that take place at the nanoscale will be discussed. To conclude this introductory module, examples of where nanotechnology can be used in our everyday lives are discussed.

Learning Outcomes

In this module, students will:

- Develop a general knowledge of nanoscience/nanotechnology.
- Become familiar with concepts of scale particularly at the nanoscale.
- Learn about interesting effects which take place at the nanoscale.
- Be able to list a range of industries where nanotechnology is applied.

teachers' notes

SYLLABUS LINKS

JC Science
→ The atom
→ Carbon
→ Cell size
→ Solar energy
→ Electronics

LC Biology
→ Cells (size)
→ Light microscope

LC Physics
→ S.I. Units
→ Semiconductors/Integrated circuits

LC Chemistry
→ Particle Size
→ Rates of reaction
→ Brownian motion

NCCA Proposed LC Revisions (2011)
→ Nanoscience terms
→ Nanoscale properties

SUGGESTED TIMING

Lesson plan
→ 40 minute class, with further 40 minute lab class and two further optional lab/activity classes

Introductory talk Teacher activity
→ 5 minutes

Powerpoint (PPT) presentation: Slides 1–6 Teacher activity
→ 25 minutes

Complete crossword/ word search Student activity
→ 10 minutes

Experiment One or Two Student & Teacher activity
→ 40 minutes

Presentations on research (Worksheet 3) Student activity
→ 40 minutes

Nano is a new buzz word in the scientific community. The word is used a lot more in society and in products such as the iPod nano. Nano has been mentioned in films like *Minority Report* and *Spiderman*. It has been in the news with increasing regularity. Governments and private organisations are spending more and more money on research at the nanoscale. But what exactly is nanoscience and why all the hype?

What is nanoscience and nanotechnology?

NANOSCIENCE is about studying how materials behave at a very small scale (at the nanoscale). A nanometre is one millionth of a millimetre. One millimetre is the smallest measurement visible on a 30 cm ruler. Nanoscience works on a scale 1000 times smaller than anything that can be seen with an optical microscope. It is not just one science, but a platform that includes biology, chemistry, physics, medicine, materials science and engineering.

NANOTECHNOLOGY is the manufacture and development of materials, devices and structures by applying an understanding of how materials behave at the nanoscale. Nanotechnology is now applied widely in the ICT (Information and Communications Technology) industry in the manufacture of smaller integrated circuits (computer 'chips') and more efficient data storage mechanisms. It is also used in the medical devices industry to make smaller products. Several commercial examples of nanotechnology are on the market, and many more promising applications of nanotechnology are being investigated. Nanotechnology will impact virtually every industry in the future.

In practice, the words 'nanoscience' and 'nanotechnology' are used interchangeably. 'Nano' by itself, is often used as shorthand to refer to these activities.

All about size

- The word 'nano' comes from the Greek word, 'nanos', meaning dwarf. It is a prefix used to describe one billionth of something (1/1,000,000,000 or 10^{-9}). A nanometre is one millionth of a millimetre.
- A human hair is about 50,000 – 100,000 nm wide. Typically nanoscientists work in the range of 1–100 nm. One nanometre is about one molecule or 3–10 atoms long (depending on the atom!).
- A red blood cell is about 10,000 nm wide.
- A common cold virus is about 30 nm tall.
- DNA is just 2 nm wide.

Optional Activity

Worksheet 2, 'How small is a nanometre' could be given as a blank template to students with only the headings (size divisions) filled out. They would then need to research everyday items that are the appropriate size and design a table.

Quirky fun size facts

Your fingernail grows about 1 nm in a second. Grass grows approximately 20 nm in a second. A man's beard grows 5 nm every second.

Why does size matter?

Objects at the nanoscale (less than 100 nm in at least one dimension) exhibit unexpected chemical and physical properties that are very different from the properties of bulk materials. The optical properties of gold behave differently at the nanoscale compared to the macroscale. While gold at the macroscale is a yellow colour, gold at the nanoscale can appear red.

