CC/NUMBER 36
SEPTEMBER 6, 1993

# This Week's Citation Classic®

**Kroto H W, Heath J R, O'Brien S C, Curl R F & Smalley R E. C : buckminsterfullerene.**
*Nature* **318**:162-3, 1985.
[Rice Quantum Institute and Depanments of Chemistry and Electrical Engineering, Rice University, Houston. TX]

The discovery that $C_{60}$ forms spontaneously in a carbon plasma was announced and its soccer ball structure postulated. [The *SCI*® indicates that this paper has been cited in more than 1,080 publications.]

## $C_{60}$—The Third Man

Harold W. Kroto
School of Chemistry and
Molecular Sciences
University of Sussex
Brighton BN1 9QJ
England

The laser-vapourisation machine (or AP2, as it was affectionately called, for "second-generation apparatus") was impressive on the day in 1984 when Rick Smalley took me on a whirlwind tour of his lab. Bob Curl had invited me to Rice and encouraged me to visit Rick, who had just demonstrated that $SiC_2$ was triangular and not linear as most would have thought. This fitted in neatly with aspects of Si behaviour that had puzzled me years earlier during studies of multiple valency.[1] Rickshowed me SiC disks that were being iaser-vapourised in AP2. He exuded the infectious enthusiasm of a successful scientist. As the day wore on I became more and more convinced that AP2 could simulate the plasma chemistry in IRC+10216, the red giant star which had captured my attention as well as that of others who had detected molecules in space by radioastronomy. Using graphite, AP2 could probably produce longer chains than I, together with Avery, Broten, McLeod, and Oka, at the National Research Council (Ottawa) and Alexander, Kirby, and Walton at Sussex had detected (1975-1978) in the cold black clouds of the galaxy. I had become convinced that the molecules originated in stars and not in the clouds.[1] That evening Bob was enthusiastic about my proposal to simulate carbon star-chemistry and agreed to discuss it with Rick. Sixteen months passed (two other groups carried out similar graphite studies!!!) when suddenly, after I had almost forgotten about it, Curl phoned (August 1985) to say my experiments were imminent—I was in Houston within three days.

I gave an extended seminar as soon as I arrived on everything I knew about carbon in space, stars, and perhaps AP2, gleaned from decades of work with carbon molecules. The experiments started on Sunday, September 1.1 worked hand-in-hand with graduate students Jim Heath, Sean O'Brien and Yuan Liu. It was exhilarating to watch results appear on the monitor and discuss them with Jim, Sean, and Yuan, who would then optimise conditions to probe further any particularly interesting features. AP2 behaved perfectly, spewing up mass spectra of not only the 5-9 atom chains detected in space, but much longer ones with 20-30 atoms. As time progressed we occasionally peeked over our shoulder to keep an eye on a new family ($C_{30-90}$) discovered at Exxon. We studied these clusters by keying in the strongest peak at the center of the bunch and optimising its signal—it was $C_{60}$. Gradually we noticed odd behaviour: As conditions were changed for the astrophysical study, sometimes all clusters appeared strongly but at other times only $C_{60}$ and $C_{70}$ appeared in large numbers, with fewer $C_{70}$ than $C_{60}$.1 considered calling them Don Quixote and Sancho Panza, but this was Texas and the Lone Ranger and Tonto seemed more appropriate.

One run, on Wednesday, September 4, was spectacular; on my printout I wrote "$C_{60}{}^{+}$(?) beside the peak; $C_{60}$ huge, $C_{70}$ also."[2] Our reactions to this and subsequent observations were noted in the AP2 book by the students: *"$C_{60}$ and $C_{70}$ are very strong!*—$C_{60}{}^{+}$ is very large—Why $C_{60}{}^{+}$?"[2] From that day on $C_{60}$ insinuated itself into our minds and deliberations. On Friday night I drove to Dallas (in particular, Half-Priced Books on Mockingbird Lane); I was happy—my experiment had been wonderfully successful and in addition we had serendipitously discovered the exceptionally stable $C_{60}$. During the long drive I mulled over our discussion on what structure could explain the stability. That night Sean found he could get $C_{60}$ 30 times stronger than the rest, and Jim (Saturday/Sunday) painstakingly pinpointed clustering conditions. When I returned on Sunday night (loaded up with art and graphics books) Jim showed me a run with almost nothing but the $C_{60}$ peak and $C_{70}$ (five times weaker) present. I was even more impressed now.

