



A REVIEW ON BUCKY BALLS: A NOVEL CARRIER FOR DRUG DELIVERY SYSTEM

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ABSTRACT

Nanotechnology deals with the study, development and practical application of structures and devices at molecular scale (between 1 and 100 nanometres, one nanometre is equivalent to 1 in 10⁻⁹ meters. Nanotechnology employs devices with dimensions of one to 1,000 nanometres. At these sizes it is no wonder that scientists have seized upon nanotechnology for myriad medical applications. Fullerenes are Nano molecular carbon cages that can serve as platforms for the delivery of drugs and imaging agents. Buckyballs represent a new and fascinating molecular allotropic form of carbon that has received a lot of attention by the chemical community during the last two decades. There are several functional modes in which fullerenes can act as drug delivery nanomaterials. With the development of new drugs, there have been many attempts to explore innovative delivery routes. Targeted delivery systems are a desired solution designed to overcome the deficiency of routine methods. To transform this idea into reality, a wide range of nanoparticles has been proposed and studied. These nanoparticles should interact well with biological environments and pass through cell membranes to deliver therapeutic molecules. One of the pioneer classes of carbon-based nanoparticles for targeted delivery is the fullerenes. Fullerenes have a unique structure and possess suitable properties for interaction with the cellular environment. This short review concentrates on newly developed fullerene derivatives and their potential as advanced delivery systems for pharmaceutical applications.

KEYWORDS: Buckyballs, C60, fullerenes, nanotechnology.

INTRODUCTION

➤ *Buckyballs – a new sphere of science*

- “Buckyballs” is the common name for a molecule called **Buckminsterfullerene**, which is made of 60 carbon atoms formed in the shape of a hollow ball. British scientist **Harry Kroto** discovered it in 1985.
- The arrangement of the atoms resembled the shape of the geodesic domes invented by architect **Buckminster Fuller**, hence the name.
- Along with American researchers Richard Smalley and Robert Curl, Kroto was able to create Buckyballs in the laboratory. For this work; the three were awarded a Nobel Prize in Chemistry in 1996. These researchers found that Bucky balls had many interesting properties.^[1]
- This is now the third form of pure carbon known to exist naturally (along with graphite and diamonds).
- Fullerenes are similar in structure to graphite, which is composed of a sheet of linked hexagonal rings, but they contain pentagonal rings that prevent the sheet from being planar.

- The **structure of C60 - buckminsterfullerene - is that of a truncated icosahedron**, which resembles a round soccer ball of the type made of hexagons and pentagons, with a carbon atom at the corners of each hexagon and a bond along each edge.^[6]
- They were very hard to break apart, even at temperatures of nearly 1000°C, and would bounce back if squeezed or slammed against a solid object.
- The colours vary from magenta to port-wine red. They can also be yellow-green to brown.
- Nanomaterials have at least one side that is less than 100 nanometres. One nanometer is one billionth of a meter or about one hundred thousand times smaller than the diameter of a human hair or, a thousand times smaller than a red blood cell.
- Fullerenes are not soluble in water, in order to make them soluble, they'd first have to be derivatized with Hydrophilic compounds.
- Overall, this carbon class has quite a lot of properties that can both be studied solely or by the introduction of more atoms inside the cage-like

structure, or even altering by adding surface chemistry.

- Fullerenes are used in electronics and as additives in oils and greases.
- They are being studied for use in personal care products, in the medical field and in sports equipment.
- The discovery of this new type of molecules can lead to so many new possibilities. They might even have the capability to be used for making new drugs or altering and improving older ones.
- One application of the compound can be their use in locating specific cells and areas in the body after an Intravenous or Subcutaneous injection.

- Also, one does not need to worry about any toxic matter entering into their body when using these compounds because the metallic ions are secure inside the hollow cage-like structure of the carbon molecule, which prevents them from breaking free.
- The field of medical sciences is benefiting a lot from Fullerenes due to the huge amount of capabilities its derivatives hold.
- It is bound to do wonders for nanomedicine in the near future by becoming an important component of to be produced, wonder drug.

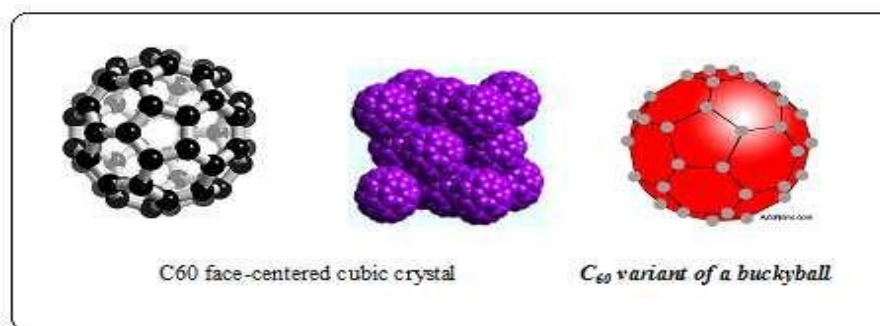


Fig. 1: Bucky balls.