The Lycurgus Cup, made by the Romans, dates to the fourth century AD. One of the very unusual features of the Cup is its colour. When viewed in reflected light, (in daylight) it appears green. When a light is shone into the cup and transmitted through the glass, it appears red. Medieval artisans were the first nanotechnologists. They knew that by putting varying, tiny amounts of gold and silver in glass, they could produce the multi-coloured effects found in stained-glass windows.

Large zinc oxide particles appear white, while at the nanoscale they are clear. This property is used in newer clear suncreams.

The chemical reactivity varies as the size of the particle changes. The purpose of the experimental activity outlined in this module is to demonstrate the different rates of reaction caused by particle size.

Why do properties change?

One reason why properties of structures are different at the nanoscale is because as particles get smaller, the ratio of surface area-to-volume of the structure increases. Most atoms are at or near the surface. Because chemical reactions take place on the surface of a particle, if there is an increased surface area available for reactions, the reaction can be very different.

Where can nanotechnology be used in our everyday lives?

Nanotechnology is becoming more and more prevalent and has the ability to affect all aspects of our lives; from clothing, cosmetics, computing and healthcare to futuristic ideas such as elevators to space. The study of materials behaviour and properties can be manipulated to make more lightweight, robust structures and smaller, more efficient devices across a range of industries.

Where is nanotechnology already being used?

- Carbon nanotubes are being used in the sports industry to make lighter and more robust equipment such as tennis rackets and lightweight bikes.
- Nanotechnology is used in surface coatings which have special properties like water, fire or scratch resistance, or are self cleaning e.g. in waterproof and stain-resistant clothing, paint, self-cleaning windows.
- Face-creams and cosmetics also contain nanomaterials (also called liposomes/ nanosomes), which help retain moisture and deliver active ingredients to cells.
- Nanotechnology is applied in the miniaturisation of computers and other electronics and in more powerful and efficient data storage techniques.
- Nanoscience is applied in the development of faster and more sensitive medical testing devices and treatments.
- Sun creams use nanoparticles of zinc oxide or titanium dioxide to absorb the harmful UV rays from the sun, while making the suncreams appear 'invisible'. Macro-sized particles are not transparent.
- Nanotechnology can help the environment – advances in nanoscience are producing more efficient solar cells and materials and devices which require lower operational energies. Nanoscience can also be used for water purification in developing countries.

We will examine these materials and products in greater detail in further modules, e.g. carbon nanotubes are covered in the 'Nano and Materials' module; the development of more efficient solar cells is described in 'Nano and the Environment'. The weblinks under 'Useful resources' at the end of this module provide more examples of how nanotechnology is being used around the world.

ACTIVITIES

Lab Activities

→ Teacher and student sheets are provided for two lab activities; one to help students appreciate surface areas and the second to investigate how surface area affects reactivity using Alka Seltzer tablets.

Worksheet: Crossword Solutions

ACROSS

- **2** Building block of every living thing: DNA
- **5** The number of nanometres a man's beard grows per second: five
- **7** The development of materials and devices at the nanoscale: nanotechnology
- **8** Chemical used in suncream: zinc oxide
- **10** Increasing this will change the reactivity of a material: surface area
- **12** Used to keep arteries open: stent
- **13** Type of carbon used in race cars and sports equipment: fibres

DOWN

- **1** The smallest thing the naked eye can see: hair
- **3** The science of studying materials at the atomic level: nanoscience
- **4** Colour of very small gold atoms: red
- **9** Self_____ when particles arrange themselves into an ordered system: assembly
- **11** This method is used for top down building of nanomaterials: etching

References

- snf.stanford.edu/Education/Nanotechnology.SNF.web.pdf
- www.97.intel.com/en/TheJourneyInside/ExploreTheCurriculum/EC_Microprocessors/MPLesson4/
- www.nanosense.org/activities/sizematters/properties/SM_Lesson3Teacher.pdf
- www.computerhistory.org/timeline/?year=1980

How do we make stuff using nanotechnology?

