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Art and science, can they ever be one and the same?

HAROLD KROTO

School of Chemistry, Physics and Environmental Science, University of Sussex, Brighton BN1 9QJ, UK. E-mail: kroto@sussex.ac.uk

Introduction

As a scientist whose primary passion is art and graphics I have, for as long as I can remember, sought to find a satisfactory bridge between Art and Science. I have invariably found the attempts that I have come across are, at best, unsatisfactory and, at worst, specious. Books purporting to find 'Art' in the 'Sciences', or vice versa, usually consist of collections of photographs that reveal some previously hidden worlds (often taken by electron microscopes) or elegant images, which are some sort of visual representation of some theoretical/mathematical results. Modern computer-graphics packages have resulted in a plethora of elegant images. But are they art? Maybe, maybe not, perhaps it is just semantics and, anyway, perhaps it does not matter in general. I would have the board from a computer and other elegant flotsam dropped overboard from our technologically advanced world, which produces so much unusable obsolete technology. It is as elegant as a Jackson Pollock painting or a Bridget Riley Op Art creation, but is it art? As always in these cases, I seek not the answer but to understand the question.

The artist Allen Jones contacted me last year about an imaginative idea for the 2004 Royal Academy Summer Exhibition at Burlington House in London. The idea that he and David Hockney had come up with, was to organize an exhibition of drawings that people who were not practising artists produced and used during their work. This was not be an exhibition of art by people who paint or draw as a sideline or hobby, but an exhibition of 'artwork' – in particular, drawings that had played a crucial role in their work. In the case of scientists, their drawings made by hand rather than by computer, and which had formed part of the research process. In response to this initiative, I collected together some drawings made during the period 1985 to 1987 when the field of Fullerene Science was born.

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The art and science of the carbon nanoworld

Two forms of the element carbon, diamond and graphite, have been known since time immemorial. Amazingly, in 1985, a third form was discovered – a 60 atom cage molecule with the pattern of a modern football, which has 12 pentagonal and 20 hexagonal patches.

Basically, one can consider the carbon atoms as residing at the 60 trigonal intersections of the seams of the football (Figures 1 and 2). After the discovery of this molecule (formula C_{60}), which I named Buckminsterfullerene after the designer of the geodesic domes, and of its slightly larger and elongated cousin C_{70}, the possibility of other smaller and larger carbon cages began to interest me and I decided to play around and construct some possible models – initially just for fun.

Just as the Platonic and Archimedean semi-regular solids had fascinated Leonardo da Vinci and Piero della Francesca who had drawn them, so the new objects I created invited similar representation in 2D. At the time there were no, readily available, molecular modelling computer programs so I improvised a sort of modern (1985) analogue of the camera obscura approach used by artists for centuries: (1) first of all, various possible model Fullerenes were constructed out of simple molecular modelling components. The nuclei of the atoms are represented by black plastic units, which are linked by plastic straws that represent the chemical bonds (electrons). This model-building exercise was carried out on the basis of some rather arbitrary aesthetic symmetry as well as chemical considerations, to see what sort of structures might arise in accordance with the recipe that 12 pentagons and any number of hexagons (except one) can close into a cage structure. (2) The models were then photographed using a Polaroid camera. The original photograph of the model for C_{28} is shown here (Figure 3). (3) The photographs were then enlarged using a photocopier. (4) On this photocopy the atoms were connected by straight lines and then, (5) the resulting network was traced to produce a series of 2D images in perspective. The result was a set of drawings of a new family of pure carbon molecules that had never previously been considered, the Fullerene Family. The family is huge, in fact infinite – as an

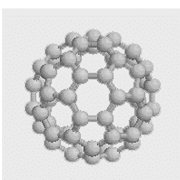

Figure 1

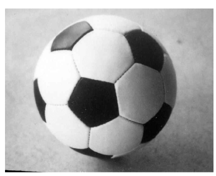

Figure 2

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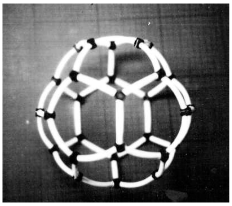

Figure 3

example there are 14,000 different cages for the case of 120 atoms. It turns out that for 60 atoms there is an especially symmetric structure, the one and only football structure.

The diagrammatic representation of molecules and chemical processes

Just as Mercator's name is associated with one solution of the problem of how to represent the surface of the World on a flat sheet (e.g. how to make a map), so the name of Schlegel is associated with the problem of representing the surface of a polyhedron in two dimensions. In the case of the C_{60} molecule, which has the same pattern of 12 pentagons and 20 hexagons as a football, the same problems arises of how to represent a Fullerene network on a 2D sheet. One Schlegel solution is shown here in Figure 4.