EXPOSURE

- Workers that use fullerenes may breathe in mists or have direct skin contact. Exposure to the general population is currently not likely.
- However, due to widespread usage research and development of new products, human and environmental exposure to nanomaterials such as fullerenes is likely to increase.
- If fullerenes are released to the environment, they will not be broken down in air. Fullerenes released to air will be in or on particles that may travel long distances. They could eventually fall to the ground.
- Some fullerene structures may be broken down by light. Some forms of fullerenes are toxic to microorganisms.
- It is not known if they will build up in aquatic organisms.^[10]

RISK

- No data on the potential for fullerenes to produce toxic effects in humans were available.
- Several national agencies are conducting research to determine whether nanoparticles pose a threat to exposed workers or consumers.
- Skin irritation and allergic skin reactions did not occur in laboratory animals following direct skin exposure to fullerenes. Minimal eye irritation occurred.
- Toxic effects were not observed in laboratory animals in several studies following direct injection of fullerenes into the airways.

- Decreased activity and altered brain chemicals were observed in laboratory animals following injection of fullerenes directly into the brain.
- Embryo abnormalities and death were observed in laboratory mice injected with a high dose of fullerene C60 during pregnancy. Data for the potential for fullerenes to cause infertility were not available.
- The potential for fullerenes to cause cancer has not been directly evaluated in humans or laboratory animals. The potential for fullerenes to cause cancer in humans has not been assessed by the U.S. EPA IRIS program, the International Agency for Research on Cancer, or the U.S. National Toxicology Program 13th Report on Carcinogens. (SRC).^[10]

➤ The discovery of "buckminsterfullerene"

- Nobel Prize in 1996 for Chemistry was awarded for the discovery of fullerenes.
- The discovery of the buckyballs can be likened to the discovery of benzene in 1825.
- Benzene is made up of a six carbon ring along with six hydrogen atoms (C₆H₆). The molecule was named for Richard Buckminster Fuller, a noted architect who popularized the geodesic dome.
- It was discovered in 1985 by Professor Sir Harry Kroto, and two Rice University professors, chemists Dr. Richard E. Smalley and Dr. Robert F. Curl Jr., [for which they were jointly awarded the 1996 Nobel Laureate for chemistry] and is the only molecule composed of a single element to form a

hollow spheroid which gives the potential for filling it, and using it for novel drug-delivery systems.^[2]

➤ **Classification of nanomaterials**

1. **Nanotubes:** Nanotubes are hollow cylinders made of carbon atoms. They can also be filled and sealed, forming test tubes or potential drug delivery devices.
2. **Fullerenes:** These crystalline particles are a form of carbon atom whose molecular architecture is arranged in a soccer ball-like structure. Also known as **buckyballs**, they were discovered in 1985 among the detritus of laser-vaporized graphite. Unlike other molecules that have applications as cancer drug delivery vehicles, fullerenes don't break down in the body and are excreted intact. This trait can be important for some cancer treatment compounds that are dangerous to healthy cells. For example, fullerene drug delivery particles that contain radioactive atoms would allow for the complete removal of radiation from the body following treatment.^[2]
3. **Nanowire:** This glowing silica nanowire is wrapped around a single strand of human hair. It looks delicate—it is about five times smaller than a virus application for nanowires include the early sensing of breast and ovarian malignancies.
4. **Nanocantilever:** In the nanoworld, they function as sensors ideal for detecting the presence of extremely small molecules in biological fluids.
5. **Nanoshells:** Nanoshells are hollow silica spheres covered with gold. Scientists can attach antibodies to their surfaces, enabling the shells to target certain cells such as cancer cells. Nanoshells could one day also be filled with drug-containing polymers.
6. **Quantum Dots:** Quantum dots are miniscule semiconductor particles that can serve as signposts of certain types of cells or molecules in the body. They can do this because they emit different wavelengths of radiation depending on the type of cadmium used in their cores: cadmium sulphide for ultraviolet to blue, cadmium selenide for most of the visible spectrum, and cadmium telluride for the far red and near-infrared.^[3]
7. **Nanopores:** Nanopores have cancer research and treatment applications. Engineered into particles, they are holes that are so tiny that DNA molecules can pass through them one strand at a time, allowing for highly precise and efficient DNA sequencing. By engineering nanopores into the surface of a drug capsule that are only slightly larger than the medicine's molecular structure, drug manufacturers can also use nanopores to control the rate of a drug's diffusion in the body.

