Edexcel GCSE Chemistry

Your notes

Bulk & Surface Properties of Matter Including Nanoparticles

Contents

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Nanoparticles

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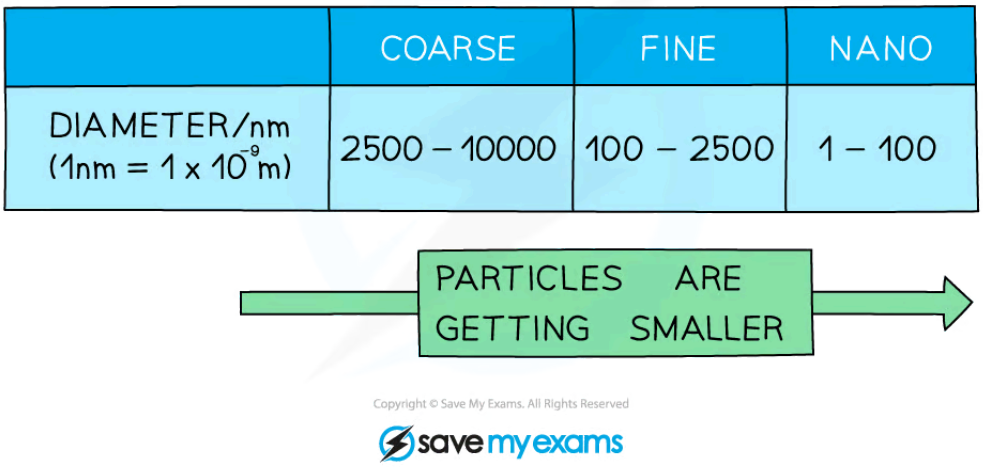
Size of Nanoparticles

- Particles can be placed into one of three categories according to their diameter:
  - Coarse particles (also called particulate-matter or dust)
  - Fine particles
  - Nanoparticles



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The diameter in nanometres used to classify particles

- Nanoparticles are between 1 and 100 nanometres in size and usually contain only a **few hundred atoms**
- Atoms and simple molecules are around 100 times smaller than this
- Nanoparticles are much smaller than **fine particles** which have diameters of between 100 and 2500 nm
- The research into the production and application of nanoparticles is called **nanoscience**

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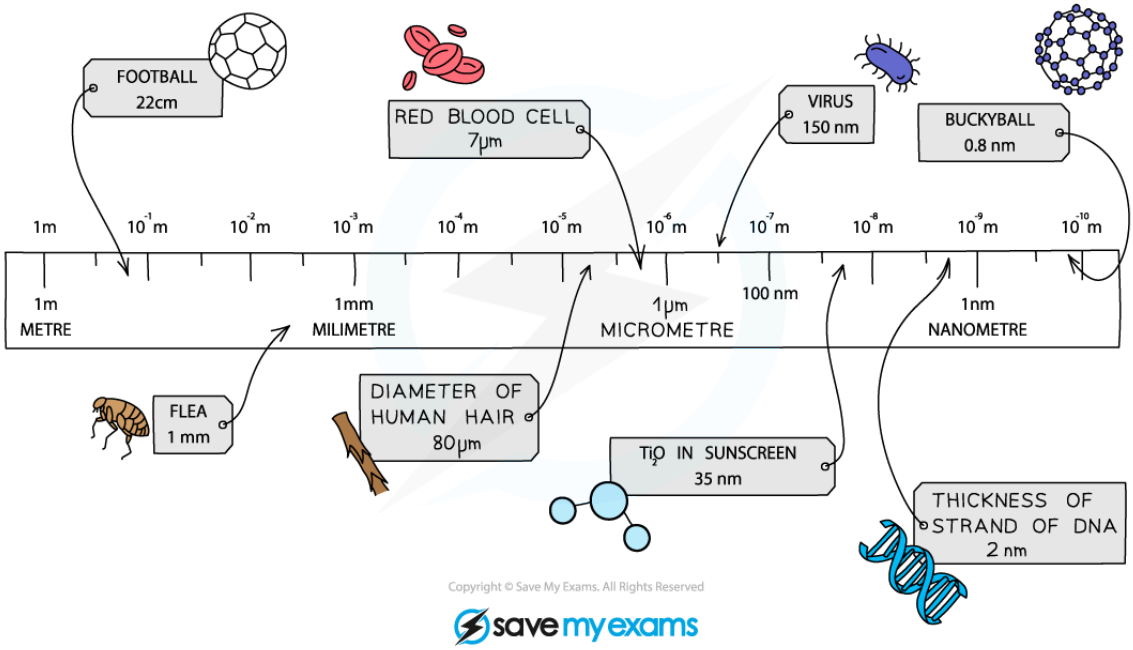

Diagram showing the size of nanoparticles relative to other objects and substances

Examiner Tips and Tricks

1 nanometre = 1×10^{-9} m = 0.000 000 001 m.

