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## Buckminsterfullerene again

It is a matter of some satisfaction that Indian scientists have got themselves involved in this exciting field recently. P. Balaram reviews (**page 47**) a special issue of the *Indian Journal of Chemistry*, which contains contributions made by Indian authors on this subject. One is happy to note that some very original contributions have come out such as: the possibility of metal complexes of $C_{60}$; a new species of fullerenes containing only carbon and nitrogen; novel views on the electronic structure and bonding in $C_{60}$ and its compounds; interesting theories on the superconductivity in cages, etc. Fullerene research has brought out a degree of co-operation among scientists all over the world in different disciplines – organic, inorganic, physical and theoretical chemists as also between material scientists and condensed matter physicists. In India too, fullerene research seems to be integrating different areas and schools of chemistry – a trend that is so welcome. There also appears on **page 25** an article reviewing the synthesis and characterization of fullerenes and doped fullerenes. It also reports some studies in superconductivity. Since the article goes into some detail of the actual preparation and characterization of $C_{60}$, it is hoped that many other laboratories of India could start work in this field of fruitful research. The authors are aware that any review article in this subject gets dated by the time it comes out in print. It is impossible to open the pages of any journal like *Nature, Science or Chemical Communication* without seeing one or more articles reporting important advances in $C_{60}$ chemistry. This molecule seems to be opening up many new aspects of chemistry. The chemical studies of $C_{60}$ and its less abundant cousin, $C_{70}$, are increasing exponentially. $C_{60}$, the tiny footballs of carbon atoms, is composed of tricoordinated carbon, making up both fused 5-membered and 6-membered rings. This immediately implies that there are two slightly different types of carbon bonds. This non-equivalence causes variations in the reactivity on the surface of the football. The multitude of investigations undertaken is really to understand the variation of this reactivity on the surface. Hydrogenation and halogenation of the cage is giving much information not only about the molecule but also the chemistry of fullerenes (*Nature*, 1992, p. 479). Chemists have succeeded in making $C_{60}F_{60}$ a fully fluorinated molecule. It was thought that this molecule would, like Teflon, be one of the superlubricants. To the great surprise of chemists, this molecule reacts with water and produces HF and so the use of it as a lubricant would be quite dangerous! However, this has led on to some other interesting possibilities. Nucleophilic reaction of fluorinated fullerenes would open up many more routes to producing novel fullerene materials.

Another challenge has been to make the hydrophobic fullerene soluble in water. A rather clever method used by the Swedish chemists at the Chalmers University (*J. Chem. Soc., Chem. Commun.*, 1992, p. 604) is to enclose the molecule in water-soluble cyclodextrins, which consist of 6–8 sugar molecules joined together in a doughnut-shaped ring. There is still speculation whether the complex is 1:2 with fullerene sandwiched between the two doughnuts or whether it is only a 1:1 complex. However it has become clear that because of water solubility, the range of reactions of this molecule will be extended. It is also expected that the water-fullerenes will react differently from fullerenes in organic solvents (*J. Chem. Soc., Chem. Commun.*, 1992, p. 665).

Much headway has been made in forming polymers of $C_{60}$ footballs using the elemental palladium as the glue. The Japanese chemists, Nagshina *et al.* (*J. Chem. Soc., Chem. Commun.*, 1992, p. 377) have polymerized $C_{60}Pd_1$, $C_{60}Pd_2$, and $C_{60}Pd_3$, which are electrically neutral and stable in air, unlike the extremely unstable $C_{60}K_3$. It appears that Pd has the chemical propensity of attaching itself to a molecule which has electron-rich chemical bonds. The metal therefore seems to be strongly attracted to the electron-rich surface of $C_{60}$. Another surprise is the palladium-rich $C_{60}Pd_{3.5}$ which can catalyse a hydrogen addition reaction and therefore may prove of importance in polymer formation.

Fullerene chemistry has led chemists to completely new fields. By reacting methane with titanium, $Ti_8C_{12}$ has been obtained by Castelman and colleagues at Pennsylvania State University (*Science*, 1992, p. 411). Even when methane is changed to ethylene, acetylene or benzene, one gets the same product. $Ti_8C_{12}$ is a pentagonal dodecahedral football having 12 pentagonal faces. Carbon cannot form such a small cage as there will be too much strain, making it unstable. The more diffuse electron orbitals of titanium can obviously relieve the strain to form this football. New techniques of analysis are being continuously introduced in this metal-cage chemistry. All this progress in the chemistry of fullerenes is being eagerly watched by the physicists and the material scientists as they expect new products which will exhibit new physical properties.