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OBITUARY

Richard E. Smalley (1943–2005)

Chemist and champion of nanotechnology.

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Towards the end of his life, Richard Smalley had begun to say, "If it ain't tubes, we don't do it". He had become fascinated by the prospect that fullerenes — the massive carbon molecules with distinctive geometrical shapes that he had co-discovered in 1985 — might be re-formed into single-walled nanotubes with exciting properties. In particular, he dreamt of making a metallically conducting cable of billions of these carbon nanotubes, which, for the same weight, would be many times stronger than steel. Smalley's time ran out before he achieved that goal; nevertheless, the legacy of this research already extends far beyond the confines of materials science, to such diverse fields as energy technology and medicine.

The single-minded obsession that Smalley, who died on 28 October, brought to nanotube research was in fact rather out of character. In his early career as an independent researcher, he had tended to create a new research field about every two years, often abandoning them with equal frequency. The tenor of this period was set in postdoctoral work at the University of Chicago, where he pioneered a technique that combined laser excitation of molecules with their cooling by supersonic jets of gas. He demonstrated that the method greatly simplified the complex spectra of the molecules' energy levels, and allowed complexes bound together by very weak van der Waals interactions to be created and observed. On arriving, in 1976, at Rice University in Houston, Texas — where he was to stay for the rest of his career — he rapidly created a series of spectroscopic tools based on this technique that are used to this day. Smalley's approach was to conceive a way to investigate a chemical system or phenomenon, construct the necessary sophisticated apparatus, do enough work to show the true potential of the method, and move on. Each new project was better than the last, offering further valuable scientific information.

The discovery of the fullerenes, which led to his Nobel Prize in Chemistry in 1996, grew out of one such project. In this, Smalley was studying jet-cooled molecular clusters formed by the condensation of laser-vaporized metals or semiconductors. In March 1984, the British chemist Harry Kroto, whose radio astronomy observations had detected long carbon-chain compounds in interstellar clouds, visited Rice. Kroto saw the vaporizing graphite in Smalley's apparatus as a way of testing his idea that these chains were being formed by the condensation of species ejected from carbon-rich stars. When the experiments were finally performed at the facility in September 1985, proof for the formation of carbon chains between 7 and 12 atoms long, the size range of the astronomical observations, was indeed found.

The experiments also showed striking evidence that more interesting, much larger carbon clusters of between 40 and 80 atoms were being formed simultaneously. The particularly high abundance of the C_{60} cluster could only be explained if it were a stable, closed cage with 20 hexagonal and 12 pentagonal interlocking faces, rather like a football, or soccer ball. Because of the transatlantic conflict between the experimentalists over the exact name of the ball and the sport it belonged to — and because the structure was reminiscent of the geodesic domes of the architect Buckminster Fuller — the C_{60} structure was named buckminsterfullerene. A more general examination of the number of carbon atoms in the other, differently sized clusters that were found led to the gradual realization that they must all be carbon cages consisting of exactly 12 pentagons and a number of hexagons that grew with increasing cluster size.

Efforts in Smalley's laboratory to make a macroscopic sample of buckminsterfullerene were abandoned fairly quickly after experiments to vaporize a graphite rod using a laser left no trace of C_{60}. The isolation in 1990 of a mixture of C_{60} and C_{70}, using an apparatus consisting of a carbon arc inside a bell jar, seemed ridiculously simple compared with Smalley's high-tech approach. Smalley reinvestigated the laser vaporization technique, and found that the amount of C_{60} produced depended strongly on the temperature of the wall of the quartz tube that surrounded the graphite rod: no C_{60} was obtained when it was at room temperature, but there was a 20% yield at 1,100 °C.

The isolation of single-walled carbon nanotubes (SWNTs), announced in June 1993, soon drove Smalley's attention and considerable powers to another domain. The development of synthesis techniques for SWNTs was a challenge unlike anything Smalley had encountered before 1990, and virtually all that was known was the need for a metal catalyst — iron, cobalt or nickel. Soon Smalley found that, by impregnating these metals into the graphite rods used to make C_{60} in the laser vaporization experiments, he could create SWNTs in the form of ropes containing more than a hundred individual tubes. Between 1993 and 2005, Smalley found a generally better way of making the tubes, as well as ways of cutting them up, performing chemical reactions on them and producing them in solution. In the last week of his life, desperately ill with leukaemia, he was enthusiastically receiving progress reports in his hospital bed and suggesting new ideas and experiments.

Rick Smalley was a remarkable person, both professionally and personally. He had two sons almost thirty years different in age, and four wives — the first two of whom were his guests at the Nobel ceremony in 1996 (when he himself was single). Everyone got along amiably, both former wives seeming to have a wonderful time. As his end neared, Smalley's fourth wife Deborah and older son Chad cared for him constantly.

Smalley's ability to vacuum up information, organize it and use it for creative scientific endeavour was prodigious. He always tackled the most challenging problems, was indefatigable in the pursuit of answers, and in all arguments met logic with logic. Smalley had a whimsical sense of humour and tremendous personal charisma. Others usually found it to their advantage to follow his lead, as collaboration with Smalley generally resulted in excellent scientific results. Smalley's persuasiveness came most effectively to bear in the campaign to convince the US government to create its National Nanotechnology Initiative, a great achievement in public policy. ■

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