BIOGRAPHICAL MEMOIRS

Dennis Frederick Evans. 27 March 1928 –– 6 November 1990: Elected F.R.S. 1981

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Dennis Evans was an extraordinarily versatile chemist whose interest spanned the conventional boundaries of inorganic, organic and physical chemistry. He made highly individual contributions to all these branches, particularly to inorganic chemistry, nuclear magnetic resonance, magnetism and the reactions of oxygen. His enjoyment of chemistry inspired and delighted those around him.

Early years

Evans was born on 27 March 1928, at 82 Woodborough Road in Nottingham—the house has since been demolished. His grandfather was a master butcher, managing a chain of shops in Bristol before settling in Nottingham; his father, George Frederick Evans, was a master carpenter, cabinet maker, violin maker and piano builder (Evans retained much of his father's furniture and was very proud of it). His mother (*née* Gladys Martha Taylor) was an accomplished dressmaker.

He was educated at Huntingdon Street Junior School, and then won a scholarship to Nottingham High School, where D.H. Lawrence had been a pupil. His interest in chemistry came early in life. Both his parents were keen amateur photographers, and it seems that it was largely his early interest in developing the photographs which was a major stimulant in introducing Evans to chemistry. When he disposed of his home chemistry set his neighbours appeared, complaining in unison about the smells arising from their sinks.

Oxford and Chicago

Evans was awarded a scholarship at Lincoln College and matriculated at Oxford University in September 1946. The college chemistry tutor was R.E. (later Sir Rex) Richards (F.R.S. 1959), who had recently succeeded N.V. Sidgwick, F.R.S. In his second year at Oxford he was runner-up (*proxime accessit*) in the highly competitive examination for the Gibbs Prize in chemistry and he won this prize in his third year. He rapidly established a reputation for his brilliance and he had a total recall of the books he had read. This is well illustrated by the true story of the relationship that grew up between Evans as a second-year undergraduate and Linus Pauling (For.Mem.R.S. 1948; twice a Nobel laureate), who in 1947 was the George Eastman Visiting Professor at Balliol College. Pauling gave a series of lectures attended by Evans, and Pauling would frequently refer to specific data from his famous book *The nature of the chemical bond*, citing a bond length or a dipole moment. Frequently Evans would raise his hand and politely indicate that this eminent lecturer had not remembered the data precisely. After the second lecture, Pauling would simply point to Evans when he required such specific data, which Evans would immediately provide.

He undertook his Part II research in 1949 under the supervision of R.E. Richards, and was awarded a first-class honours degree in chemistry in July 1950. In September 1950 he started on research for the DPhil degree, also under the supervision of R.E. Richards. His earliest postgraduate research was concerned with calorimetry, and he showed his extraordinary skills in the design and construction of scientific equipment by building a deceptively simple but highly sensitive and accurate calorimeter. He also studied the preparation and magnetic properties of clathrates containing oxygen and nitric oxide. During his postgraduate years he published no fewer than ten scientific papers, an astonishing number for those days. Although his research did not at that stage concern nuclear magnetic resonance (NMR) spectroscopy it was from this time that his interest in the subject was aroused, because R.E. Richards was a pioneer of this new form of spectroscopy. Leslie (Les) Pratt, another student of R.E. Richards's, was then working on NMR spectroscopy; he and Evans became firm and lifelong friends. Evans was an ICI Research Fellow in the year 1952/53, and then again in 1954/55. His DPhil thesis was submitted on 27 October 1953 and was entitled 'Thermochemical studies on molecular structures'; it was examined by L.A.K. Staveley and H.D. Springall.

In the academic year 1953/54 he was a postdoctoral research associate at the University of Chicago. He worked there with Robert S. Mulliken (For.Mem.R.S. 1967), the distinguished theoretical chemist, who was awarded the Nobel Prize for Chemistry in 1966 for his studies on chemical bonding and the electronic structure of molecules by the molecular orbital method. Evans worked with him on the electronic spectra of halogens in organic solvents and with polymers, and produced four papers under his own name, again a remarkable achievement for such a short period.

Imperial College

In 1955 Geoffrey (later Sir Geoffrey) Wilkinson (F.R.S. 1965; Nobel laureate) was appointed Professor of Inorganic Chemistry at Imperial College. Wilkinson appreciated the potential of

the new developments in the field of high-resolution NMR spectroscopy. He contacted Rex Richards at Oxford to seek a suitable new staff member with familiarity in NMR spectroscopy. The young Evans, then twenty-eight years old, was duly appointed as a lecturer there in October 1955. Subsequently he was promoted to Senior Lecturer in 1963 and to Reader in 1964, a position that he occupied until 1981. In that year he was elected a Fellow of The Royal Society and was awarded a personal chair at Imperial College, which he held until his death in 1990.

