Switch on STEM

SCIENCE

Chemistry of the Nanoworld

Introduction

Chemistry usually works with materials on a large scale. Even just a gram of a chemical consists of millions of millions of millions of molecules and chemical reactions affect all the particles in the sample.

Nanochemistry works with materials at the atomic level. The individual fullerene molecules or nanotubes have different properties from the bulk material. Fullerenes are molecules that are based around the C_{60} Buckminsterfullerene molecule.

Equipment

- Posters and display boards
- Molecular models of Fullerenes
- Ferrofluid in sealed container(s)
- Strong magnets
- Sunscreen with nanoparticles
- Zinc Oxide cream
- Security Pen
- UV light
- UV beads

Poster for backdrops

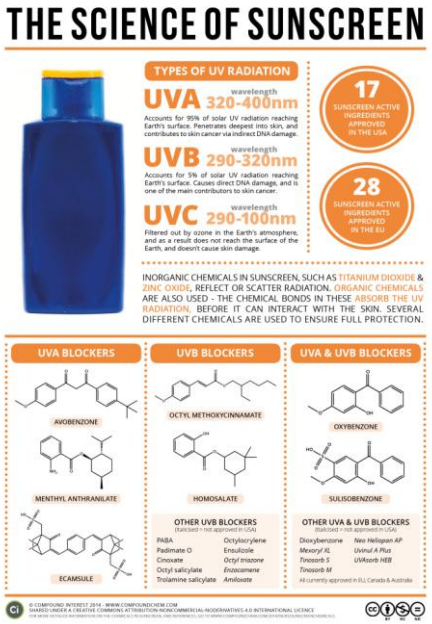
SOURCE

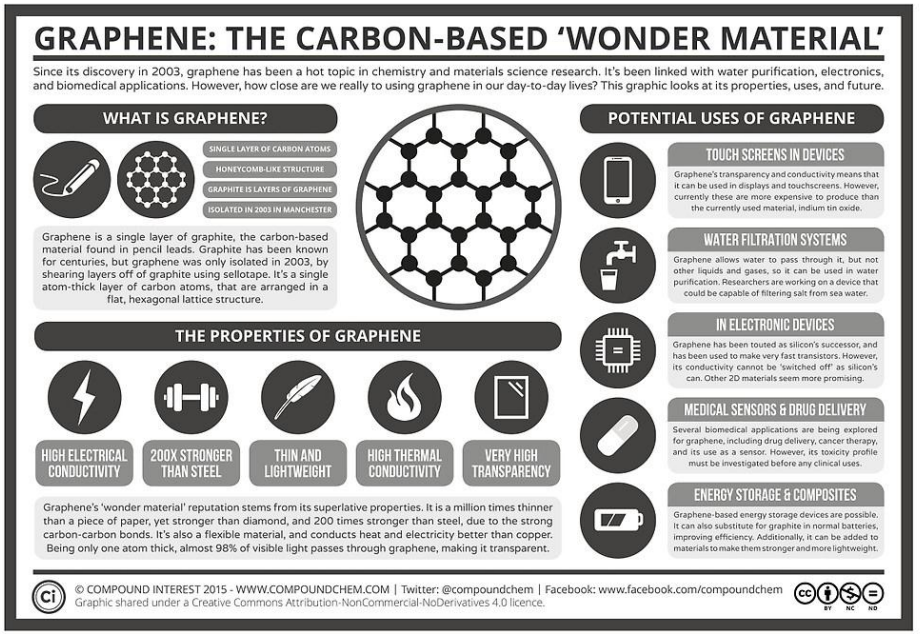
Compound interest

http://www.compoundchem.com/shops/

Poster orders

http://www.redbubble.com/people/compoundchem/shop





Equipment

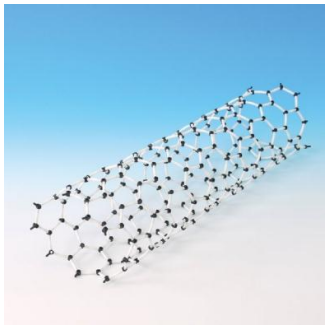
Molecular models

SOURCE

ShawScientific

MLM010100 Minit carbon nanotube model kit

2 @ €28.86

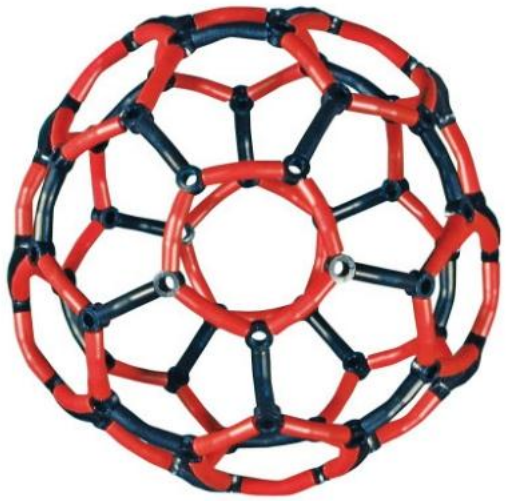


MMD 030030 Buckminsterfullerene kit

1 @ € 25.38

MLM035030 Orbit Carbon 60 – Fullerene

2@ € 8.21



Equipment: Ferrofluids

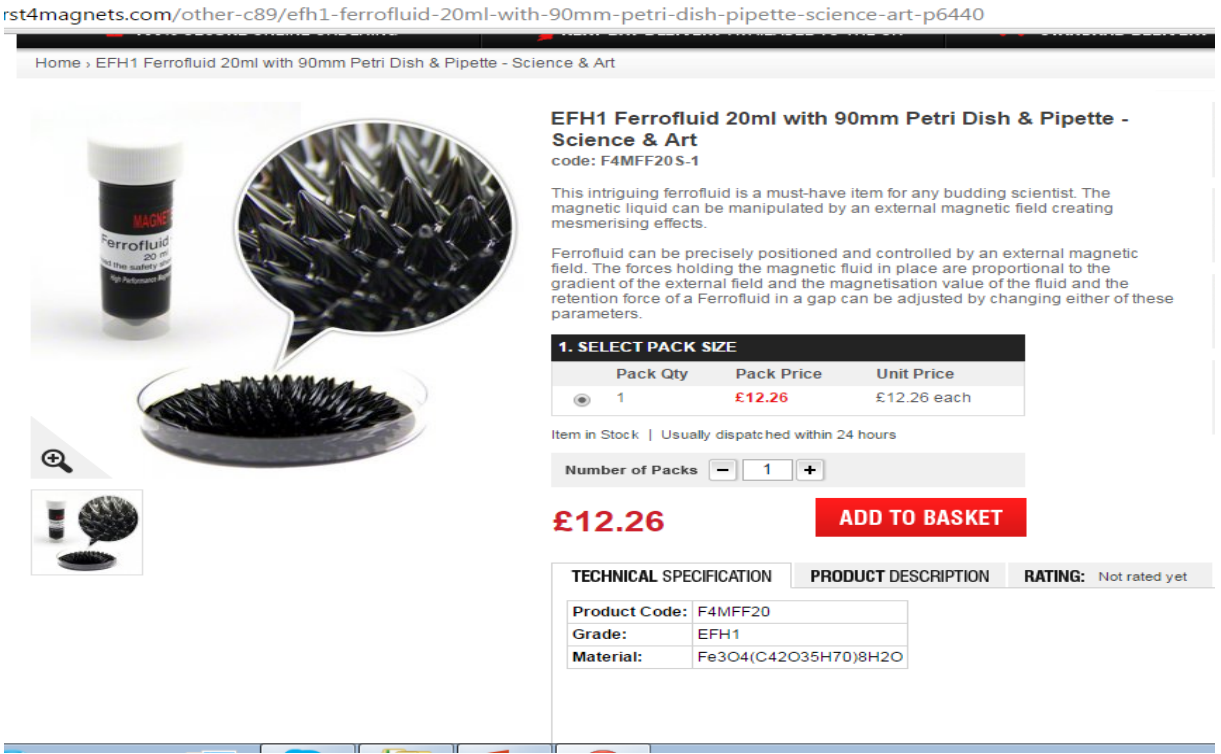
SOURCE: first4magnets.com €20 per unit

Pack of five ferrite magnets at approx. €5 (see next page)

Jam jars with lids (can see effect of external magnets easily)

Petri dishes (sealed when fluid inside)

