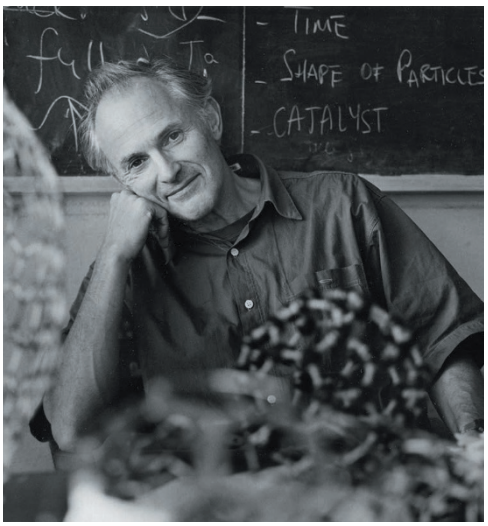
Harry Kroto

(1939–2016)

Discoverer of new forms of carbon.



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Harry Kroto was part of the team that discovered buckminsterfullerene, the football-shaped carbon-60 molecule that came to be known as a buckyball. The realization that such a large molecule could self-assemble from hot carbon vapour forced a reassessment of the science of carbon. By prompting searches for other structures — carbon nanotubes and nanowires were among the materials later found — the discovery ultimately provided a foundation for nanoscience and nanotechnology.

Kroto, who died on 30 April, was born Harold Krotoschiner in 1939 in Wisbech, UK, the son of German refugees. During the Second World War, his father Heinz was interned on the Isle of Man as an enemy alien, and Kroto and his mother Edith went to live in the town of Bolton. After the war, the family stayed in Bolton, where his father opened a balloon factory and shortened the family name to Kroto. After finishing school, Kroto studied chemistry at the University of Sheffield, completing his undergraduate degree in 1961 and his PhD in 1964.

After two postdoc positions, Kroto and his wife Margaret moved to Brighton in 1967, where he took up a teaching post at the University of Sussex. During the 1970s, Kroto began work that led to a lifelong fascination with the chemistry of interstellar space.

Kroto studied a class of linear molecules called cyanoacetylenes with the atomic composition H–$(C)_n$–C≡N. These were hypothesized to exist in the molecular clouds that surround stars with carbon-rich atmospheres. He combined molecular spectroscopy of these carbon chains — which he created fleetingly in the lab — with measurements made by radioastronomers who were aiming to detect the same molecules in the material surrounding carbon stars. By the early 1980s, radioastronomers had detected cyanoacetylenes in space that contained up to 11 carbon atoms. The relatively high abundance of these molecules challenged existing models of interstellar chemistry, which predicted the presence of much smaller molecules.

Around this time Kroto learned about Richard Smalley's cluster-beam experiments. Smalley, then a physical chemist at Rice University in Houston, Texas, was using a laser to vaporize a material with a high melting point (called a refractory target). As the hot atoms cooled, they would condense. Smalley halted this chemistry after only a few microseconds using supersonic expansion: a high-pressure gas was passed through a small orifice into a large vacuum chamber to cool the molecules and stop all chemical reactions.

The technique offered the perfect way to test whether vaporized carbon would condense to form carbon chains similar to those found in certain interstellar environments. So in 1985, Kroto travelled to Houston to work in Smalley's lab. It was during this visit that he, along with Smalley and his group (including the two of us), discovered C_{60} and the other fullerenes. And Kroto was able to prove his hypothesis that long carbon chains were reaction products of condensing carbon.

Before that, three different crystalline forms, or allotropes, of carbon were known: graphite, diamond and lonsdaleite, a rare modification of diamond. The first two provided text-book examples of how physical properties reflect atomic structure: the electron arrangement in graphite (sp^2-hybridized) makes the allotrope an electrical conductor and a dry lubricant; whereas that of diamond (sp^3-hybridized) makes it an insulator and the hardest known mineral. Equally fundamental, the molecular chemistry of carbon provides the foundation of organic chemistry and biochemistry.

It is thus not surprising that our proposed structure for C_{60} — a truncated icosahedron in which the 60 carbon atoms form a cage of interlocking pentagons and hexagons — was initially viewed with scepticism (H. W. Kroto *et al. Nature* **318,** 162–163; 1985). Our experimental support for the C_{60} structure arose from a combination of mass-spectra data and circumstantial evidence. This was hardly the gold standard of single-crystal X-ray analysis for absolute molecular structure determination. However, the football structure followed Occam's razor: it tied together many observations in a simple and elegant way, and yielded many predictions that were later proved to be correct, including the structure of a second fullerene, C_{70}.

Absolute confirmation of these structures came five years later, when physicists Don Huffman and Wolfgang Krätschmer and their groups worked out how to make C_{60} in bulk. Today, the buckyball is a crucial component of solar cells.

In 1996, Kroto shared the Nobel Prize in Chemistry with Smalley and one of us (R.F.C.), and was knighted. From 2002 to 2004, he served as president of the Royal Society of Chemistry, and in 2004 he left Sussex to take up a chair at Florida State University in Tallahassee.

Harry was strongly opinionated. He did not profess modesty, and as an atheist, he would often engage his religious acquaintances in fierce debate. But with children (he had two sons), he was always terrific. After receiving the Nobel, he devoted much of his time to elevating the importance of science teaching. Seeing that the football-like structure of C_{60} would resonate with almost any child, he would set up games in which buckyballs would pop out of unexpected places, or have children assemble buckyballs themselves.

Harry had an impish sense of humour similar to that of the British comedy group Monty Python, which he greatly admired. He also had the distinction of being the only Nobel laureate to have appeared on stage with the actor Ian McKellen — in a school production when they were both teenagers.

Harry (who remained friends with McKellen) had a deep appreciation of the arts, and was himself a skilled graphic artist. He published several designs, one of which was chosen for the 2001 UK postage stamp celebrating the Nobel centenary. Of course, it included a drawing of a buckyball. ■

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