Nanotechnology (A2)

Science involving nano-sized particles is called nanoscience.

Nanotechnology involves particles whose size can be measured in nanometres.

Nanotechnology is the design and creation of machines that are so small and their measurement is in nanometres.

The scale of length:

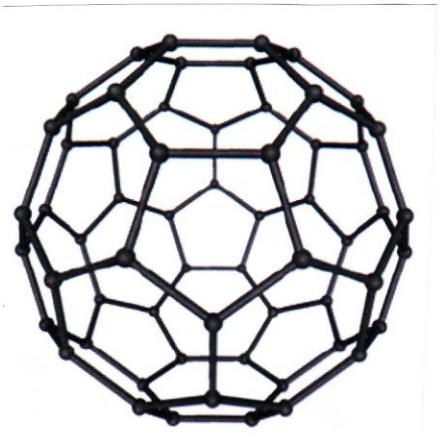
Small	attometre	am	0.00000000000000000001 m	1×10^{-18} m
	femtometre	fm	0.000000000000001 m	1×10^{-15} m
	picometre	pm	0.000000000001 m	1×10^{-12} m
	nanometre	**nm**	**0.000000001 m**	**1×10^{-9} m**
	micrometre	μm	0.000001 m	1×10^{-6} m
	millimetre	mm	0.001 m	1×10^{-3} m
	centimetre	cm	0.01 m	1×10^{-2} m
	metre	m	1 m	1×10^{0} m
	decametre	dm	10 m	1×10^{1} m
	hectometre	hm	100 m	1×10^{2} m
	kilometre	km	1000 m	1×10^{3} m
	megametre	Mm	1000000 m	1×10^{6} m
	gigametre	Gm	1000000000 m	1×10^{9} m
Large	terametre	Tm	1000000000000 m	1×10^{12} m

Buckyballs

A bucky ball has its full name as buckminsterfullerene.

It is composed entirely of carbon atoms.

It is a third allotrope of carbon.



a buckyball, or buckminsterfullerene

A total of 60 carbon atoms are present forming a sphere consisting of five-carbon and six-carbon atom rings arranged in the same pattern as the seams on a modern soccer ball.

It is just less than a nanometre in size.

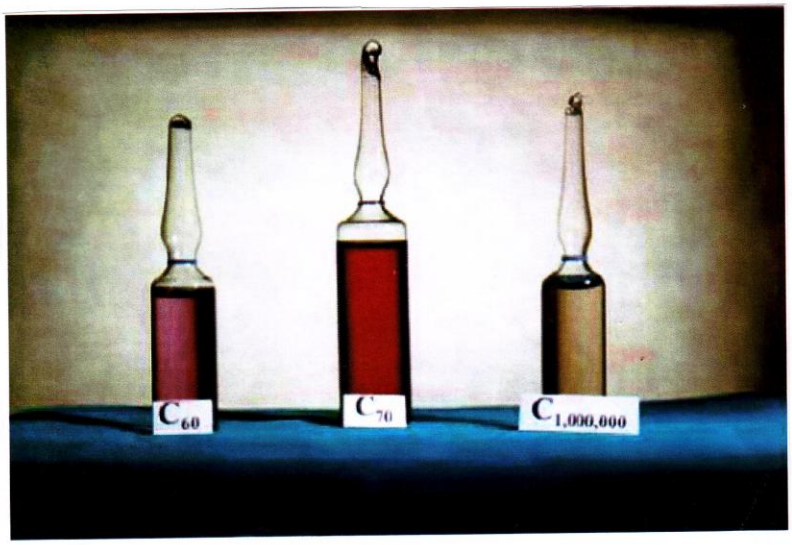
allotropes – the same element can exist in different forms in the same physical state.

Buckminsterfullerenes were first discovered during experiments with carbon clusters in supersonic beams.

Beside C_{60}, other sized balls have also been created.

Unlike other forms of carbon, fullerenes may be soluble.

Example: C_{60} is pink and C_{70} is red in solution.



buckyballs in solution

Macro and micro properties of buckminsterfullerene

Its properties determined by micro and macro structure of buckminsterfullerene.