Dropper pipettes



Chemistry – sample 3

Chemistry and the nanoworld

FERROFLUIDS

SOURCE: first4magnets.com

Pack of five ferrite magnets at approx. €5

Equipment

- Security pens http://cpcireland.farnell.com/security-markers-uv-pens 4 @ €5.50
- Source of UV light (torch or black box) Maplin €15
  - http://www.maplin.ie/p/ultraviolet-mini-lantern-uv-fluorescent-zc10l
- Body lotion without UV block
- Sun screen lotion SP15 up with nanoparticles of Zinc Oxide (see ingredient list)
- UV beads
  - http://www.amazon.co.uk/SolarActive%C2%AE-Colour-Changing-Beads/dp/B00IUNFO50/ref=sr_1_2?ie=UTF8&qid=1455276166&sr=8-2&keywords=UV+beads

Preparation and Set Up

- Gather and display the molecular models of the Buckyball and Carbon Nanotube.
- Prepare the Ferrofluid in sealed container(s)
- Familiarise yourself with the background information on fullerenes, ferrofluids and nano-active suncreams.

Demonstration Manual

- Introduce students to the concept of ‘nano’.
- Explain that ‘nano’ means 10^{-9} in the same way that ‘centi’ means 10^{-2} or 1/100.
- Say that nanometres are very small, the full stop in this sentence is 1,000,000 nanometres.
- Ask students to write their height on the worksheet in nanometres or measure other objects and write the size in nanometres.

Fullerenes

- Explain that Fullerenes are made from carbon atoms joined together to make balls, ‘cages’ or tubes of carbon. The molecules of Buckminster Fullerene are spherical and are also known as 'buckyballs' – formula C60.
- Show students the models of the Buckyball and the carbon nanotube.
- Explain that these are nano-sized molecules.
- Mention some applications of Nanotubes.

Ferrofluids

- Define what a Ferrofluid is: A ferrofluid is a suspension of magnetic nanoparticles in a fluid, usually iron oxide particles about 10 nanometres in size.
- Let the students see the effect of a magnet on the ferrofluid, moving it towards and away from the container.
- Ferrofluids behave as both liquids and solids. They are paramagnetic - behaving as (solid-like) magnets **only** in the presence of a magnetic field.
- Make sure the ferrofluid is in a sealed container as, while not toxic, it is extremely staining.

Suncream

- Ask students to write with the Security Pens.
- Show what they wrote using the UV light.
- Ask the students to put suncream on part of their writing. Alternatively ask some students to put zinc oxide cream on part of theirs.
- Leave the cream to act for a few minutes while you explain how nanoparticles in suncream work.

Suncream ctd.

- Wipe away all but a thin layer of the cream.
- Show that the writing underneath is no longer visible with the UV light.
- Be careful to minimise the student's exposure to the UV light.
- An alternative is to have UV beads in petri dishes, one half with sunscreen the other without.

Background Information

- Fullerenes are made from carbon atoms joined together to make balls, ‘cages’ or tubes of carbon. The molecules of Buckminster Fullerene are spherical and are also known as 'buckyballs' – formula C60.
- Buckminster Fullerene is a black solid although it's deep red when in solution in petrol.

- The tube fullerenes are called nanotubes which are very strong and are conductors of electricity. Their unusual electrical properties mean that nanotubes are used as semiconductors in electronic circuits. Their strength makes them useful in reinforcing structures where exceptional lightness and strength are needed for example, the frame of a tennis racket. They're also used as a platform for industrial catalysts.
- The nanotube’s structure allows it to be used as a vessel for transporting a drug into the body. A molecule of the drug can be placed inside the nanotube cage which keeps the drug ‘wrapped up’ until it reaches the site where it's required. In this way, a dose that might be prohibitively damaging to other parts of the body can be delivered safely to, say, a cancerous tumour.

- The structure of nanotubes involves a massive surface area. Spreading a catalyst, atom by atom, on the surface of a nanotube provides a huge surface area where reactants can come into contact with the catalyst.
- The examples above might be described as molecular manufacturing or nanotechnology. Building a product molecule by molecule, positioning molecules one at a time or producing nanoscale features by removing matter from a bigger structure may enable us to do things which only a short time ago were undreamed of.