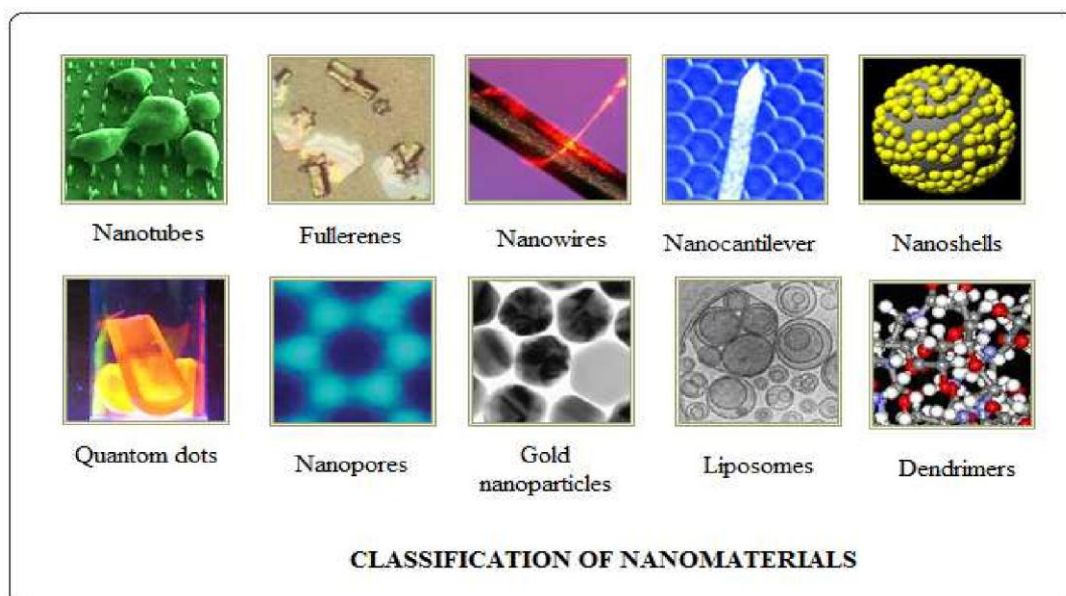


Fig. 2: Classification Of Nano Materials.

8. **Gold Nanoparticles:** These nanoparticles, seen in a transmission electron micrograph image, they have a solid core. Researchers at North-western University are using gold nanoparticles to develop ultrasensitive detection systems for DNA and protein markers associated with many forms of cancer, including breast and prostate cancer.
9. **Liposome's:** Tiny pouches made of lipids, or fat molecules, surrounding a water core—widely used for clinical cancer treatment. Several different kinds of liposome's are also widely employed against infectious diseases and can deliver certain vaccines.
10. **Dendrimer:** This fascinating particle holds significant promise for cancer treatment. Its many branches allow other molecules to easily attach to its surface. Researchers have fashioned dendrimers into sophisticated anti-cancer machines carrying five chemical tools—a molecule designed to bind to cancer cells, a second that fluoresces upon locating genetic mutations, a third to assist in imaging tumour shape using X-rays, a fourth carrying drugs released on

demand, and a fifth that would send a signal when cancerous cells are finally dead.

➤ **Chemical and physical properties of buckyballs**

- Buckyballs and other fullerenes because of their chemistry and their unusual hollow, cage-like shape extremely stable and can withstand very high temperatures and pressures.
- The carbon atoms of buckyballs can react with other atoms and molecules, leaving the stable, spherical structure intact.
- Researchers are interested in creating new molecules by adding other molecules to the outside of a buckyballs and also in the possibility of trapping smaller molecules inside a buckyballs.^[1]

Table no.1: Properties of Bucky balls.

Property name	Property value
Molecular weight	720.6g/mol
X log P3-AA	18
Hydrogen bond donor count	0
Hydrogen bond acceptor count	0
Rotatable bond count	0
Exact mass	720g/mol
Mono isotopic mass	720g/mol
Topological mono surface area	0A
Heavy atom count	60
Formal charge	0
Complexity	2030
Isotope atom count	0

- Solutions of C60 fullerene in hydrocarbon solvents are magenta.
- C70 fullerene are port-wine red. In some solvents C76 /and C84/ fullerene gives yellow-green solutions.
- C82 fullerene has a less greenish tinge. Solutions of C78 fullerene are golden chestnut brown.^[11]

➤ **Solubility**

- Virtually insoluble in acetone, ethers, and alcohols.
- /C60/ is essentially insoluble in polar solvents, sparingly soluble in alkanes. In aromatic solvents and in carbon disulfide appreciable solubilities are observed.