Contributions to chemistry

His science was wide-ranging and it is possible here to give only a very broad account. He was always exceptionally innovative and, unlike most academic chemists, he remained close to the bench all his life. He was a fearless experimentalist and used dangerous and highly toxic chemicals without trepidation. He was the despair of safety personnel, but they had no need to worry, for his was a safe pair of hands—he knew exactly what he was doing and what the dangers were. One of the experiments that he did very soon before his untimely death was to make some beryllium complexes for his students—they were, with justification, apprehensive about performing the work, so he did it himself, successfully and safely.

He was a very skilled glassblower (a lost art to most chemists today) and was always willing to make or mend glass apparatus for others. Right to the end he performed experimental work with his own hands.

Electronic spectra of mixed gases with oxygen under high pressure

His earliest work at Imperial (1956–61) involved measurement of the electronic spectra of aromatic hydrocarbon–dioxygen mixtures under high pressures. Dioxygen, which is paramagnetic, has the effect of perturbing the singlet–triplet energy levels in the organic substrates, and Evans measured these shifts. During these studies a sample of acetylene and oxygen at 140 atmospheres pressure exploded in his laboratory, destroying the high-pressure steel cell that contained it and almost destroying the brand new state-of-the-art ultraviolet spectrometer belonging to Professor Derek (later Sir Derek) Barton, F.R.S. Evans was lucky to escape with his life—even he had very occasional accidents—suffering only superficial cuts. Subsequently, when he lectured on this explosive mixture, he would invite the audience to pass round a similar cell filled with such a benzene–dioxygen mixture under about 50 atmospheres pressure (the bright yellow colour of the shifted electronic transitions was clearly visible): understandably the more craven members of the audience would decline this invitation.

NMR spectroscopy

Some of his best-known achievements were in NMR spectroscopy and in its applications to magnetochemistry.

Wilkinson had in 1956 bought the first commercial NMR instrument in the country, a Varian 40 MHz machine, for the then very high sum of £20 000, an investment subsequently fully justified by the many fundamental results that it produced. Evans's Oxford colleague Les Pratt was appointed to Imperial College as a lecturer by Wilkinson in 1957, and an important part of Pratt's job was to tend and guard this wayward and difficult machine. He and Evans performed fundamental work on the proton NMR spectra of organometallic complexes,

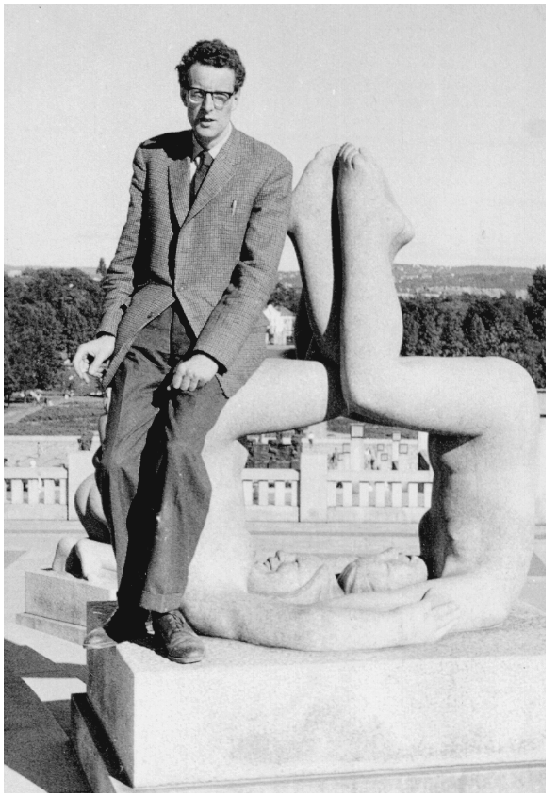

Figure 1. Dennis Evans sitting on a sculpture in the Vigland Park, Oslo, in about 1964.

mostly those made by Wilkinson's students, and they published a number of joint, fundamentally important papers in the area.

