What You Find When Looking for a Soccer Ball

With classic serendipity, a chemist's quest to make spherical carbon molecules has produced a bevy of intriguing spinoffs

"I'M LUCKY," says University of California, Los Angeles, chemist Orville L. Chapman. "I just keep looking at the things nature gives me. And they're nice things."

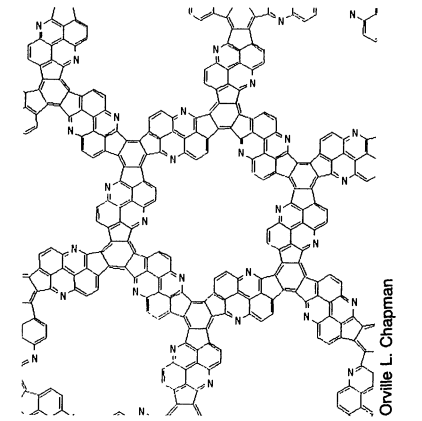
Indeed they are—although Chapman has been giving nature plenty of encouragement. In Honolulu recently, he told an international chemical conference* about his decade-long pursuit of a distant vision—the synthesis of spherical carbon molecules—and how that quest has led him and his students into such intriguing incidental discoveries as "azite," a black, ceramic-like substance that is nearly as hard as quartz, less than half as dense, and capable of conducting electricity.

"It's a pretty special material," says Chapman. "It's porous, it's hydrophobic, it conducts, it's very strong." He envisions it being used as organic electrodes in lightweight batteries, or in a wide variety of other applications that demand high strength and low weight. "It's definitely the most interesting thing we've come across in the practical sense," he says.

Many chemists in the audience seemed to agree. "What struck me about that talk was the freshness," Walter S. Trahanovsky of Iowa State University told *Science*. While cautioning that neither he nor anyone else has had a chance to study the results in detail—Chapman is still writing them up for publication—his sense was that some of Chapman's reactions were very strange and new. The azite, as well as a series of odd, cup-shaped molecules and some new types of polymers, "all have the potential for unusual properties," says Trahanovsky.

Chapman traces his fascination with carbon spheres back to the summer of 1981. "Quite frankly," he says, "I felt that what I was doing at the time [photochemistry and physical organic chemistry] was pretty prosaic." So, as he headed for Germany on a Humboldt fellowship, he set himself a little problem: "If God would give me one molecule to make, what would it be?"

The carbon sphere was his answer. "It would be spectacular," he says—a single molecule in which dozens of carbon atoms would form links like the seams of a soccer ball. It would be a totally new kind of material, with unknown and potentially useful properties; after all, the known forms of carbon, diamond and graphite, are not molecules at all, but endlessly repeating crystals. Moreover, several theoretical chemists had already pointed out that a sufficiently large carbon sphere might be stable, since the curvature would then put relatively little stress on the carbon-carbon bonds. Chapman therefore set his sights on making C_{60} and C_{80}, two spheres that promised to be particularly symmetrical and stable.



Azite up close. *The lacy network allows the material to be very hard, but very light.*

Nine years later, Chapman admits that he is still a long way from his goal. And yet there have been some tantalizing hints that it might be attainable. The most dramatic of these came in 1985, when Richard E. Smalley and his colleagues at Rice University used a laser beam to vaporize a sample of graphite and found that the debris contained C_{60} in abundance. Under the assumption that the structure is indeed a sphere—even today, the evidence is indirect—they immediately dubbed it "buckminsterfullerene." It is extraordinarily stable, Smalley says, with at least 24 electron volts of energy required to break it up. It may even be abundant in nature, both in ordinary soot here on Earth and in the dusty outer envelopes of red giant stars throughout the galaxy.

For Chapman, the discovery of C_{60} was both an inspiration and a frustration. If the laser-induced molecule is truly spherical, he says, then it is certainly nice to know that what he is looking for is real. On the other hand, that tells him nothing about how to synthesize the thing. The mechanism by which C_{60} forms in the laser debris is still what he calls "magic and mystery." Until someone can figure it out, he is left with the more prosaic techniques of the laboratory bench—mixing, stirring, separating, and analyzing. Happily, these techniques have produced some extremely interesting molecules along the way.

For example, Chapman and his students have developed a variety of techniques for making cup-shaped aromatic molecules—which typically would rather lie flat. One of these, a triangular pinwheel containing a half dozen five-sided rings along with four six-sided benzene rings, is essentially half of a spherical C_{60}. In principle, says Chapman, it may be possible to sew two molecules together to make the complete sphere.

And then there is azite. Chapman's group stumbled upon the substance about 2 years ago when he asked graduate student Daniel Loguercio to synthesize a certain carbon- and nitrogen-containing molecule that Chapman thought might also be cup-shaped. Instead, the result was a hard black crud. "We tended to treat it as junk at first," he says. "But then we began to realize that it was much more interesting than what I had been looking for."

It developed that their nitrogen-containing molecule, a triangular network of five- and six-membered rings similar to the cup-shaped molecule mentioned above, had polymerized, forming into chains of carbon and nitrogen rings surrounding huge hexagonal holes—a kind of two-dimensional lacework that accounts for the material's uncommonly low density. Azite also proved to be stable up to at least a temperature of 500°C and perhaps much higher.

Meanwhile, another graduate student, Trilliant Fang, recognized the material's conductivity and hardness. "If you try to grind it up in an agate mortar and pestle," says Chapman, "it scratches the agate badly." He suspects that practical applications may still be a good ways off, if only because the stuff is so difficult to work with.

But then, if Chapman were personally interested in practical applications, he wouldn't be doing this kind of research in the first place. "I like to be out there alone, where I can make my own mistakes," he says. "If I can read too much about it, I'm not interested. Also, if I'm in a horse race, just trying to beat somebody else, that's not appealing. I just want to work on the important problems."

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*The International Chemical Conference of Pacific Basin Societies, 17 to 22 December 1989, Honolulu, Hawaii.