(60) fullerene	Solubility in mg/ml
n-pentane	0.005
n-hexane	0.043
cyclohexane	0.036
n-decane	0.071
decalins	4.6
dichloromethane	0.26
Carbon disulfide	7.9
dichloromethane	0.26
chloroform	0.16
tetra chloromethane	0.32
tetrahydrofuran	0
benzene	1.7
Toluene	2.8
Tetralin	16
Benzonitrile	0.41
Anisole	5.6
1,2-dichlorobenzene	27
1-methylnaphthalene	33
1-chloronaphthalene	41
Acetone	0.001
Methanol	0

➤ **Solubilities in various solvents at 25 °C:**

- Ethanol (1.4 mg/L),
- Octanol (42.9 mg/L),
- Distilled octanol (38.9 mg/L),
- Water-saturated octanol (34.7 mg/L),
- Tetrahydrofuran (11 mg/L),
- Toluene (3000 mg/L),
- Water-saturated toluene (2430 mg/L)

➤ **Melting Point**

- At 260 K, a first-order phase transition from face-centered cubic crystal structure to a simple cubic structure is observed, accompanied by a lattice contraction. At 90 K the molecules rearrange to attain the best global minimum.
- At this temperature, the rotational degrees of freedom are frozen, and the solid structure is designated as a pseudo-face-centered cubic crystal structure.
- C70 Fullerene is rotationally disordered at room temperature and undergoes a transition to a low-temperature phase.^[11]

➤ **Heat of formation**

- 42.54 kJ/mol per C atom (C60); 40.40 kJ/mol per C atom (C70).
- Upon increasing the size of the fullerenes their energy content will asymptotically reach that of graphite solid state.
- C60 molecules crystallize in a face-centered cubic crystal structure with a lattice constant of 1.417 nm.^[11]
- Capable of enclosing ions or atoms in a host-guest relationship.^[12]

- **Biological Half-Life**
- Fullerenes are spherical molecules consisting entirely of carbon atoms (C(x)) to which side chains can be added, furnishing compounds with widely different properties.

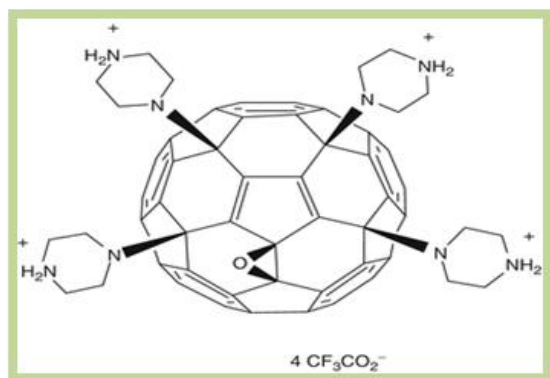


Fig. 3: Biological half life of Bucky ball.

- Absorption, distribution and excretion strongly depend on the properties of the side chains.
- The pristine C(60) has a very long biological half-life, whereas the most water-soluble derivatives are eliminated from the exposed animals within weeks.^[13]

• **Determination of half-life**

- Male rats were exposed to C60 fullerene nanoparticles (2.22 mg/cu m, 55 nm diameter) and micro particles (2.35 mg/cu m, 0.93 μ m diameter) for 3 hr a day, for 10 consecutive days using a nose-only exposure system.
- Nanoparticles were created utilizing an aerosol vaporization and condensation process.
- Nanoparticles and micro particles were subjected to high-pressure liquid chromatography (HPLC), XRD, and scanning laser Raman spectroscopy, which cumulatively indicated no chemical modification of the C60 fullerenes occurred during the aerosol generation.
- Lung half-lives for C60 fullerene nanoparticles and micro particles were **26 and 29 days**, respectively.

➤ **Bucky ball in gene and drug delivery**

- The term used for transporting medicines to the desired destination at the time of need is known as drug delivery, while gene delivery is referred to as introducing foreign DNA into cells, through which certain changes become visible. Therefore, it is very important to deliver these molecules successfully while making sure no harm comes to them.
- Fullerenes in drug and gene delivery, the direct delivery of drugs and bio molecules through cell membrane into cells has attained increasing attention and has put a main focus on the development of efficient and safe carriers to transport genes or drugs.

