Level 3 Certificate/Extended Certificate
APPLIED SCIENCE

Unit 3 Science in the Modern World

January 2023

Pre-release Material

- This pre-release material should be opened and issued to learners on or after **1 November 2022**.
- **A clean copy of the pre-release material will be provided at the start of the examination.**

Information

This pre-release material is to be issued to learners for use during preparation for this examination. The pre-release material consists of four sources (**A–D**) on the subject of **Nanotechnology**.

This material is being given to you in advance of this examination to enable you to study each source in preparation for questions based on the material in **Section A** of the examination.

A wider understanding of the topics and issues raised in the sources would be beneficial for the assessment. You are not required to understand any detailed scientific explanations beyond that outlined in **Sources A–D** and that in the Applied Science specification.

You may write notes on this copy of the pre-release material, but you will not be allowed to bring this copy, or any other notes you may have made, into the examination room. You will be provided with a clean copy of this pre-release material at the start of the examination.

It is suggested that a minimum of three hours detailed study is spent on this pre-release material.

IB/M/Jan23/E8

Source A: Adapted article from *Explain that Stuff*

Nanotechnology

by Chris Woodford

Nanotechnology article not reproduced here due to third party copyright restrictions.

Nanotechnology article not reproduced here due to third party copyright restrictions.

Nanotechnology article not reproduced here due to third party copyright restrictions.

END OF SOURCE A

Source B: Adapted article from *The Conversation*, 15 February 2017

Five ways nanoscience is making science fiction into fact

Original article published in *The Conversation* on February 15, 2017
Also published as an academic blog on the Cardiff University website on January 22, 2019
by Josh Davies – Research Student, School of Chemistry, Cardiff University

Russian author Boris Zhitkov wrote the 1931 short story *Microhands*, in which the narrator creates miniature hands to carry out intricate surgeries. And while that was nearly 100 years ago, the tale illustrates the real fundamentals of the nanoscience researchers are working on today.

Nanoscience is the study of molecules that are one billionth of a metre in size. At this tiny size, materials possess properties that lie somewhere between a lump of metal and that of a single atom. This unique environment means they can become very reactive and be used as catalysts. The ideas behind nanoscience are often easier to understand when considered simply in terms of how a single material's properties change. But the field is not limited to just that: we are now moving into the realm of healthcare therapies, and vehicles smaller than a speck of dust. What were once regarded as science fictions are rapidly becoming fact.

1. Medi-gels

In video games like Bioware's *Mass Effect*, players are able to heal characters' injuries with the seemingly miraculous medi-gel. Though it may not give you the unlimited life or epic adventure that a video game can, there is a real-life gel that can similarly stop an arterial bleed in seconds.

'Veti-gel' is made of polysaccharide polymers found in the cell walls of plants which, when applied to wounds, can mimic the structure of the extracellular matrix – the complex web in which cells sit. The gel essentially acts as scaffolding for the matrix to reform, pulling it back together and stopping bleeding without any pressure.

2. Healing molecules

Indeed, wound healing is a key feature of many an action-packed science fiction plot line. Handheld tools have already been created, similar to Star Trek's dermal regenerator, to heal injuries.

On the nano-level, a team has developed gel nanoparticles which target a specific enzyme which slows the migration of skin cells to wounds. They hypothesised that reducing the levels of this enzyme would increase rates of wound healing. However, delivering the molecules of Silencing RNA (SiRNA) needed to slow the enzyme down would normally be difficult, as unprotected chains of RNA quickly degrade within the body. So these SiRNA molecules were placed inside nano-sized gel shells to aid uptake and their transport into cells. Wounds treated this way healed twice as fast as those which were not, while maintaining normal tissue regeneration.

3. Self-repairing tech

The film *Terminator 2* features an evil robot that can repair itself, 'healing' in a few seconds. Thankfully, the reality is nowhere near as scary – though we are close to having technology that fixes itself.

Chemists have devised self-healing carbon fibre polymers that break when stress is applied, allowing an epoxy resin to seep from the material and mix with a catalyst. When the resin and catalyst come into contact, a strong plastic with a healing efficiency of up to 108% is formed. At a basic level, this may mean that we need never worry about a cracked phone screen again. But it could also repair the tiny cracks that develop on planes while they are in flight, or even seal bullet holes.