Monday (the ninth) was a day of fervent excitement and discussion over $C_{60}$ Ideas were tossed about and a consensus developed that a closed hexagonal graphene cage with no dangling bonds might explain the unreactivity. I recalled again Buckminster Fuller's geodesic dome in Montreal which I had visited in 1967. I also remembered a polyhedral cardboard starmap (stardome) which I had made years before for my kids. At that moment it was in a Xerox box at home in England, and I wondered whether to calf and ask my wife to count the vertices—perhaps it had 60.1 was going home the next day so that evening I took the group to dinner at our favourite Mexican restaurant. We discussed only $C_{60}$—the tortillas were stone cold by the time we got round to eating them. We discussed cages, domes, and the stardome which I recalled had pentagonal as well as hexagonal faces. I longed to be back home—it is not so easy to be creative outside one's own environment. That night Jim and his wife experimented with cage models and Rick with paper hexagons. On remembering our pentagon discussion Rick tried them and found that the flat hexagon-only model curled up, and on adding 12 pentagons a closed ball with 60 vertices grew.[3] When he tossed the ball on the table the next morning we were ecstatic.[2,4]

it was so beautiful it just had to be right. I delayed my flight home by one day to help write up the paper. I suggested the name "buckminsterfullerene"—conjured from air thick with the Monty Python scripts we had plundered for a decade for Sussex pantomimes. I delighted in the way the name—though long—rolled smoothly off the (English) tongue and relished the fight to ram this mouthful! down the throats of those who might not appreciate its virtues (or its humour!). It is very satisfying to see "fuilerene" accepted as the family name. The name brings an extra aura to the field through the association with the geodesic domes. Though the majesty of the original name is diminished somewhat, to see the eyes of schoolkids shine as they talk excitedly about "buckyball" *chemistry* is marvellous.

On Wednesday I flew home on such a high that I swear the plane flew without engines. I wondered what to say to anyone who asked, "How did it go?" There could only be one answer, "sensationally." The first person was Julie August, one of my research students, who duly asked, "How did it go?" and I duly answered "SENSATIONALLY."

The discovery was a grand synthesis of ideas on carbon in space and exceptional technical advances made by Rick at Rice. AP2's raison d'etre was to unveil "The Third Man" of the carbon allotropic family. The wonderful extraction by W. Kratschmer, L.D. Lamb, K. Fostiropoulos, and D.R. Huffman[5] has ignited the scientific explosion recorded by ISI®.[6]

I am a true admirer of A. Kurosawa, who in *Rashomon* suggests that reality lies in the *totality*of individual subjective (personal) accounts of all participants in an event.[7] Thus, in addition to this brief persona/account, other accounts should be consulted.[2,4] *Finally, lam most grateful to David Walton, who first got me wrapped up in the chains which now tie me to this fascinating ball.*

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1. **Kroto H W.** Scmislable molecules in the laboratory and space. *Chem. Soc. Rev.* 11:435-91, 1982.

2.-------------------. $C_{60}$: buckminsterfullerene. the celestial sphere that fell to earth. *Angew. Chem. Internat. Ed.* 31:111 -29, 1992

3. **Smalley R** E. Great balls of carbon. *The Sciences* 3**1** (2):22-8, March/April 199**1**.

4. **Curl R F.** $C_{60}$: yesterday and today. *Chem. NZ* (47):3-14. 1992. (Newsletter.)

5. **Kratschmer W, Lamb L D, Fostiropoulos K & Huffman D R.** Solid *$C_{60}$.:* a new form of carbon. *Nature* 347:354-8. 1990. (Cited 1,070 times.)

6. Carbon clique continues conquest of chemistry cohort. *Science Watch*® 3(8):7. October 1992.

7. **Kurosawa A & Richie D.** *Rashomon.* New Brunswick, NJ: Rutgers University Press. 1987. 201 p.


Received July 12, 1993