Properties of Nanoparticles

- One of the most interesting features of nanoparticles is their very high **surface area** to **volume** ratio
- As particles decrease in size, their surface area **increases** in relation to their volume
- As the side of a cube decreases by a factor of 10, the surface area to volume ratio increases by a factor of 10
- This is why nanoparticles may have properties different from those for the same materials in bulk
- It may also mean that smaller quantities are needed to be effective than for materials with normal particle sizes
- Fullerenes (nanoparticles made of carbon) behave very differently to larger compounds of carbon like diamond and graphite

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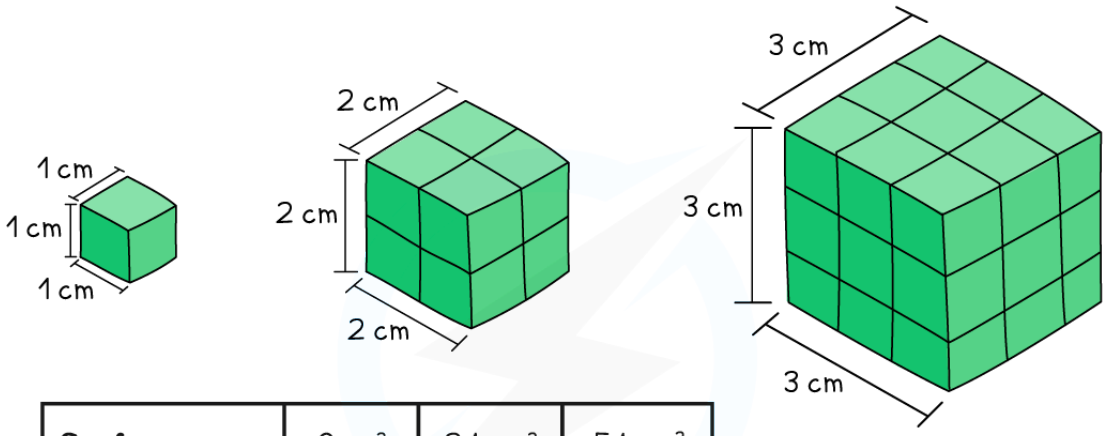
- The surface area to volume ratio is an important feature in **catalysis** and **surface chemistry**
  - The **higher** the ratio then the more surface area is available for reaction, hence the **better** the catalyst



Surface area	6 cm^2	24 cm^2	54 cm^2
Volume	1 cm^3	8 cm^3	27 cm^3
Surface area : volume	6:1	3:1	2:1

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This diagram shows the surface area to volume ratio of three different sizes cubes

- The main industrial application of nanoparticles is in **catalysis** due to their high surface area to volume ratios
- Titanium dioxide is a good example of how the same chemical has different properties in bulk and nanoparticle form
- Titanium dioxide in **nanoparticle** form is used in **sunscreens** as it blocks **UV light** but leaves **no white marks** on the skin
- The same chemical in **bulk form** is used as a **white pigment** in paints
- Fullerenes are used in the **medicine** and **drug design** as they are more easily absorbed than other particles and can deliver drugs to target areas more effectively
- Fullerenes are also used in **electronic circuitry** and as **coatings** for artificial limbs and joints
- Nanoparticles of silver are sprayed onto the fibres of medical clothing and surgical masks which gives them the flexibility of a material but with the added benefit of the **antibacterial** properties of silver

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Examiner Tips and Tricks

Nanoparticles display different properties to the same element in bulk form due to their high surface to volume ratio.

Risks

- Nanoparticles have widespread uses and applications that can provide an immense advance in materials technology
- The use of nanoparticles in science is in its **early stages** so there are still a lot of **unknown** factors and potential risks
- In particular there is a lack of understanding on how they may affect **health**
- Although there haven't been any serious **short term** side effects, there could be long term side effects which we haven't detected yet as they haven't been in use long enough
- Even a small amount of toxicity in a particular nanoparticle would be multiplied due to the high surface area to volume ratio
- This coupled with the fact that they are not easily disposed of by the body are a cause for caution in the medical application of nanoparticles

Examiner Tips and Tricks

You may be asked to explain other uses of nanoparticles not included here but you will be given sufficient information in the question to be able to provide a fully developed answer.