He turned his wide knowledge of the theory of NMR spectroscopy to practical advantage in the discovery of what became known as the 'Evans method', for the measurement of the weak but crucially important magnetic properties of molecules in solution. The method required a 'split' NMR tube in which a capillary tube of a diamagnetic protic material (normally t-butanol) was surrounded by a solution of the paramagnetic material in a water–butanol mixture. Two NMR signals of the hydroxy proton of butanol were observed: one was due to the pure butanol in the capillary; the second butanol peak was shifted by the presence of the paramagnetic sample. From the frequency difference between these two peaks the magnetic susceptibility and hence the magnetic moment (a measure of the number of unpaired electrons in a molecule of the sample) could easily be calculated. This work was extended in 1973 by devising the new technique of 'magnetic titrations', in which reactions involving a paramagnetic species were followed by changes in the magnetic susceptibility of that compound, using the Evans method. The Evans method, as it is invariably called, is widely used to this day and his 1959 paper has a substantial number of citations each year.

His work on the determination of the relative signs of spin-coupling constants (1962–68) by using the technique of double irradiation of organic compounds was of seminal importance. The methodology for double-resonance experiments had been made available by

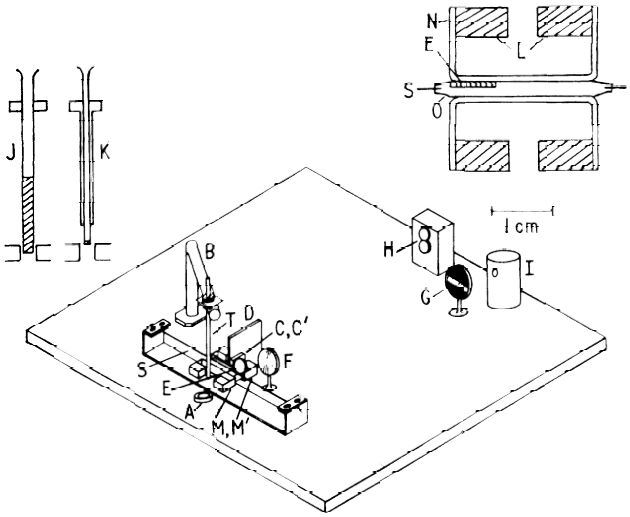

Figure 2. Evans's drawing of the first version of his magnetic balance.
Reproduced with permission from *Journal of Physics* (E), 1974, vol. 7, p. 248.

D.W. Turner (F.R.S. 1973), also then on the staff at Imperial College. Starting in 1961, Evans performed studies on double resonance (sometimes called double irradiation or, perhaps more commonly, spin decoupling). In a pioneering paper of 1961 he used selective double irradiation to determine the relative signs of nuclear spin–spin coupling constants. He was later to extend this work to a variety of other systems, including work on thallium–proton spin–spin interactions in organothallium complexes (1963–65). He also added the thallous compounds to buttered cream crackers to eliminate, with some success, the rat population in the basement of the old chemistry building at Imperial College.

Magnetochemistry

At Oxford one of the topics that Evans investigated with R.E. Richards was the magnetic properties of oxygen and of nitric oxide in crystalline matrices (clathrates) at low temperatures; the paper published by them in 1952 contributed both to his interest in magnetochemistry and to his later studies on oxygen.

In 1967 he devised an ingenious reworking of the Gouy procedure for measuring the magnetic susceptibilities of solids. In the normal Gouy method the sample is held between the poles of a large and necessarily unwieldy permanent magnet; the attraction or repulsion on the suspended sample by the magnetic field is then measured with a sensitive microbalance. Evans neatly reversed this procedure by weighing a small but powerful magnet (*ca*. 200 g) against the static sample, thus leading to much quicker but equally accurate data. In 1974 this was further refined: two small but high-field magnets, only 6 g each, were mounted on a torsion strip. The force that the sample exerted on one of the magnets was balanced by a current passed through a coil placed between the pole of the second magnet; the magnitude of this current gave the degree of magnetic interaction (see figure 2). He developed a commercially successful digital version of this design in association with Johnson, Matthey. This Evans magnetic balance, as it is known, is used worldwide to this day.

Studies on oxygen and hydrogen peroxide

Evans was fascinated by the chemistry of dioxygen and in particular by its very reactive, short-lived, high-energy state in which its two unpaired electrons become paired (singlet oxygen). In 1969 he started much fundamental work on the formation and detection of singlet oxygen, and from 1979 to 1985 performed much work in detecting its presence in aqueous solution by the use of traps that gave stable endoperoxides, and he also devised new ways of generating singlet oxygen in water.