Just as in the case of Mercator's projection, in which the countries of the World are distorted to varying relative degrees, so the various polygonal shapes also are also distorted to varying relative degrees. What we have is a 2D network that is very useful for atom identification and chemistry bookkeeping purposes. In a way it is analogous to Beck's famous London Underground Map, which is very useful for deciding quickly how to get from one location to another, but rather less useful for the representation of the actual geographical logistics involved A hypothetical chemical reaction is represented in which two carbon atoms are 'ingested' into a Fullerene cage network, effectively inflating the cage; two atoms on the surface assimilate into the network (Figure 5). A facile series of bond (localized electron)

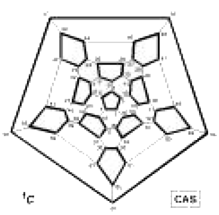

Figure 4

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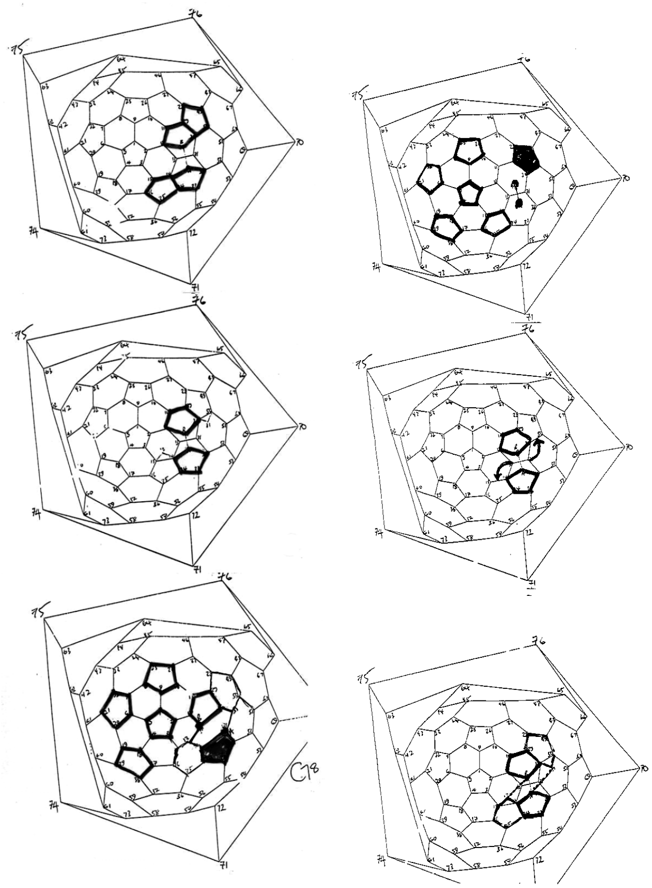

Figure 5

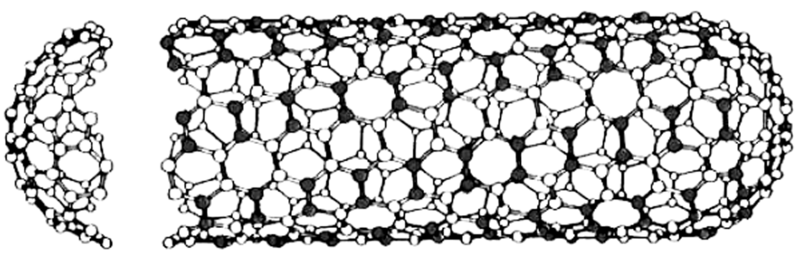

Figure 6

shifts, indicated by the arrows, results in a new slightly larger cage. The interesting thing is that this process can continue sequentially and C atoms may add, by the same mechanism, two at a time ad infinitum, resulting in a chiral (helical) tubular structure. Such a tubular structure is depicted in a somewhat more readily appreciated perspective representation in Figure 6.

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The elegant aspect here is that the end-cap pattern (which is the same pattern as half a football with one pentagon displaced) has not actually changed – but appears to have rotated one notch at a time. This is what we call a pseudo-rotation.

Conclusion

The example is described above in which a model building exercise, which started out as a fun ('artistic') exercise, resulted in an elegant scientific advance. Furthermore, the process of transcribing the results for publication required the use of diagram construction devices, which find parallels in the approaches that artists from Leonardo da Vinci to Picasso have used for centuries. The drawings that resulted formed part of a display at the 2004 Royal Academy Summer Exhibition of drawings, made by people who were not practising artists, as important adjuncts in their professional work.

Acknowledgements

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About the Author

Harold Kroto is Professor of Molecular Spectroscopy at the School of Chemical Sciences at the University of Sussex and is also a Professor at Florida State University, Tallahassee, Florida. Together with Robert Curl and Richard Smalley he was responsible for the discovery of the previously entirely unknown form of carbon, which they named 'buckminsterfullerene'. This name reflects Kroto's deep interest in architectural and artistic forms. The three scientists shared the 1996 Nobel Prize in Chemistry.