- Transport of any compound into the nucleus of an intact cell is a major challenge, as transfer is limited by at least three membrane barriers which are the cell membrane, the endosomal membrane and the nuclear membrane. Hence it is important to fully understand the mechanism through which carriers enter cells.
- There are four major groups of drug and gene carriers which are organic cationic compounds, viral carriers, recombinant proteins and inorganic Nano particles.
- A large number of nanoparticles can be potentially used as carriers for the cellular delivery because of their versatile properties, including good biocompatibility, selective targeted delivery and controlled release of carried drugs.
- Fullerenes belong to the class of inorganic nanoparticles and show wide availability due to their small size (~ 1 nm) and biological activity.
- The activities of this allotropic form of carbon rest upon the properties of both, the fullerene core and its chemical modification.
- The fullerene core is very hydrophobic, while the functional groups attached to the core add further complexity to the behaviour of fullerene molecule.
- By attaching hydrophilic moieties, fullerenes become water-soluble and are capable of carrying drugs and genes for the cellular delivery.

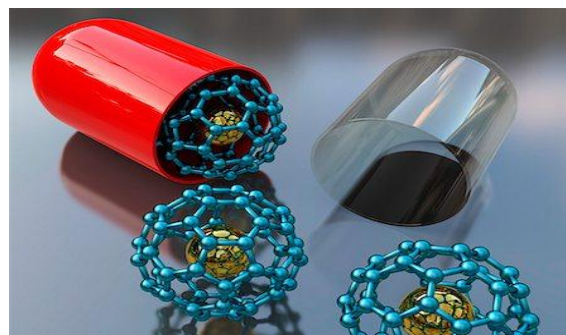


Fig 4: Bucky balls used in drug delivery.

- Biochemical studies on the mechanism of transfection indicate that the fullerene reagent forms a protective sheath around bound DNA, which increases the lifetime of DNA in endosomes and thus supports their chromosomal incorporation.
- For the attachment of DNA-sequences preferably amino fullerenes are employed. The detachment of DNA in the cytoplasm can be achieved either through loss of its amino groups or loss of the binding ability of amines by transformation into neutral compounds.
- A lipophilic slow-release drug delivery system which employs fullerene derivatives to enhance therapeutic efficacy in tissue culture was designed by Zakharian et al (2005).
- Modified fullerenes have the potential to provide such a lipophilic slow-release system and are comprised of significant anticancer activity in cell

culture as demonstrated with C60-paclitaxel conjugate.

- Furthermore the ability of fullerenes to penetrate through intact skin is widening their application in cellular drug and gene delivery.
- Underivatized fullerenes aggregate in water where they are supposed to cause oxidative damage to cellular membranes even at relatively low concentrations (20 ppb level).^[14]

❖ **Applications of Buckyballs as Nanomedicine**

Buckyballs may see widespread use in future products and applications, from drug-delivery vehicles for cancer therapy to ultra hard coatings and military armor, chemical sensors and hydrogen-storage technologies for batteries and automotive fuel cells and few are described here.^[4]

- ❖ Hollow success - buckyballs for cancer treatment.
- ❖ Bucky ball-Antibody Combination Delivers Antitumor Drugs
- ❖ Buckyballs to Fight Allergy
- ❖ Bucky balls for Medical Diagnostics
- ❖ Bucky balls as Antioxidants
- ❖ Bucky balls as Antiviral Agents
- ❖ Bucky balls as Photo sensitizers in Photodynamic Therapy
- ❖ Buckyballs and Carbon Nanotubes in Cancer Therapies and Medical Treatment

1. **Hollow success- buckyballs for cancer treatment**

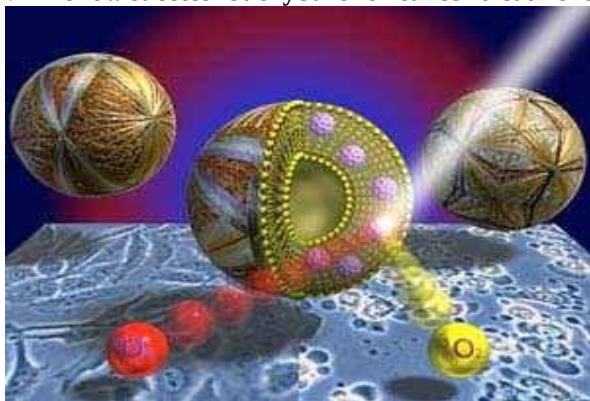


Fig. 5: C60 trapped in lipid membrane releases toxic singlet oxygen to kill cancer.

- Researcher says Trapping C60 Buckyballs in lipid globes could deliver improved cancer treatments, the carbon isotope C60 could be delivered into human cancer cells by hollow lipid spheres and used to induce cell death under visible light irradiation.
- Combining a light source with a light-sensitive drug - a photo sensitizer - to destroy cancer cells in this way is the principle behind photodynamic therapy (PDT).
- C60 yields singlet oxygen under irradiation and it is this that induces cell death. The problem facing Ikeda was how to dissolve the insoluble C60 in water and so open the possibility of transporting the compound into the cancer cells.