He was deeply interested in the properties of hydrogen peroxide: this is now widely used as an ecologically friendly industrially useful oxidant, but Evans was one of the first, many years ago, to understand its practical significance for such purposes. During the period 1985–90 he developed ingenious new procedures for synthesizing hydrogen peroxide, one of which used manganese complexes as catalysts; this was patented and could well form the basis of a new industrial method for the production of this valuable material. In a patent with Solvay Interox (published posthumously in 1993) he described a remarkable catalytic procedure for converting the highly toxic hydrogen sulphide (H_2S) to sulphur and the much more acceptable hydrogen peroxide.

Vibrational spectroscopy

Evans used infrared (and Raman) spectroscopy for a variety of studies: on hydrogen bonding in complex cyanide acids (1964); on the structure of Grignard reagents and metal alkyl complexes in solution (1966–69); and on a variety of main-group fluoro complexes (1967–75). In 1982 he made creative use of the 'isotopic dilution' technique for the study of weak hydrogen-bond interactions in organic molecules.

Inorganic and organometallic chemistry

Many of his the research interests lay in the realm of physical chemistry. However, he was always fascinated by inorganic chemistry—a legacy perhaps of his undergraduate Oxford days with Sidgwick—and the work in his final decade was almost entirely on aspects of coordination chemistry. Indeed, throughout his career at Imperial College he taught undergraduates inorganic chemistry and for a short period in the late 1980s he was the head of the inorganic chemistry section.

As early as 1957 he ingeniously demonstrated the constitution of 'blue perchromic acid' to be $CrO(O_2)_2$. It is a peroxo complex used in the analysis of chromium, the molecular nature of which had long baffled chemists.

He was interested by Grignard reagents, the magnesium alkyl and aryl halide complexes made by Grignard in 1900 but still widely used today in organic syntheses. He performed proton NMR studies and, later, vibrational spectra in efforts to establish their complex solution structures (1967–71). In a typically ingenious extension to the chemistry of these species, he showed for the first time that divalent lanthanides (samarium, europium and ytterbium) formed Grignard-like compounds (1970–71).

A recurrent research theme was main-group fluoro complexes (1965–70), and oxygen–donor complexes (1969–90). His later work in this area concerned the preparation and application of water-soluble Schiff's base complexes (1985–88) and the coordination chemistry of beryllium (the latter with a view to combating the dreadful disease of beryllosis), aluminium—implicated then in Alzheimer's disease—and silicon. The beryllium work was published posthumously in 1992.

The scientist and the man

Dennis—as he was always known to all—was greatly loved and respected at Imperial College. He was unassuming and extremely tolerant, but possessed of vast knowledge (not only of chemistry but of many other matters). He was always generous with his time and with his knowledge, and was popular with students, more as a laboratory demonstrator and tutor than as a lecturer—he was always happiest with a small group of students. On first acquaintance Evans was rather shy, but soon revealed a warm, sympathetic and attractive personality. He was a loyal friend, unsparingly generous, ready to share anything and everything unquestioningly.

Evans played a crucial role in building the research activities in inorganic chemistry after the arrival of Geoffrey Wilkinson. He was a mentor, advisor, critic and friend to all the new graduate students in the Wilkinson group. While pursuing his own research he would also provide continuous advice to all who sought it. His originality and experience in experimental techniques made him invaluable in the earliest days at Imperial College to the new and inexperienced students, who at that time included M.A. Bennett (F.R.S. 1995), R. Colton, M.L.H. Green and W.P. Griffith, all of whom had academic careers.

He knew about vacuum greases, adhesives, seals and how to stick metal to glass and many other arts and crafts of the experimentalist, and had an exceptional knowledge and experience of solvent properties and of how to dry solvents. He devised a high-pressure tube for NMR experiments, which could achieve a hydrogen gas pressure of up to 100 bar. He regularly read a wide range of chemical journals and knew precisely on which days each would arrive in the chemistry library; he would draw the attention of others to new articles that were relevant to their work. Evans read chemical catalogues of compounds, and said he found these a useful source of ideas. He was a severe and invaluable critic with whom one could lead explore and discuss ideas. He would always assist in the interpretation of specific data.

In the normal course of events Evans rarely appeared in the laboratory before midday, but he then stayed late into the evening and left between 23:00 and 01:00. His somewhat bizarre social life normally took place between 02:00 and 04:00—and he normally worked at the weekends. His office was chaotic and he was poorly organized with his correspondence, administration and other matters of routine organization. Evans was not judgmental and gave his advice to all who approached him. He never refuted ideas or arguments in a dismissive manner; rather he would advance his alternative ideas in a hesitant and questioning manner, but these were for the most part correct.