- Ferrofluid is a colloidal suspension of small magnetic particles in a fluid. In a suspension, solid particles are dispersed. The viscosity of the fluid, the tiny size of the particles, and the particles' constant motion keep the solids from settling out. The magnetic particles in ferrofluid are around 10 nanometers in size. (A nanometer is a billionth of a meter.) Particles this size are known as colloids.
- The magnetic particles in ferrofluids are usually iron oxide (magnetite), synthesized in solution and precipitated as nanoparticles:
  - Iron salts (iron II chloride and iron III chloride) are mixed in a basic solution. Tiny particles of iron oxide (Fe_3O_4) precipitate from the solution.
  - The iron oxide particles are coated with a surfactant to keep them from sticking to each other.
  - The particles are dispersed in a water- or oil-based fluid.

- Iron oxide is the same compound as magnetite, a naturally magnetic mineral found in many igneous and metamorphic rocks. The first ferrofluids, developed by NASA in the 1960s, were ground from natural magnetite.
- How can it act like a liquid and a solid? Ferrofluid is superparamagnetic, a property that is found only at the nanoscale. At the macroscale, ferromagnetic materials (like refrigerator magnets) are permanently magnetic. But when ferromagnetic materials are nanometer-sized, they became paramagnetic, which means that they behave like magnets only in the presence of a magnetic field.

- When there is no magnet nearby, the magnetite particles in ferrofluid act like normal metal particles in suspension. But in the presence of a magnet, the particles are temporarily magnetized. They form structures within the fluid, causing the ferrofluid to act more like a solid. When the magnetic field is removed, the particles are demagnetized and ferrofluid acts like a liquid again.
- If you hold a euro note near a magnet after you have demonstrated the ferrofluid it should move because the ink used in printing contains ferrofluid. This special ink is used to deter counterfeit printing. The ferrofluid used in the ink also helps vending machines know if you've put in a five, ten or even twenty Euro note.

- How is this nano? A material can act differently when it's nanometer-sized. (A nanometer is a billionth of a meter.) Nanometer sized magnetite particles suspended in liquid (ferrofluids) behave like paramagnets, meaning that it's magnetic only in the presence of a magnet. But on the macroscale, magnetite is permanently magnetic.
- Nanotechnology takes advantage of special properties at the nanoscale—such as paramagnetism—to create new materials and devices.
- In addition to the ink used in printing paper currency, ferrofluid is used in rotary seals for computer hard drives and other rotating shaft motors, and in loudspeakers to dampen vibrations. In medicine, researchers are looking at ways to use ferrofluid as a contrast agent for magnetic resonance imaging (MRI).

Sunscreens

- The sunblock contains tiny, nanosized particles of zinc oxide. (A nanometer is a billionth of a meter.) The nanoparticles of zinc oxide are so small that they don’t reflect visible light, making the sunblock transparent on skin. The sunscreen is effective at absorbing UV radiation and keeping it from reaching your skin, but many people prefer sunblock that rubs in clear to other ointments.
- Research shows that sunblocks containing nanoparticles of zinc oxide and titanium dioxide are safe to use. The zinc and titanium minerals in the sunblock don’t go through the outer layer of healthy, adult skin. Still, some people have concerns about the use of nanoparticles in sunblock and other products.

- Many other health and beauty products contain nanosized particles, including hair products, cosmetics, and toothpaste. These products are not regulated by the U.S. Food and Drug Administration (FDA), and are not required to indicate whether their formulations include nanosized particles.
- Some people are concerned that the particle size of the ingredients may make a difference in how safe they are. That's because materials can act differently when they're nanosized—so just because something is safe on the microscale doesn't necessarily mean it's safe on the nanoscale. More research is needed before we can know for sure.

Links

Excellent video on Ferrofluids:

https://www.youtube.com/watch?v=kL8R8SfuXp8

Other Links:

- http://www.bbc.co.uk/schools/gcsebitesize/science/add_gateway_pre_2011/chemical/nanochemistryrev1.shtml
- http://www.nisenet.org/catalog/programs/exploring_materials_-_ferrofluid
- http://www.nisenet.org/catalog/programs/exploring_products_-_sunblock_nanodays_2011_2012
- http://www.nisenet.org/catalog/programs/exploring_properties_-_uv_bracelets_nanodays_2013