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Ceramics, Polymers, Composites & Metals

The physical properties of glass and clay ceramics, polymers, composites and metals are related to their uses:

Glass Ceramics

- Transparent and strong, glass **insulates** against heat
- Glass ceramics are also more **durable** than other materials hence they are better suited for use in windows than plastic
- Most of the glass produced is soda-lime glass which is made by heating a mixture of limestone, sand and sodium carbonate (soda) until it melts
- On cooling it solidifies to form glass
- A variation is **borosilicate glass** which is made using sand and boron trioxide and has a higher melting point than soda-lime glass

Clay Ceramics

- These are hardened materials that resist **compressive forces**
- Clay is a soft material dug up from the earth which hardens at high temperatures and when it is **fired**, produces a very strong and hard material
- This allows bricks to be used to build walls which withstand the **weight** and **pressure** of the material bearing downwards on itself

Polymers

- Can be tailor designed to have **specific properties** for specific uses
- Can be made **opaque** or **transparent**
- Usually **tough** and **flexible**, some specialist polymers can be brittle
- Poor conductor of heat and electricity

Composites

- Made from two components: **reinforcement** and **matrix**
- The matrix is what binds the reinforcement together
- Common examples include **fibreglass** and steel reinforced **concrete**

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- The properties of composites depend on the reinforcement and matrix used so composites can be **tailor engineered** to meet specific needs

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Examples of Everyday Composite Materials

Composite	Reinforcement	Matrix
Concrete	Steel	Concrete
Fibreglass	Glass fibres	Polymer resin
Carbon fibre / tubes	Carbon fibres / nanotubes	Polymer resin

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Metals

- **Shiny**, **malleable** and **ductile** so can be hammered into different shapes
- Can be mixed with other elements to form **alloys**, which have **different properties** to the elements they contain
- Corrosion resistant metals can be produced which last longer than other metals
- Good conductors of heat and electricity

Effective Use of Materials

Glass & Metals

- Glass and steel are extremely useful building materials
- Apart from its transparency, the hardness and the high compressive strength of glass makes it an ideal material for making walls and windows
- Metals are used extensively in **electrical cabling** and in **electronics** due to their ability to **conduct electricity**
- **Copper** is the most frequently used as it is a good conductor and is very malleable and easy to thread into cables
- **Aluminium** is a very strong metal but is also very **light**
- This makes it ideal for use in the construction of airplanes as it has a high **strength-to-weight** ratio

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Glass and metals are exceptional building materials due to their high strength and durability

Composites

Reinforced concrete

- Steel reinforced concrete has immense **tensile** and **compressive strength** allowing it to be used as columns and supporting structures in construction

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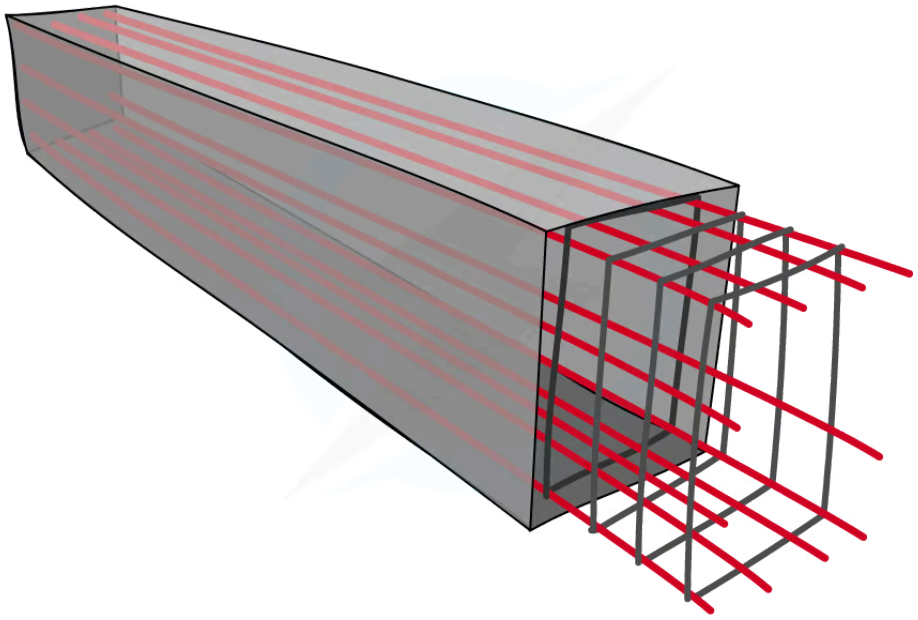