4. Racing micro-cars

In 1966, cinema-goers were wowed as the crew of a submarine was shrunk down to microscopic size, and injected into the body of a scientist in the film *Fantastic Voyage*. Though we are certainly not anywhere near injecting tiny humans into other humans, scientists have created molecular-size vehicles that can be driven in particular directions.

Turn over ►

In 2011, scientist Ben Feringa constructed a four-wheeled nanocar, comprised of four molecular motors on a carbon chain chassis. With wheels only 60 atoms in size and a width 666 666 666 times smaller than a Formula 1 car, it might be hard to imagine driving, let alone racing, these tiny vehicles. But in 2017 the first two-day nanocar race will take place. Teams will compete on a course made entirely of gold, painstakingly constructed atom by atom. Extra atoms will be placed on the surface to act as obstacles which competitors will have to navigate around.

5. Fantasy foods

Roald Dahl's Charlie and the Chocolate Factory has made millions of mouths water over the years, thanks to the author's vivid descriptions of quirky tastes and inventive sweets.

In reality, there aren't chewing gums that taste like a three-course dinner – just yet – or fizzy pop that makes you fly. But food manufacturers have been working on ways to change tastes and textures using molecular technology. Australian bakery Tip-Top are using nanocapsules to add omega-3 oil to bread. The capsules only open in the correct environment – the stomach – and so can bring the benefits of Omega-3 without the unpleasant taste. Likewise, companies such as Nestle and Unilever are also researching nanocapsules to improve the texture of their food.

Though nano-technology can't do everything that science fiction has promised just yet, it is changing the world as we know it. And the smaller we continue to go, the bigger the potential will be.

END OF SOURCE B

Source C: Adapted article from *PHYS.ORG*, 20 August 2019

A new way to deliver drugs with pinpoint targeting

by David L. Chandler, Massachusetts Institute of Technology
AUGUST 20, 2019

Most pharmaceuticals must either be ingested or injected into the body to do their work. Either way, it takes some time for them to reach their intended targets, and they also tend to spread out to other areas of the body. Now, researchers at MIT and elsewhere have developed a system to deliver medical treatments that can be released at precise times, minimally invasively, and that ultimately could also deliver those drugs to specifically targeted areas such as a specific group of neurons in the brain.

The new approach is based on the use of tiny magnetic particles enclosed within a tiny hollow bubble of lipids (fatty molecules) filled with water, known as a liposome. The drug of choice is encapsulated within these bubbles, and can be released by applying a magnetic field to heat up the particles, allowing the drug to escape from the liposome and into the surrounding tissue.

The findings are reported today in the journal *Nature Nanotechnology* in a paper by MIT postdoc Siyuan Rao, Associate Professor Polina Anikeeva, and 14 others at MIT, Stanford University, Harvard University, and the Swiss Federal Institute of Technology in Zurich.

"We wanted a system that could deliver a drug with temporal precision, and could eventually target a particular location," Anikeeva explains. "And if we don't want it to be invasive, we need to find a non-invasive way to trigger the release."

Magnetic fields, which can easily penetrate through the body—as demonstrated by detailed internal images produced by magnetic resonance imaging, or MRI—were a natural choice. The hard part was finding materials that could be triggered to heat up by using a very weak magnetic field (about one-hundredth the strength of that used for MRI), in order to prevent damage to the drug or surrounding tissues, Rao says.

Turn over ►

Rao came up with the idea of taking magnetic nanoparticles, which had already been shown to be capable of being heated by placing them in a magnetic field, and packing them into these spheres called liposomes. These are like little bubbles of lipids, which naturally form a spherical double layer surrounding a water droplet.

When placed inside a high-frequency but low-strength magnetic field, the nanoparticles heat up, warming the lipids and making them undergo a transition from solid to liquid, which makes the layer more porous—just enough to let some of the drug molecules escape into the surrounding areas. When the magnetic field is switched off, the lipids re-solidify, preventing further releases. Over time, this process can be repeated, thus releasing doses of the enclosed drug at precisely controlled intervals.