Two aspects to look at:

- an isolated molecule
- a bulk sample of the material.

Low melting point and soluble in organic solvents

The bonding within a single molecule of buckminsterfullerene is very strong.
The bucky ball is very unlikely to be easily squashed or deformed.
So the molecule itself could be described as being hard.
But buckminsterfullerene has a low melting point, and is soluble in organic solvents.
It should have the typical properties of a compound whose intermolecular forces are mainly van der Waals'.
In bulk sample, buckminsterfullerene is expected to be soft, like a polycyclic hydrocarbon such as anthracene ($C_{14}H_{10}$).

Nano-sized ball bearings

As hard spheres, the molecules of buckminsterfullerene could be looked upon as nano-sized ball bearings.

Graphite is known for its slippery property, because the sheets of hexagonally-arranged carbon atoms can easily slide over one another.

Many greases contain graphite.

Perhaps in future, super greases will contain buckminsterfullerene.

Electrical conductivity

In buckminsterfullerene the carbon atoms are all joined by delocalised π bonds.

It would be expected that an electric current should easily pass around the molecular sphere.

However, transferring the current from one molecule to the next is another matter.

Electrons do not find it easy to jump from one molecule to another.

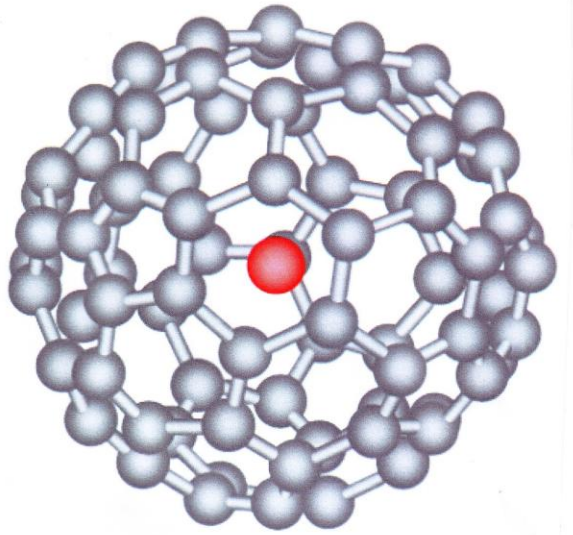
In bulk form, samples of simpler molecules that contain delocalised electrons (such as benzene) are good isulators.

NMR shows that electrons readily move around the aromatic ring within each molecule.
However, if the delocalisation is extended in space, such as in the long conducting polymers, then the energy gap between molecules can be bridged.

Development of buckminsterfullerene

The above mentioned restrictions apply to the relatively small buckminsterfullerene molecule only.
These may be overcome by designing and synthesising larger molecules that contain buckminsterfullerene-type elements.

A buckyball can enclose an atom of another element inside itself.
This can be a reactive element or molecule such as a lanthanum atom.
The highly reactive atom becomes trapped like a 'tiger in a cage'.



lanthanum atom caged in a buckyball.

While lanthanum atom is protected by the carbon cage it cannot react.
As soon as the cage is removed, it can react again

Exercise 1

What is meant by nanoscale objects?

Workings

objects whose size ranges from 1×10^{-9} to 1×10^{-7} metres; i.e. from 1 to 100 nanometres

Exercise 2

Buckminsterfullerene is an allotrope of carbon. What is an allotrope?

Workings

Allotropes are different forms of the same element in the same physical state.

Exercise 3

One type of nuclear magnetic resonance (NMR) analyses the ^{13}C isotopes in carbon and its compounds. As proton NMR produces peaks for each type of non-equivalent ^{1}H atom, carbon-13 NMR shows peaks for each non-equivalent carbon atom. Predict the number of peaks on the carbon-13 NMR spectrum of buckminsterfullerene.

Workings

A single peak as all the carbon atoms in C_{60} are equivalent.

Exercise 4

What would you expect to see on a proton NMR spectrum of buckminsterfullerene?

Workings

No peak as there are no hydrogen atom present.

Exercise 5

Which form of carbon has bonding similar to that found in fullerenes?

Workings

Graphite.