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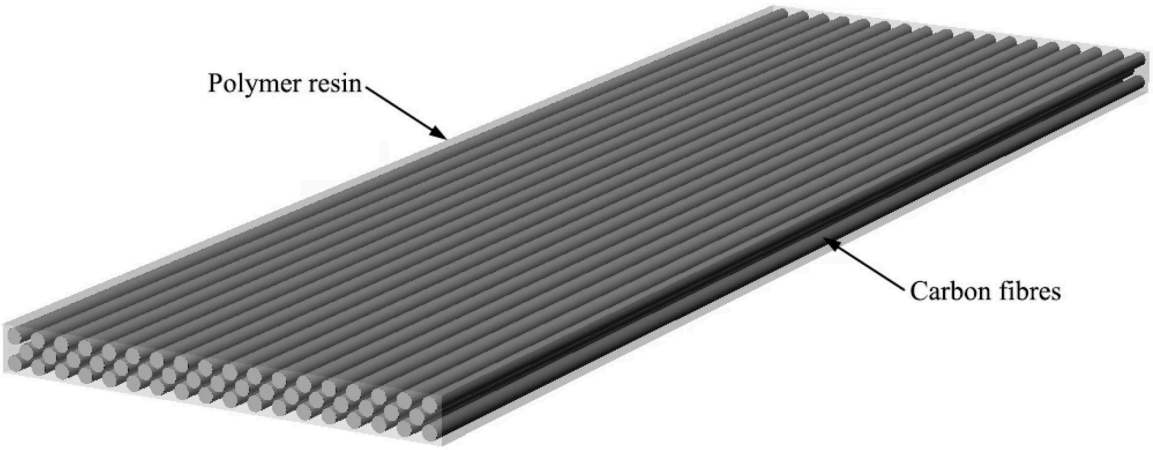
Diagram showing a concrete beam which is reinforced with steel, providing much more tensile strength

Carbon-Fibre Composites

- Carbon fibres composites are extremely **strong** and **low weight,** hence they are used in aviation, aeronautics and for making professional racing bicycles



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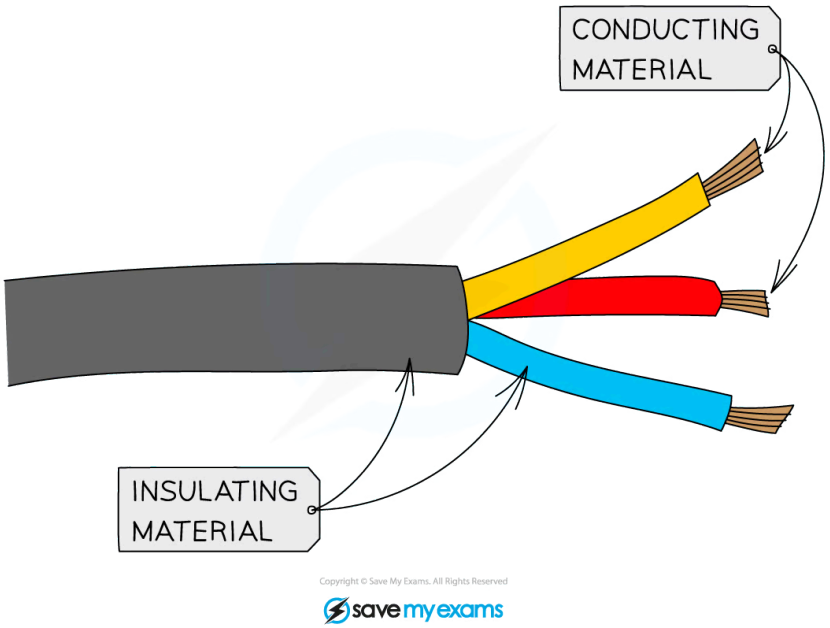
Carbon fibre composites have a very high strength to weigh ratio

Polymers

- As they are poor conductors of heat and electricity, this makes polymers good **thermal** and **electrical** insulators
- These properties are extremely useful for **insulating electrical wiring** as they prevent **electric shocks** and **overheating**
- The low melting points and flexibility of polymers enable them to be moulded easily into an infinite variety of shapes



The plastic coating on electrical wires makes use of the flexibility and insulating properties of polymers

Examiner Tips and Tricks

Don't get confused between an alloy and a composite: Alloys are uniform mixtures of metals whereas composites have two or more distinguishable materials.

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