The drug carriers were engineered to be stable inside the body at the normal body temperature of 37 degrees Celsius, but able to release their payload of drugs at a temperature of 42 degrees. "So we have a magnetic switch for drug delivery," and that amount of heat is small enough "so that you don’t cause thermal damage to tissues," says Anikeeva, who holds appointments in the departments of Materials Science and Engineering and the Brain and Cognitive Sciences.

In principle, this technique could also be used to guide the particles to specific, pinpoint locations in the body, using gradients of magnetic fields to push them along, but that aspect of the work is an ongoing project. For now, the researchers have been injecting the particles directly into the target locations, and using the magnetic fields to control the timing of drug releases. "The technology will allow us to address the spatial aspect," Anikeeva says, but that has not yet been demonstrated.

This could enable very precise treatments for a wide variety of conditions, she says. "Many brain disorders are characterized by erroneous activity of certain cells. When neurons are too active or not active enough, that manifests as a disorder, such as Parkinson’s, or depression, or epilepsy." If a medical team wanted to deliver a drug to a specific patch of neurons and at a particular time, such as when an onset of symptoms is detected, without subjecting the rest of the brain to that drug, this system "could give us a very precise way to treat those conditions," she says.

Rao says that making these nanoparticle-activated liposomes is actually quite a simple process. "We can prepare the liposomes with the particles within minutes in the lab," she says, and the process should be "very easy to scale up" for manufacturing. And the system is broadly applicable for drug delivery: "we can encapsulate any water-soluble drug," and with some adaptations, other drugs as well, she says.

Anikeeva says that while her team has focused on neurological disorders, as that is their speciality, the drug delivery system is actually quite general and could be applied to almost any part of the body, for example to deliver cancer drugs, or even to deliver painkillers directly to an affected area instead of delivering them systemically and affecting the whole body. "This could deliver it to where it's needed, and not deliver it continuously, but only as needed."

Because the magnetic particles themselves are similar to those already in widespread use as contrast agents for MRI scans, the regulatory approval process for their use may be simplified, as their biological compatibility has largely been proven.

END OF SOURCE C

Source D: Adapted articled from *PHYS.ORG, 21* August 2019

Colour-changing artificial 'chameleon skin' powered by nanomachines

University of Cambridge
AUGUST 21, 2019

Researchers have developed an artificial 'chameleon skin' that changes colour when exposed to light and could be used in applications such as active camouflage and large-scale dynamic displays.

The material, developed by researchers from the University of Cambridge, is made of tiny particles of gold, coated in a polymer shell, and then squeezed into microdroplets of water in oil. When exposed to heat or light, the particles stick together, changing the colour of the material. The results are reported in the journal *Advanced Optical Materials*.

In nature, animals such as chameleons and cuttlefish are able to change colour thanks to chromatophores: skin cells with contractile fibres that move pigments around. The pigments are spread out to show their colour or squeezed together to make the cell clear.

The artificial chromatophores developed by the Cambridge researchers are built on the same principle, but instead of contractile fibres, their colour-changing abilities rely on light-powered nano-mechanisms, and the 'cells' are microscopic drops of water.

When the material is heated above 32 °C, the nanoparticles store large amounts of elastic energy in a fraction of a second, as the polymer coatings expel all the water and collapse. This has the effect of forcing the nanoparticles to bind together into tight clusters. When the material is cooled, the polymers take on water and expand, and the gold nanoparticles are strongly and quickly pushed apart, like a spring.

"Loading the nanoparticles into the microdroplets allows us to control the shape and size of the clusters, giving us dramatic colour changes," said Dr Andrew Salmon from Cambridge's Cavendish Laboratory, the study's co-first author.

The geometry of the nanoparticles when they bind into clusters determines which colour they appear as: when the nanoparticles are spread apart they are red and when they cluster together they are dark blue. However, the droplets of water also compress the particle clusters, causing them to shadow each other and make the clustered state nearly transparent.

At the moment, the material developed by the Cambridge researchers is in a single layer, so is only able to change to a single colour. However, different nanoparticle materials and shapes could be used in extra layers to make a fully dynamic material, like real chameleon skin.

"This work is a big advance in using nanoscale technology to do biomimicry," said co-author Sean Cormier.

END OF SOURCE D

There are no sources printed on this page

There are no sources printed on this page

There are no sources printed on this page