- Whilst some C60 derivatives are soluble in water, unmodified C60 yields singlet oxygen more efficiently^[2]
- The group used various lipids, including phospholipids and amino lipids, to make the lipid membrane-C60 structures, called **LMI [60] fullerenes**.
- The LMI [60] fullerene with a cationic surface was found to have a considerably higher PDT activity than the structures with anionic and neutral surfaces; Ikeda said that a future challenge will be to develop PDT photosensitizers with specific tissue distribution properties.
- His plan is to study the enhanced permeability and retention effects of LMI [60] fullerenes and also to tune the lipid membrane surface using various lipids with functional groups.
- LMI [60] fullerenes will be used not only as a new cancer therapy, but also as antibacterial or antifungal agents.

2. **Buckyball-Antibody Combination Delivers Antitumor Drugs**

- Combining a monoclonal antibody known to target melanoma tumours with multiple C60 buckyballs, researchers at University of Texas M.D. Anderson Cancer Centre have developed a new way to deliver multiple drugs simultaneously to tumours.
- Unlike other methods that use multiple targeting agents, such as antibodies, to deliver individual drug-loaded nanoparticles to malignant cells, this new approach attaches multiple nanoparticles to an individual tumor targeting antibody.
- The M. D. Anderson Cancer Centre investigators shown that **ZME-018**, which binds to a tumor protein known as **gp240**, will deliver anticancer drugs into melanoma tumours', while the Rice group has been developing buckyballs as drug delivery agents.^[1]

3. **Buckyballs to Fight Allergy**

- Allergic disease is the sixth leading cause of chronic disease in the United States, and while various treatments have been developed to control allergy, no cure has been found.
- These findings advance the emerging field of medicine known as nano immunology.
- US researchers has identified a new biological function for a soccer ball-shaped nano particle called a buckyball or fullerene- the ability to block allergic response, setting the stage for the development of new therapies for allergy.
- Allergic reactions take place when Mast Cells release mediators when a person comes into contact with something that could trigger their allergy.
- Fullerene derivatives can be used to control such allergic reactions in the near future, by having a direct effect on the Mast Cells.

- From smaller allergic reactions like "Hay Fever", to life-threatening situations, Fullerenes derivatives might be able to totally prevent the allergic reaction before it can spread or get exponentially triggered.
- Most allergy medicines (anti-histamines, H1-receptor blockers) neutralize or prevent the Mast Cells from responding, but Fullerenes can help completely terminating the reaction before it even has the chance to escalate.
- They can also protect you against ultraviolet radiation, acting as cytoprotectants. This happens when the molecules bind themselves to Reactive Oxygen Species and stop the cells from getting damaged.
- Cosmetics use a radical sponge as well i.e. a water-soluble Carbon sixty derivative. This molecule is so good at what it does because it quickly absorbs into the skin.

4. Bucky balls for Medical Diagnostics

- Various methods are employed to ensure that toxic substances do not enter one's body. For that purpose, the Gd is formulated in chelate, which is created as to remain in the body for small intervals of time and then be removed through a renal elimination. But a dangerous situation might occur if the solution stays in the body for too long, e.g. when treating kidney diseases.
- Over extended periods of time, the chelate and Gd are bound to separate, thus releasing the toxic substances in the body.
- We can prevent this from happening by the use of our discovery, Trimetasphere, to produce a Trimetasphere based agent, which due to its structure, does not let the toxic substances separate from the solution, even over a long period of time in the body.
- MRI can surely be improved to a great extent. Many new diseases can be detected easily upon increasing the relaxivity through Trimetaspheres, which would then improve the MRI's sensitivity.
- This serves as a gateway to the discovery and treatment of many new diseases, a turning point in the history of medicine for sure.
- Compact and portable versions of the otherwise large MRI systems can also be created in the near future, using Trimetasphere based contrast agents. The compound will be able to detect Atherosclerotic plaque buildup in the blood vessels, thus giving a clear image of the problem and in return, helping solve it.
- This process could eliminate impending heart attack by making both the doctor and the patients aware of the patient's current health and status by providing enough information and taking calculated measures beforehand.

5. Bucky balls as Antioxidants

- Fullerenes are relatively reactive due to the fact that they possess a high electron affinity and conjugated double bonds, making them amazing antioxidants.
- Carbon molecules with up to sixty atoms are known as "radical sponges" due to possessing the ability to be highly interactive with various radicals e.g. Carbon sixty can react with about thirty-four methyl radicals until it becomes dormant.
- One of the most important uses of fullerenes as antioxidants is that they can be put inside the cell.

