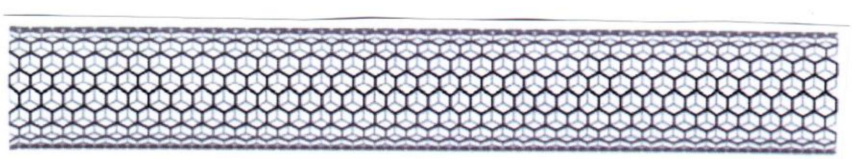
Carbon nanotubes.

The discovery of buckyballs led to the discovery of other forms of carbon that are structurally related, e.g. carbon nanotubes.

These are cylindrical in structure and also resemble a rolled-up sheet of graphite, with the carbon molecules arranged in repeating hexagons.

They have a diameter of a few nanometers and can be open at both ends, sealed at one end or sealed at both ends.



a carbon nanotube open at both ends.

Carbon nanotubes have proved to have very useful properties.

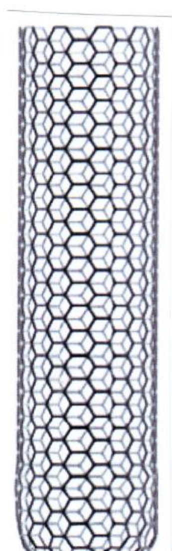
'Mini but Mighty', they are many times stronger than steel.

The mechanical (stiffness, strength, toughness), thermal and electrical properties of pure buckytube materials enable a multitude of applications, from batteries and fuel cells to fibres and cables to pharmaceuticals and biomedical materials.

They are found in the batteries of most laptop computers.

<u>The world's smallest test-tube</u>

The world's smallest test-tube has been made from a carbon nanotube.



a carbon nanotube closed at one end - a nano 'test-tube'

One end of the tube is closed by a fullerene cap that contains both pentagons and hexagons.

The tube has a volume of $1 \times 10^{-24} dm^3$.

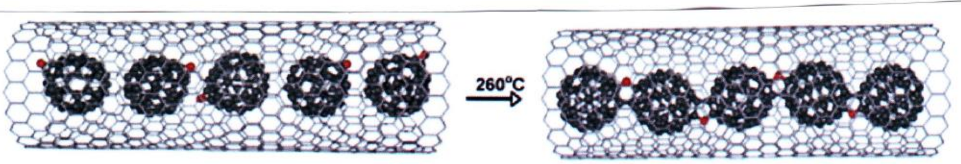
The tube has enabled Oxford scientists to use the tube's one-dimensional cavity to provide a template for the synthesis of unbranched polymer chains of $C_{60}O$, fullerene oxide.

This process normally requires expensive catalysts that are sensitive to air and water.

Without the one-dimensional cavity, the polymer would branch in all directions.

Reactions in nanoscale test-tubes

The potential of nanoscale test-tubes for carrying out reactions is being explored. The nanoscale test-tube has various derivatives attached, is shown as follow:



a chemical reaction in a nanotube – polymerisation of $C_{60}O$ to form $(C_{60}O)_n$

These could be immobilised enzymes enabling fast reactions in the synthesis of new drugs. There are distinct advantages of carrying out these reactions on a nanoscale.

In a normal test-tube, the particles have to collide to react and these collisions rely on random movement.

In many reactions not all the particles react, or unwanted side-products are produced.

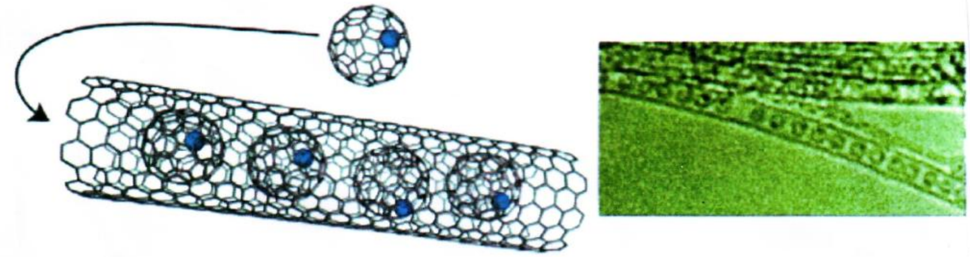
These problems result in reduced yield.

By contrast, a nanoscale reaction, where individual molecules are brought together, can have an exceedingly high yield.

