Dhirubhai Ambani Institute of Information and Communication Technology

Fullerene

Mohamed Shadab
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Abstract

This term paper contains a deep analysis of the Carbon Molecule known as Fullerene. It includes a brief introduction, history/origin, properties, current application and the future potential of Fullerene.

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History & Introduction

Fullerenes are carbon molecules formed of various shapes along the lines of tubes, circles, 3D squares, and so on. One thing that portrays fullerenes is they have a hollow center. Fullerene is considered as the third form of carbon alongside graphite & diamond. It's comprised of just carbon, and there is dependably an empty space inside the structure.

The different types of Fullerene are:

- Buckyball: C_{20} , C_{60}
- Nanotubes
- Megatubes
- polymers
- Nano onions
- linked dimers
- fullerene rings

Fullerene was first discovered in 1985 by Sir Harold W. Kroto & by Richard E. Smalley and Robert F. Curl. Utilizing a laser in order to vaporize graphite poles in an environment of helium gas, cagelike molecules were discovered which were made out of 60 carbon iotas (C60) consolidated by single and double bonds in order to form a hollow sphere.

In 1996 they (Harold W. Kroto, Robert F. Curl and Richard E.) were won the Nobel Prize for this discovery. The C60 molecule named buckminsterfullerene after the American engineer R. Buckminster Fuller, whose geodesic vault is built on the same auxiliary standards.

In 1991, Iijima Sumio in Japan, examined material separated from solids that developed on the tips of carbon anodes in the wake of being released under C60 arrangement conditions. Iijima found that the solids comprised of small tubes made up of various concentric "graphene" barrels, every chamber divider comprising of a sheet of carbon particles organized in hexagonal rings. The chambers more often than not had shut off closures and ran from 2 to 10 micrometers long and 5 to 40 nanometres in distance across.

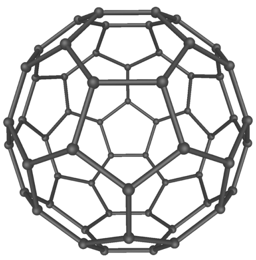
Properties

Fullerenes have a lot of different properties some desirable the others undesirables. Some of them are the aromaticity of fullerenes, solubility, chirality and properties pertaining to quantum mechanics and superconductivity.

Physical Properties

Fullerenes are made of twenty hexagonal & twelve pentagonal rings as the fundamental basis of an icosohedrael closed-cage structure. Every single carbon particle is bonded to 3 others and is sp2 hybridized. A few fullerenes are naturally chiral as they are D2-symmetric.

The structure of C60 (buckminsterfullerene) is very similar to that of a football :



Fullerene C60 [Image Source - https://en.wikipedia.org]

In principle, an unbounded number of fullerenes can exist, their structure in light of pentagonal and hexagonal rings, developed by rules for the purpose of making icosahedra.

C60 has a density of 1.65 g/cm^3 and appears as a black solid while being odourless and also is soluble in solvents like benzene, toluene and chloroform.

Chemistry and Aromaticity

Fullerenes have a variety of a chemical properties some of which include redox chemistry organic fullerene chemistry, electrophilic aromatic substitutions, organometallic fullerene chemistry and formation of endohedral compounds. The reactions fullerenes are able to produce: Nucleophilic addition, Pericyclic reactions, Hydrogenation, Oxidation, Hydroxylation, Electrophilic addition, Retro additions, Carbene additions, Radical additions.

C60 and C70 have comparative properties. Oxidation of C60 & C70 is not reversible. The primary decrease for the two fullerenes is ~1.0V for (Fc/Fc+), demonstrating they have electron tolerating properties. C76 displays both electron contributor/acceptor properties.

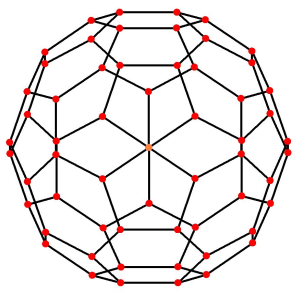
C60 has an inclination of abstaining from including double bonds inside the pentagonal rings which makes electron delocalisation poor, and results in the way that C60 is not super-aromatic. C60 carries on especially along the lines of an electron lacking alkene and promptly responds with electron rich species.

Buckminsterfullerene

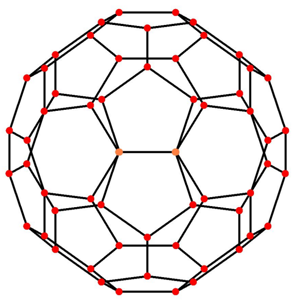
Buckminsterfullerene is a stable compound able to sustain high temperatures & weights. The uncovered surface of the structure can specifically respond with different species while keeping up the circular geometry.

