## Fullerenes: From Carbon to Nanomedicine

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Abstract: Fullerenes, the third carbon allotrope, have emerged as agents which could revolutionize the treatment of many diseases. Fullerenes possess different biological applications like neuroprotective agents, antioxidants, anti-HTV activity, enzyme inhibition, antiapoptotic activity and the list is ever increasing. Moreover, they are being utilized as drug carrier systems and also for many non-biological applications like superconductors, catalysis and so on. Their size has made them promising agents for nanotechnology. This article aims at outlining the chemistry, properties and non-biological applications, thereby traversing their evolution from simple carbon allotropes to present day nano-medicinal agents.

Keywords: Anti HIV, antioxidant, antiapoptotic, enzyme inhibition, nanomedicines, neuroprotective.

## INTRODUCTION

Fullerenes are a family of carbon allotrope molecules, in the form of a hollow sphere, ellipsoid, tube or plane. The fullerene revolution began with the discovery of the buckyball ( $C_{60}$ ), composed of 60 carbon atoms arranged in a hollow soccer ball shape. Buckminster Fullerene (Fig. (1)) was named after Richard Buckminster Fuller, the architect who created the dome in 1967 with the same shape as that of the carbon cluster [1].



## Fig. (1). Buckminsterfullerene.

Fullerenes containing 60-70 carbon atoms with diameter of about 1 nanometer (nm), were discovered in 1985 by Kroto *et al.* The structure was confirmed by mass spectrometry [2] and they were awarded nobel prize for their discovery of fullerenes in 1996.

## **Chemistry and Properties of Fullerenes**

Fullerenes were synthesized by using laser vaporization of graphite as a target to produce clusters of carbon chains. Time of flight mass spectrometry was used to probe the carbon plasma produced by laser vaporization. A strong peak at 720 amu indicated that a carbon molecule with 60 carbon

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atoms was formed [2]. Fullerenes are separated by sublimation HPLC, or liquid chromatography on alumina [3].

Pure fullerenes have closer packing than impure fullerenes and therefore dissolve slowly [4].  $C_{60}$  and  $C_{70}$  are decomposed by light, with oxygen and ozone playing a role [5, 6]. This photolytic degradation is responsible for cage opening reaction of fullerenes. Light catalyzed degradation occurs on alumina chromatography columns especially for  $C_{70}$ , and it is observed that carbon/silica gel columns produce  $C_{60}$  of higher purity and crystallinity [7]. Films of  $C_{60}$  degrade on storage, possibly because of the ability of  $C_{60}$  to chemisorb oxygen, which increases its density. On heating in oxygen,  $C_{60}$  is gradually oxidized: C-O adducts are formed at 200°C and decomposition is substantial at 400-500°C [8, 9].

Fullerenes tend to react as electrophiles. Saturation of double bonds leads to relief of strain, which in turn acts as a driving force for electrophilic reactions. The extent of functionalization is instrumental for the progress of reactions i.e. monoaddition or multiple additions and in case of multiple additions their topological relationships (new substituents huddled together or evenly spaced).

As electrophiles, fullerenes react with a host of nucleophiles such as Grignard reagents and organolithium reagents. Reactions of  $C_{60}$  with methylmagnesium chloride stops quantitatively at the penta-adduct with the methyl groups centered around a cyclopentadienyl anion which is subsequently protonated [10]. Another nucleophilic reaction is the Bingel reaction [11] (Fig. (2)). The malonate (functionalized with the halide atom) is often obtained *in situ* in a mixture of base and tetrachloromethane or iodine. The reaction is also known to take place with the ester groups replaced by alkyne groups in dialkynylmethanofullerenes.

Fullerenes undergo Friedel Crafts alkylation with chlorobenzene yielding 1,2 addition adduct (Ar-CC-H) [12]. The [6,6] bonds of fullerenes react as dienes or dienophiles in cycloadditions, for instance Diels Alder reactions. 4-membered rings can be obtained by [2+2] cycloadditions for

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