6. Bucky balls as Antiviral Agents

- Fullerenes have quite a lot of potential of being used as antiviral. One of the most important applications of fullerenes might be the ability to battle and suppress the property of replication in HIV, a persisting and contagious virus, and therefore help in delaying the occurrence of AIDS.
- The prevention of replication of HIV 1 takes place when the Dendro Fullerene 1 and Derivative 2 trans-isomer deactivates the HIV protease.
- These molecules work by being inserted inside the binding areas of protease in HIV, i.e. in the water unreactive areas of protein. The molecules also target the reverse transcriptase in HIV and are way more reactive than the initially used non nucleoside analog inhibitors.
- Hepatitis C can be dealt with by using fullerene derivatives.
- Being antibacterial and anti proliferative, cationic fullerene derivatives have wide applications as well. A special type of fullerene derivatives, i.e. the water-insoluble ones, can be used to battle various viruses.

7. Bucky balls as Photo sensitizers in Photodynamic Therapy

- PDT, also known as Photodynamic Therapy is a type of therapy where a special non-toxic light-sensitive compound is used, which turns toxic whenever it comes in contact with light and is used to kill cells that become hostile. Fullerenes are used as the "compounds" in the above method.
- Fullerenes possess the ability to gain bouts of energy upon being exposed to light, when coming back to the ground state, these compounds release energy which has the ability to convert oxygen molecules into singlet oxygen which might turn out to be cytotoxic.
- Being excellent electron acceptors, fullerenes can be converted into radicals in the presence of electron donors. By transferring the extra electrons to oxygen molecules, these radicals can produce both hydroxyl radicals and anionic superoxide.
- The DNA damage is caused by these radicals and it can also cause cell death.
- In some cases, some particular fullerenes combine with DNA and proteins. It is highly likely that they can be used to develop another technique of anticancer therapy.

8. Buckyballs and Carbon Nanotubes in Cancer Therapies and Medical Treatment

- L. Wilson have modified 60carbon fullerenes, called buckyballs, to home in on bone when injected into the body.
- The molecule has one unpaired electron, making it magnetic. This property makes the compound a potential contrast agent for magnetic resonance imaging (MRI).
- A contrast agent injected into a patient can sharpen an MRI picture, revealing otherwise invisible features.^[5]

➤ Biological Activities

The list of exciting biological activities of water-soluble fullerene derivatives includes the inhibition of enzymes of –

- Human immunodeficiency (HIV)
- Hepatitis A, B and C viruses,
- Anticancer action,
- Ant proliferative effects,
- Photodynamic therapy And efficient neuro protective activity.

Some fullerene derivatives can be successfully applied as advanced bacteriostatic agents and contrast materials in X-ray and magnetic resonance imaging.

➤ Buckyballs Can Be Nontoxic

- Buckminsterfullerene, a form of carbon containing 60 atoms arranged like the facets of a soccer ball and one of the first and best studied nano scale

structures, has come under scrutiny in recent years over concerns that it may be toxic to living organisms.

- While media headlines have largely focused on studies showing that C60-fullerenes, or buckyballs, are toxic to bacterial, algae, and fish, other studies have failed to find such toxicities.
- Now, a new study from an international team of researchers suggests that the toxic effects of these molecules may result from the polar organic solvents used to dissolve them.
- But studies do show that upon using non aggregated fullerenes for in-vivo and in-vitro assays, the compound is not toxic if normal doses are taken.

➤ Buckyball synthesis under control

- Fullerenes are formed when vaporized carbon condenses in an atmosphere of inert gas. The gaseous carbon is obtained e.g. by directing an intense pulse of laser light at a carbon surface.
- The released carbon atoms are mixed with a stream of helium gas and combine to form clusters of some few up to hundreds of atoms.
- The gas is then led into a vacuum chamber where it expands and is cooled to some degrees above absolute zero.
- The carbon clusters can then be analyzed with mass spectrometry.