The orthogonal projections of the buckminsterfullerene molecule:

Vertex Centered:



Edge 5-5:



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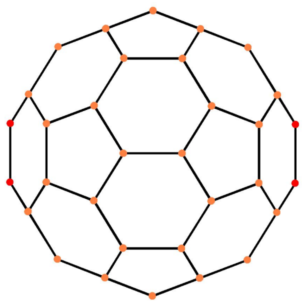
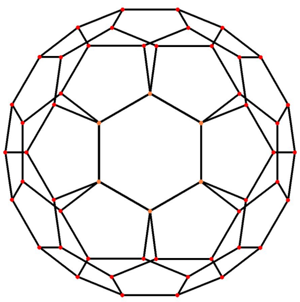
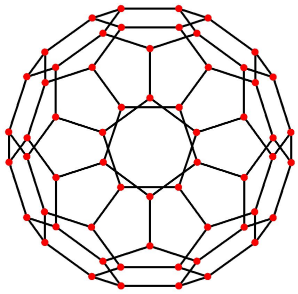


Face Hexagon:



Face Pentagon:



Current Applications

Previously Fullerenes were proposed in order to be used in various fields but eventually as research became more extensive and deep the uses of fullerene were seen best in the biomedical industries.

Fullerenes show antiviral activity, antioxidant activity and they can be used for the purpose of drug and gene delivery, for diagnostic actions and also finally can be used photosensitizers. The above uses of fullerene prove to be extremely useful in medical applications. For example they become useful especially in binding antibiotics to the bacteria and can also be used in order to target specific cancer cells.

The Fullerene cage can be used as a potential isolated chamber which can hold an unstable atom. This basically means that the fullerene cage will isolate the unstable atom so that it does not react with the environment. Endofullerenes are such fullerenes and they are currently being used in the Magnetic Resonance Imaging (the MRI) machine which a modern day medical necessity. They are also used in X-ray imaging & Radioactive pharmaceuticals used in cancer treatment.

The photosensitizing ability of the Fullerene allows it to be used as a medical application in curing tumors. While past growth examine has included cancer treatment, photodynamic treatment is critical to think in medicines for tumor cells will give more alternatives to patients with various conditions.

Fullerenes also are used as antioxidants as they have the ability to localize themselves inside of the cell to the mitochondria & the other parts of the cell where the free radicals form. Buckminsterfullerene have the capacity to battle the disintegration of motor function because of various sclerosis and also are used to trap free radicals which are generated due to an allergic reaction & help block the inflammation caused due to the allergic reaction.

The combination of buckyballs, nanotubes and more allow to develop low cost solar cells which can be made by the means of painting it on a surface. They can also be used to make bullet-proof vests due to their cage like structure.

Future Potential

The most stable type of a carbon combination structure is a buckyball or a nanotube. This new comprehension isn't confined to unadulterated carbon yet additionally applies to other sheet framing materials, for example, boron nitride, which can likewise shape nanotubes. Closed fullerene structures, fusing sulfides of such metals as tungsten and molybdenum, show magnificent strong ointment properties. Directing carbon nanotubes might be covered with sheaths of metal sulfides to deliver modest protected electrical wire.

Fullerenes/nanotubes have induced much energy, particularly concerning conceivable future applications. For instance, in the event of when SWNTs (Nanotubes) can be made in groups of 100 billion, at that point a material will be created that may approach the breaking points of elasticity workable for any known material including the synthetic bond. No material can reach its hypothetical strength,] as a result of breakdowns expedited by the engendering of minute deformities through the material.

A heap of nanotubes, notwithstanding, may sidestep this issue, as minute deformities may temper along the length of a specific tube and positively ought not proliferate over the package—subsequently keeping away from the issues that happen in regular materials. The effect of such a material on structural designing, building development, flying crafts, and cars would be breathtaking. To understand this potential new procedures should be found that can create long impeccably packages in which every one of the 100 billion nanotubes ideally have a similar breadth and nuclear course of action.

Also further research is being done in the superconductivity properties of Buckminsterfullerene which can make this material a groundbreaking one.

Modern research is trying to alter the structure of a buckyball to fit the segment of the HIV particle that ties to proteins, conceivably hindering the spread of the infection. Buckyballs might have the capacity to diminish the development of microscopic organisms in funnels and layers in water frameworks. Buckyballs can also be used to store hydrogen, which implies it can be used in vehicles powered by means of hydrogen.

Bibliography

1. http://www.ch.ic.ac.uk/local/projects/unwin/Fullerenes.html
2. https://www.britannica.com/science/fullerene
3. http://www.understandingnano.com/buckyballs-fullerenes.html
4. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2676811/
5. https://en.wikipedia.org/wiki/Fullerene_chemistry
6. https://en.wikipedia.org/wiki/Buckminsterfullerene