Trapped atoms in a carbon nanotube.

Another kind of structure being developed involves buckyball cage containing trapped atoms.

These buckyball cages are then entrapped inside a nanotube, rather like peas in a pod.



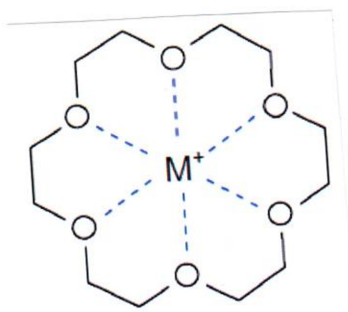
'peas in a pod' – buckyballs containing trapped atoms, themselves inside a carbon nanotube.

The purpose of this work by scientists in Oxford is to investigate the structure as an information storage display.

Supramolecular chemistry - making super-molecules

Supramolecular literally means 'beyond the molecule'. Due to molecules can recognise each other, biological molecules such as enzymes recognise and bind other molecules.

Crown ethers were created as synthetic molecules which can recognise and bind to metal ions to form a complex.



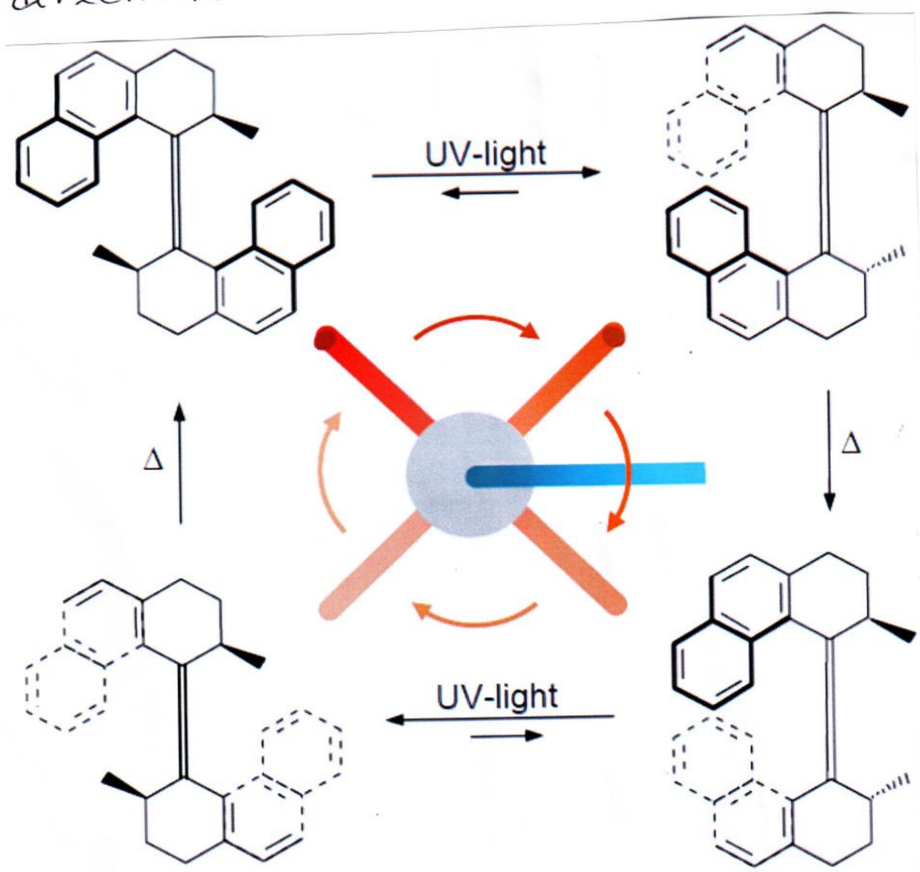
a metal ion bound by a crown ether molecule

The field has developed in many directions with chemists synthesising ever more complex and finely-tuned super-molecules from molecules that recognise each other and bind to each other by non-covalent effects, including hydrogen bonding and van der Waals' forces

These super-molecules are being designed to be catalysts, to transport drugs, to transmit electricity and to harvest light, among many other things.

Molecular motor

The molecular motor is powered by light.
The molecule rotates about a carbon-carbon double bond.
The groups either side of the double bond are identical and UV light causes these to undergo cis-trans isomerisation.
Because of the large size of the groups, which are chiral, the motor can only rotate in one direction.



the first light-driven molecular motor