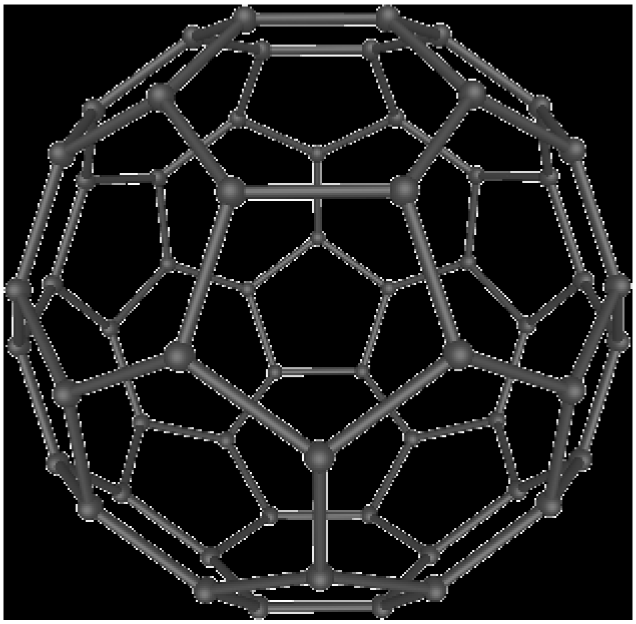
Fullerenes and nanotubes – carbon takes the stage

Fullerenes, or carbon cage molecules, are the rage in research labs and may become the key material of the 21st century, says S.Ananthanarayanan

They take their name from Buckminster Fuller, who discovered the geodesic dome, because they have the same structure, like a football made of hexagonal patches.



But what is special about the atomic structure of carbon that it is able to have such properties?

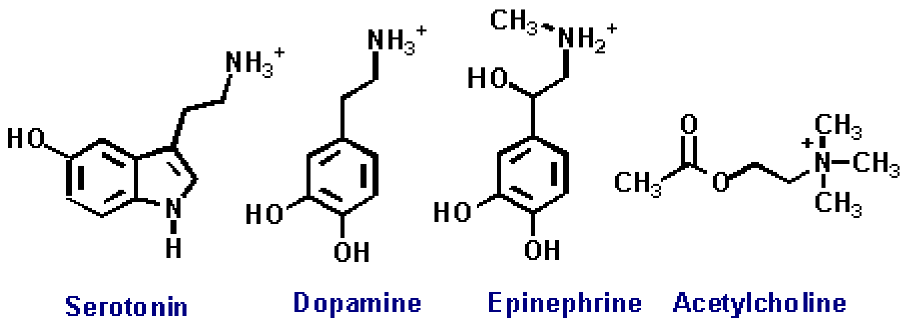
Atomic structure

Atoms consist of a positive nucleus surrounded by electrons in 'shells'. A rule in forming the shells is that the outermost shell must have no more than 8 electrons. Thus, if there is a 9th electron, a new shell is formed with only 1 electron.

Another property of atoms is that they 'strive' to have 2 or 8 electrons in the outer shell. They manage this by 'exchange' or 'sharing', by combining with other atoms. Thus, hydrogen, which has only 1 electron, combines with another hydrogen, so that the two atoms 'feel' they each have 2. Or, hydrogen combines with chlorine, which has 7 electrons, and 'lends' 1 electron to chlorine, so that they have 'none and eight'! Or sodium, which has 1 electron in the outer shell, combines with chlorine for an 'eight and eight'.

The case of carbon is peculiar, with 4 outer shell electrons. So, carbon can form different stable combinations, like with 4 hydrogen atoms, that 'share' one electron each, or with mixed atoms, like hydrogen, another carbon atom and then nitrogen or chlorine. It could even be with oxygen, which shares 2 electrons with 2 of the 4 carbon electrons, etc. This ‘four-way’ linking permits great variety in the combinations, including ‘chains’ and ‘rings’!

This has made possible a whole range of ‘organic’ compounds, like plastics, petrochemicals, synthetics, and the very building blocks of life!



Physical variety

Chemical properties apart, this 4-electron property enables carbon to have different physical forms, like graphite and diamond. In diamond, the four electrons are symmetrically balanced in three dimensions, which makes for its great hardness. But the structure of graphite is of hexagons in a single plane, and graphite occurs in sheets, or ‘graphenes’, just one atom wide!

But the discovery of the last century was that if carbon is vaporized and allowed to condense in a controlled way, it settles down in a structure of 60 (or more) atoms, distributed in pentagons and hexagons, like a football, the ‘Buckyball’!

Nanotubes

But it turns out that, in addition to this symmetric, spherical form, of pure carbon, addition of a few atoms of nickel or cobalt results in the carbon vapour condensing into ‘tubes’!

These are physical tubes, just nanometers in diameter, with carbon atoms themselves as sides! There is feverish research going on and methods are evolving to seal one end of the tube and conduct ‘atom-scale’ experiments in a ‘nano-test-tube’. It is also found that nanotubes can conduct electrons and hence function as atomic-scale electric wires. Ways are also being developed to control the way they conduct electricity, to fashion electronic components!