Broadly speaking, there are two approaches in nanotechnology for manufacturing:

TOP-DOWN – This can be considered as the miniaturization approach. It is the main technique used in the electronics industry, to make smaller more powerful computers. It involves building something by starting with a larger component and carving away material (like a sculpture). In nanotechnology, an example of this is with patterning (using photolithography) and etching away material, to build integrated circuits (computer 'chips'). More detail in how chips are built is given in the module 'Nano and ICT'.

BOTTOM-UP – Building something by assembling smaller components (like building a car engine). In nanotechnology, scientists are working on a greater understanding of the self-assembly of atoms and molecules, which happens naturally in chemical and biological systems.

Useful Resources

General
- www.nanoandme.org/home
- www.nano.gov
- www.nisenet.org
- www.nanoyou.eu
- www.nanoed.org
- www.nanozone.org

On Size and Nanorulers
- www.nano.gov/html/facts/The_scale_of_things.html
- www.nanotech-now.com/basics.htm
- www.sciencemuseum.org.uk/antenna/nano/lifestyle/122.asp
- www.microcosm.web.cern.ch/microcosm/P10/english/P0.html

Nanotechnology Applications
- www.nnin.org/nnin_edu.html
- www.nanotechproject.org/inventories/consumer

experiment 1

Aim
To develop a visual understanding of surface area, as items are made smaller and smaller.

Materials
- Blocks of cheese (feta is good) or tofu
- Knives
- Weighing scales

Method
- Students can work in teams to explore the increased surface area exposed as items are made smaller and smaller.
- Students work out the surface area of a whole block of cheese or tofu, and then the cumulative surface area of smaller blocks they create by cutting the original block in half, and quarters – down until all blocks created are at about ½ inch in width.
- To help visualise how the surface area has increased, get students to pour sugar on the tofu/cheese.

Expected outcome
- As the block is chopped up into smaller units, the surface area increases.
- A small amount of sugar is needed to coat the large tofu block, more sugar is required to coat all the tiny cubes cut from the large block of tofu.

experiment 2

Aim
To investigate how surface area affects reactivity

Materials
- Two empty film canisters and their lids per group (clear canisters work better than black) – you can buy a pack of 30 film canisters for about 25 euro from www.stevespanglerscience.com/product/film-canisters
- Two Alka Seltzer tablets per group
- One small mortar and pestle (or suitable implement to grind tablets)
- Safety glasses
- Clock/timer or watch with a second hand

Method
- Grind one tablet into powder using the mortar and pestle.
- Place the uncrushed Alka Seltzer and the crushed Alka Seltzer each into a different film canister. Each canister should contain Alka Seltzer before you proceed to the next step.
- Simultaneously fill each film canister halfway with tap water (do NOT fill completely) and immediately put their lids on.
- Time the two reactions.
- Record how much time it takes for each canister to blow its lid off.
- Rinse the film canisters with water when finished.

Expected outcome
The powdered tablet will react quicker than the full tablet due to the increased surface area.

Safety
- Safety glasses must be worn.

Suggested answers to Additional Questions

The reaction produces a gas, what tests could you use to identify this gas?

The gas produced is carbon dioxide. Limewater changes from clear to milky when carbon dioxide is bubbled through it.

