

These 240 fall into two sets, one set with 180 electrons are used to form the bonds that hold it together in the pattern that you normally see for a soccer ball. Each one of those 180 electrons is paired up with another one to make the covalent bonds, the single bonds. In an ordinary molecule, like benzene, you can call it the sigma bonding framework. Here it is much the same, except it is wrapped around the surface of the sphere.

That leaves 60 electrons to be delocalized in, sort of, an almost metallic sea, going around in what would be the π -bonds of benzene, but these are now radially directed carbon orbitals, one sticking out from every carbon, at the vertices, on the radius line. It turns out that 60 is a very special number for those electrons and they again can all find partners to pair up, and it closes what's called an electronic shell. So it's a closed shell molecule, all the electrons are paired up, which is what you need to have to have a really stable molecule.

The next most energetic way of moving electrons around the sphere is quite a distance up. That makes bucky fairly weakly colored in the visible range. If you had a polycyclic aromatic with anything like 60 carbons in it, and you put that in a solution and looked at that in one of these bottles at the concentrations, or even a hundredth of the concentrations that you see these bottles of C_{60} , a typical polycyclic aromatic molecule would be pitch black by that point. So these are not very absorbent molecules: In fact, the color from C_{60} is entirely due to forbidden transitions that wouldn't be true if it weren't vibrating.

The strong absorptions are in the ultraviolet; that's because the structure is so stable, and the next level up is so far away. Now, when you make a crystal of this, and you add alkaline metals to the outside, those alkaline metals have an extra electron associated with a single valence electron, and they don't hold on to them very tightly. C_{60} actually has quite a high affinity for electrons. Electrons can go onto the ball, and they go into this next higher level in the electronic structure, and effectively spin around the outside of the ball.

There's room for six electrons there. If you put six electrons into it, that material will be an insulator, but if you'd put in less than six electrons, you'll have a conducting material. Effectively, each ball becomes metallic. The metallic electrons on the surface of the ball can hop from ball to ball, and therefore, you get a bulk conductivity. This conductivity becomes super when you cool it down. One model for the superconductivity is that each ball is itself a superconducting ball: You just happen to have a close-packed lattice of superconducting balls where the supercurrent is hopping between balls.

One of the things that makes C_{60} so unusual is that it is so big for a molecule. It behaves in many ways more like a graphite ball than like a big benzene molecule. Also being along the size range of 1 nanometer [1 billionth of a meter] it sits just squarely right where we like to be when we start building structures. One of the things we are hoping is that

this will get organic chemists excited about dealing on this level. They could be in a position to push back the frontiers of nanotechnology rather dramatically.

Q: Another feature of C_{60} is the "free rotation" of these carbon balls in the lattice. It's described to be on the order of billions of revolutions per minute. Is that an unusual feature?

Smalley: Benzene, itself, in the crystal at room temperature is actually spinning around its sixfold axes. Other symmetrical molecules in their crystals often do spin. What is unusual in C_{60} is the broad temperature range over which this happens, and the fact that the spinning is isotropic, or at least it appears to be. There is no preferred direction, because this is a spherical one.

No, it is not by any means unprecedented. Methane, for

Beginning with benzene

Benzene is a ring of six carbon atoms and is a basic building block in organic chemistry. Benzene was first isolated in 1825 by Michael Faraday, but, of all the proposed structures for this molecule, none seemed to fit. In 1865, German chemist Friedrich August Kekulé came up with a satisfactory structure for benzene. This is how Kekulé recounted his insight in his journal:

"During my stay in Ghent, I resided in elegant bachelor quarters. My study, however, faced a narrow side-alley and no daylight penetrated it. For the chemist who spends his day in the laboratory, this mattered little. I was sitting, writing at my textbook, but the work did not progress; my thoughts were elsewhere. I turned my chair to the fire and dozed. Again atoms were gamboling before my eyes. This time the smaller groups kept modestly in the background. My mental eye, rendered more acute by repeated visions of the kind, could now distinguish larger structures of manifold conformation: long rows, sometimes more closely fitted together, all twining and twisting in snake-like motion. But look! What was that? One of the snakes had seized hold of its own tail, and the form whirled mockingly before my eyes. As if by a flash of lightning, I woke; and this time also I spent the rest of the night in working out the consequences of the hypothesis.

"Let us learn to dream, gentlemen, then perhaps we shall find the truth. But let us beware of publishing our dreams till they have been tested by the waking understanding."

Translated by F.R. Japp, Journal of Chemical Education (1958).