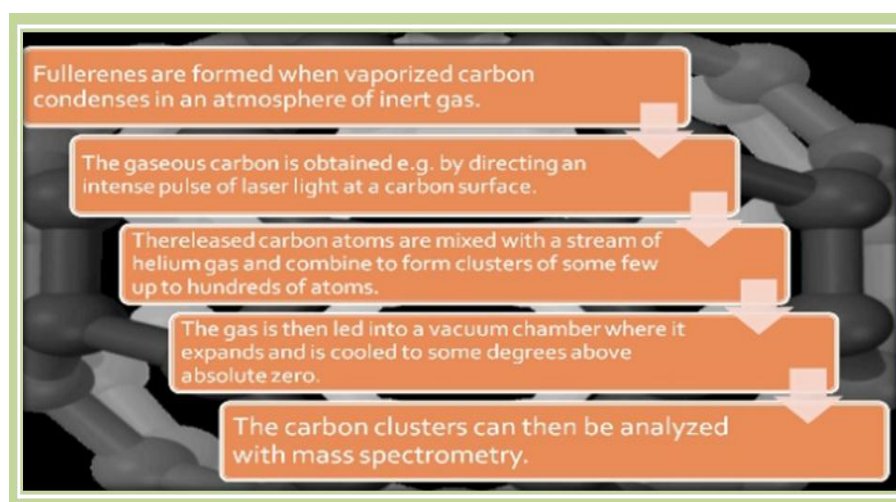


Fig. 5: Bucky balls synthesis.

- Their technique not only allows controlled heterofullerene synthesis, but could also be adapted to make buckyballs that encapsulate small molecules.^[7]

➤ DEMERITS

❖ Buckyballs Hurt Cells

- "Buckyballs are already being made on a commercial scale for use in coatings and materials

but we have not determined their toxicity studies showing that they can cross the blood-brain barrier and alter cell functions, which raise a lot of questions about their toxicity and what impact they may have if released into the environment."

- The resulting model showed that buckyball particles are able to dissolve in cell membranes, pass into cells and re-form particles on the other side where they can cause damage to cells.^[8]

❖ **Buckyballs 'Have High Potential To Accumulate In Living Tissue**

- Synthetic carbon molecules called fullerenes, or buckyballs, have a high potential of being accumulated in animal tissue, but the molecules also appear to break down in sunlight, perhaps reducing their possible environmental dangers "Because of the numerous potential applications, it is important to learn how buckyballs react in the environment and what their possible environmental.
- The researchers mixed buckyballs in a solution of water and a chemical called octanol, which has properties similar to fatty tissues in animals. Findings indicated buckyballs have a greater chance of partitioning into fatty tissues than the banned pesticide DDT. However, while DDT is toxic to wildlife, buckyballs currently have no documented toxic effects.
- When nanotechnology is referred to relative to therapeutics, it generally means that the active agent is targeted to specific locations in the body and that we are working on the molecular basis or with very small particles, such as, for example, gold nanoparticles.^[4]

❖ **Difficulty of targeting drug delivery to the location**

- One major problem for current therapeutics is the difficulty of targeting drug delivery to the location where it is desired.
- The result of non-targeted delivery is that the drug can be active all over the body that means that large doses, larger than would otherwise be required, must be used, or that we realize a lot of peripheral damage to otherwise healthy parts, killing healthy cells or causing immune reactions.
- A second major problem for therapeutics is delivery of the active agent. This issue is related to the targeting problem but is broader than just that.
- Currently, we design active drugs and expect them to circulate through the body, pass through barriers such as the digestive system, the cell, and the blood-brain barrier, and still to be active as a drug after doing all that and it is not surprising that many drugs cannot effectively do this.
- The issue is even more critical for cancer treatment where drugs often do great damage at the wrong locations. This issue will have to be solved by new delivery agents, materials which will do several jobs—that will direct the drug to the desired location, that will help the active agent get through the barriers, that will protect the drug from degradation during delivery, and, finally, that will release the drug once it is inside the cell or in the preferred location.^[9]

Uses

- The first and main use that scientists are hoping to implement with Bucky balls is the use in the medical field. In 2007, there was a study conducted that used Bucky balls to get medication into cancer

cells. They did this by creating proteins that could attach to the cell membrane of a cancer cell and then push through. Similar to how a virus is able to get into a cell, scientists were able to make Bucky balls do the same thing

- The use of Bucky balls in fiber optics.
- Fullerenes hold great promise also in non physiological applications where oxidation and radical processes are destructive (food spoilage, plastics deterioration, metal corrosion).
- The C60 molecule can also bind large numbers of hydrogen. This property suggests that Bucky balls may be an efficient medium to make hydrogen fuel more accessible to the general economy.
- Buckminsterfullerene could also inhibit the HIV virus. In particular, C60 inhibits a key enzyme in the human immunodeficiency virus known as HIV1 protease; this could inhibit reproduction of the HIV virus in immune cells.
- In medicine, buckyballs are able to function as miniature containers. Useful drugs can be inserted within the hollow spheres for later release within the body.
- Buckyballs also are small enough to enter skin pores directly and deliver subsurface medicine where needed.
- The Zelen Fullerene C60 Day Cream which incorporates nano scale C60 Fullerene and it turns out that the material has remarkable antioxidant properties.
- Zelens claims its newly released day cream is the first to harness the power of Fullerene C-60 carbon for cosmetics applications.

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