As a scientist, Evans was fascinated by hallucinogenic chemicals and was very knowledgeable about alkaloids such as mescaline. For a brief period he used his considerable skills in synthetic organic chemistry to synthesize new derivatives of compounds such as diethyltryptamine and then he would test them on himself to discover their effects. He gave public lectures on hallucinogenic chemicals. The audience for these often included oddly dressed people who sat in the back row of the lecture theatre and were clearly not from the institution at which the lecture was held. His expert knowledge of illicit drugs led him to become an expert defence witness for those accused of harbouring these materials, and he told some hilarious (and harrowing) tales of his experiences in this area.

Evans remained true to his working class background, despite his high academic achievements and brilliant career at Oxford. His politics were well to the left of centre and he

was very sympathetic to those whom he regarded as being unfavourably treated by authority. He took part in a protest demonstration during the Suez crisis and a front page photograph appeared in *The Guardian* of Evans fending off a mounted policeman in Trafalgar Square.

He allowed himself to be exploited by some but he could be very determined when faced with injustice or, for example, ruthless landlords. In one instance he was the last occupant in a large house that the landlord wished to develop and who had forced the evacuation of most of the occupants. Despite threats of violence and the removal of a substantial portion of the staircase, Evans refused to move from his second-floor flat. Eventually he was offered a substantial sum to move, which he accepted.

His many eccentricities are legendary. His friends outside his professional interests came from many walks of life. He mixed with artists and often he would relax in the Chelsea Arts Club into the small hours, where he was a well-known and popular member. He once shared his apartment for several months with Christine Keeler—well after the Profumo affair. He knew petty criminals, strip artists and for several years he looked after and helped a woman friend who suffered from drug addiction. He also knew a number of now-famous artists such as William Burroughs, Jean Rhys and Bridget Reilly.

He was a much sought-after performer at the Imperial College summer fairs, where he would do experiments that delighted his young audiences: freezing rubber tubes in liquid nitrogen and then smashing the frozen tubes; 'drinking' liquid oxygen and exhaling the gas through a lighted cigarette; and igniting ammonium dichromate. He would pretend to eat gramophone records (bakelite), candles (lighted) and wine glasses (thin-walled: the substantial glass fragments were stored in the inside of his cheek for discreet disposal off-stage). He also demonstrated breathing hydrogen or helium and then speaking in the characteristic 'squeaky' voice. He was popular with students. Once, in the early days at Imperial College when the undergraduate inorganic course seemed to consist of little else but qualitative and quantitative analysis, an unfortunate student attempted to clean up his platinum crucible by washing it with *aqua regia* (a mixture of nitric and hydrochloric acids, which attacks platinum). He asked Evans what to do—such crucibles were of course expensive and jealously guarded by the staff, and each was scrutinized on return. Evans spent several hours sandpapering it to remove the characteristic etch marks that *aqua regia* leaves on platinum. Although the crucible lost some 10% of its weight by this double attack this was, fortunately, not noticed by the authorities.

He had a considerable knowledge of and affection for animals and insects, and a number of these shared his Chelsea flat with him. They included a five-foot-long sand snake George, which he would feed with live toads obtained from his local pub. George escaped and was found slithering down the King's Road. Evans (in the light of perhaps understandable hostility from his landlord, who wanted him evicted) felt that the best solution was to donate George to the London Zoo. He also kept at various times locusts, a Lord Kitchener lizard, a bird-eating spider and a giant black scorpion. The latter escaped and Evans decided not to make enquiries of his neighbours for its whereabouts. Some of the locusts escaped also. In his early South Kensington days (Thurloe Street), where he shared a flat with M.L.H. Green, he kept a cayman alligator called Augustus. All these pets he cared for well, learning their habits and cultivating them. Evans left his small estate to his daughter.

Dennis had a remarkable life. Few in recent years have contributed to so many areas of chemistry with such distinction. He was an English eccentric in the true tradition, and inspired much affection and loyalty among his exceptionally broad spectrum of friends. He

will be remembered not only for his chemistry, but also for his guidance, support and understanding, which he so readily gave to so many.

Acknowledgements

We thank his cousin Mrs Shirley Starbuck and family friends Mr and Mrs Appleyard for their reminiscences of Evans, and Professor Martin Bennett, F.R.S., for his help with the manuscript.

The frontispiece photograph was taken in about 1964 by M.L.H. Green.

General references

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A full bibliography appears on the accompanying microfiche, a photocopy of which is available from The Royal Society's Library at cost.