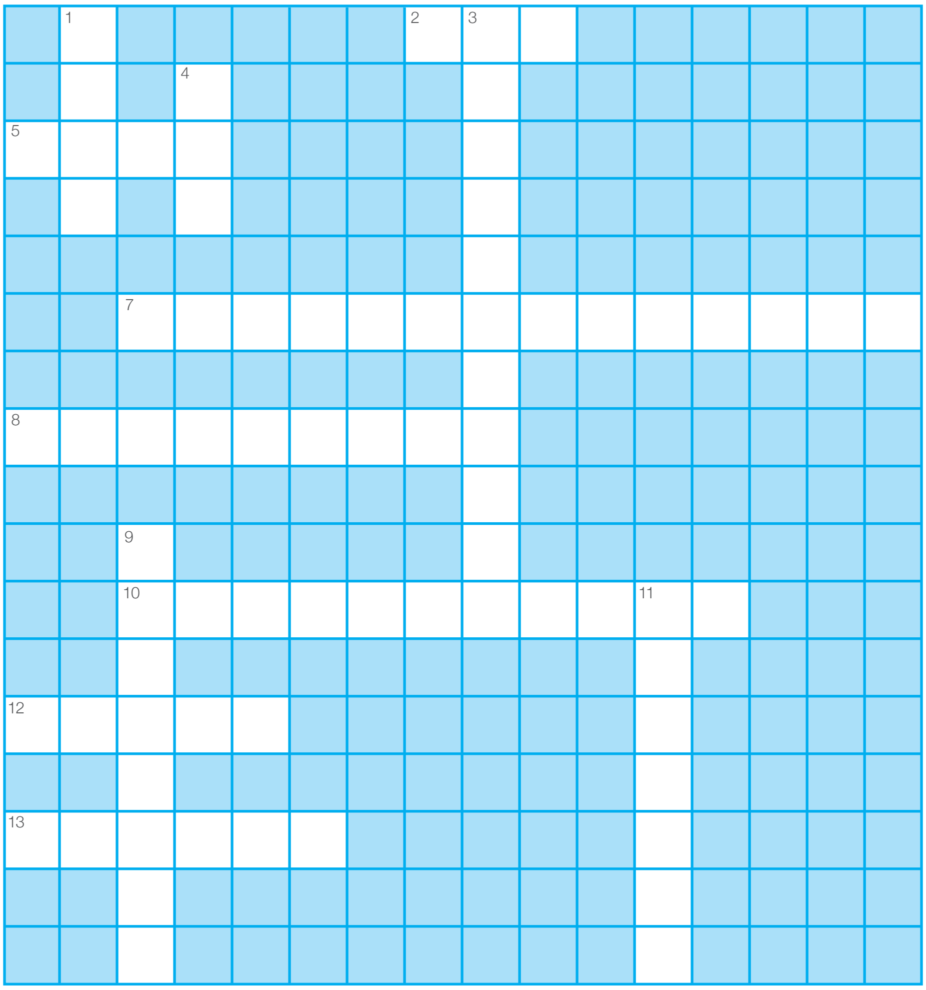
Was this experiment a fair test? Explain your answer

Variable: Amount of Alka-Seltzer in each canister – was there any loss of material on grinding?
Constants: Amount of water/canister/conditions, such as water temperature, which can play a role in the rate of reaction.

worksheet 1

Name

Date



Across

2 Building block of every living thing
5 The number of nanometres a man's beard grows per second
7 The development of materials and devices at the nanoscale
8 Chemical used in suncream
10 Increasing this will change the reactivity of a material
12 Used to keep arteries open
13 Type of carbon used in race cars and sports equipment

Down

1 The smallest thing the naked eye can see
3 The science of studying materials at the atomic level
4 Colour of very small gold atoms
9 Self________: when particles arrange themselves into an ordered system
11 This method is used for top down building of nanomaterials

The answers to all these clues can be found in the PowerPoint presentation 'Module 1: What is nano?'

worksheet 2

Name

....

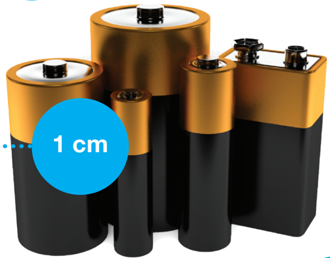
Date

....

How small is a nanometre?

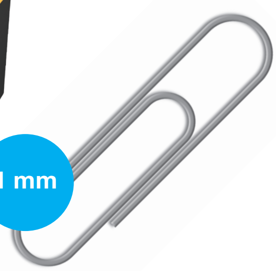
Start with a metre
A metre is about the length of a golf club, hurley or baseball bat

1 m



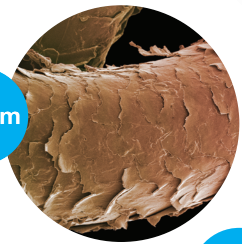
Now divide it into 100 equal parts.
Each part is one centimetre long. About the diameter of one AAA battery or the width of a nail on your finger.

1 cm



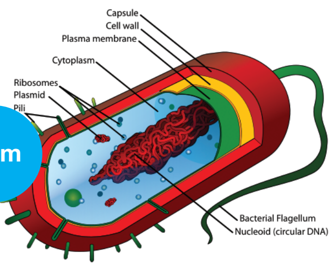
Now divide it into 10 equal parts.
Each part is one millimetre long. About the width of the wire on a paperclip or a grain of salt.

1 mm



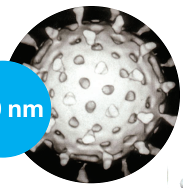
Now divide that into 10 equal parts.
Each part is 100 micrometres long. About the width of one human hair.

100 µm



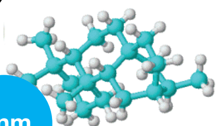
Now divide that into 100 equal parts.
Each part is a micrometre long. About the size of a bacterium.

1 µm



Now divide that into 10 equal parts.
Each part is a 100 nanometre long. About the size of a virus.

100 nm



Finally divide that into 100 equal parts.
Each part is a nanometre. About the size of a few atoms or a small molecule.

1 nm

worksheet 3

Name

Date

Where is Nanotechnology used?
Working in groups, research one product that uses nanotechnology and present an oral report to the class. You should also prepare a written report. The following questions should be addressed in your presentations.

What is the product and what is it used for?

Describe the nano part of the product – what nanoparticles or nanotechnology was used to make the product?

How has nanotechnology made the product more effective?

Try to find out whether you can buy this product locally? If not – where is the nearest place it can be bought? What is the price difference?

Further information

experiment 1

Name

Date

Aim

To develop a visual understanding of surface area as items are made smaller and smaller.

Materials and Equipment

- 2 identical blocks of cheese or tofu
- Knives
- Weighing scales

Method

1 Work out the surface area of the block of cheese/tofu.

Surface area of a rectangle = (Width x Height)
Surface area of a square = $side^2$
Surface area of a cube = 6 x $side^2$
(See diagram below right)

2 Cut one block in half and work each half's surface area and the cumulative area.
3 Cut the block in quarters and work out each surface area and the cumulative area.
4 Repeat the step above until the blocks created are about ½ inch in width.
5 Weigh the block of uncut tofu/cheese and take note of the weight.
6 Pour some sugar on the uncut tofu/cheese, until it is all covered.
7 Coat sugar on the individual pieces of the cut block of tofu/cheese.
8 Weigh the block covered in sugar and the individual pieces.
9 How much sugar is required to coat one large block, compared to all the cubes?

Adapted from 'Exploring at the Nanoscale', www.tryengineering.org

	1 block	2 blocks	4 blocks	8 blocks	16 blocks
Surface area					

Conclusions

experiment 2

Name

Date

Aim
To investigate how surface area affects reactivity.

Set-up
Work in groups of 2.

Materials and Equipment
- Two empty film canisters and their lids per group
- Two Alka Seltzer tablets per group
- One small mortar and pestle (or suitable implement to grind tablets)
- Clock/timer or watch with a second hand

Method
1. Grind one tablet into powder using the mortar and pestle.
2. Place the uncrushed Alka Seltzer and the crushed Alka Seltzer each into a different film canister. Each canister should contain Alka Seltzer before you proceed to the next step.
3. Simultaneously fill each film canister halfway with tap water (do NOT fill completely) and immediately put their lids on.
4. Time the two reactions.
5. On your lab sheet, record how much time it takes for each canister to blow its lid off.
6. Rinse the film canisters with water when finished.

	Time to dissolve	Observations
Whole tablet		
Powdered tablet		

Conclusions: Compare the results. Which reaction took place faster? Why?

Additional Questions

The reaction produces a gas, what tests could you use to identify this gas?

Was this experiment a fair test? Explain your answer.