Book Reviews

A Celebration in Chemistry

The Chemical Bond. Structure and Dynamics. AHMED ZEWAIL, Ed. Academic Press, San Diego, CA, 1992. xviii, 313 pp., illus. $49.95. Based on a symposium, Pasadena, CA, Feb. 1991.

Linus Pauling is deservedly considered one of the great chemists of this century. His book *The Nature of the Chemical Bond*, first published in 1939, affected the way generations of chemists thought about chemical bonding and about molecular structure. It was the first non-required textbook that I bought as an undergraduate, and I still use it today. His *Introduction to Quantum Mechanics with Applications to Chemistry*, coauthored with E. Bright Wilson, was also important and has been used by most graduate students in physical chemistry since it first appeared in 1935. Pauling was at the forefront of theoretical chemistry in the 1930s and was instrumental in introducing chemists to the importance of quantum mechanics. Besides his impact on the understanding of chemical structure, Pauling, together with his Caltech colleague Max Delbrück, helped to found modern molecular biology in seeking the fundamental physical principles that underlie the nature of proteins and DNA. Thus it was fitting that Caltech, where Pauling did so much of his great work, hosted a symposium in February 1991 in honor of his 90th birthday. This book is a result of that symposium.

The editor of the book, Ahmed Zewail, was also the organizer of the symposium and brought together an interesting mix of people, including six Nobel laureates. The first half of the symposium was devoted to structural biology, in which Pauling has had an enormous impact, and the second to detailed studies of molecular reaction dynamics, which is the current research interest of the editor. Considering the disparate fields of the various authors and the fact that molecular biologists are not usually grouped with those who study the reactions of systems with three or four atoms, the book is surprisingly unified. The credit for this has to go to the authors, who focused their discussions on how the ideas of Pauling underlie much of modern chemistry. As might be expected in such a volume, there are widely differing styles, but I found that the variety made the book more readable, and it is certainly not "dry."

Following the organization of the symposium, the five chapters in the first section of the book are devoted to molecular structure, particularly its applications to molecular biology. Two of these are by Pauling himself. In both contributions, Pauling relates how he became interested in the study of the chemical bond, with the second having a more historical perspective. In his more technically oriented chapter, Pauling focuses on the nature of "icosahedral quasicrystals." These materials, discovered in the 1980s, have fivefold symmetry axes, which in terms of classical crystallography cannot occur because one cannot have translational symmetry with pentagons. Pauling's interest in this area grows out of his desire to develop a theory of bonding for metallic and intermetallic compounds. In his inimitable fashion, Pauling has delved into the fundamental crystallographic questions and proposes that these icosahedral quasicrystals are actually twinned crystals with enormous unit cells (approximately 60 Å on a side) having tens of thousands of atoms. He came to these conclusions by studying electron-diffraction photographs, a skill that is not widely practiced today. Although there are still many unanswered questions in this field, Pauling puts forth strong arguments to back up his conclusions. It would have been nice in both of his chapters if references to the important early and more modern articles had been given.

The other three papers in the first half are by some of the greatest practitioners in structural biology. The contribution by Max Perutz covers the importance of the hydrogen bond in biological systems. Although today the notion of hydrogen bonding is accepted as common chemical behavior, it was not always the case that such weak bonds were regarded as having any importance, and certainly not in biochemistry. Pauling helped to introduce this idea in *The Nature of the Chemical Bond* and 10 years later suggested that hemoglobin was a great place to look for this type of bonding. A discussion of how the chemistry of hemoglobin affects its structure takes up the remainder of the chapter.

In his chapter, Francis Crick takes a more historical, and more informal, approach. Crick reinforces the crucial role of Pauling's ideas on the importance of weak bonding, on complementarity, and on the structure of proteins in the development of molecular biology. He provides other examples as well, most notably Pauling's work with antibodies, sickle cell anemia, and the "molecular clock." Crick concludes that Pauling stands as a founder of modern molecular biology because "he had the right basic ideas about the chemistry." There is unfortunately only one formal reference in the chapter.

The chapter by Alexander Rich focuses on how structure can be used to understand how proteins recognize DNA. This contribution is the most formal and scientific in the section on structure and is quite encyclopedic in its coverage of protein-DNA interactions. This type of molecular recognition is also based on weak bonds, and so again the discussion emphasizes Pauling's contributions.

The second section of the book contains chapters on modern experimental methods for studying the detailed dynamics of chemical reactions. George Porter begins with a survey of flash photolysis, noting that within 45 years scientists have gone from being unable to even consider milliseconds to studying chemistry in microseconds and femtoseconds. Just as Pauling's concept of the weak bond was revolutionary, so were the developments in this area, which proved the existence of electronically excited states and free radicals. Porter also discusses the photochemistry involved in photosynthesis. He describes the early identification of the ClO radical and the chemistry of chlorine and oxygen. This was fundamental science and funded as such, yet this little radical has had a profound impact on us because of its involvement in the loss of ozone in the stratosphere. The whims of government and their effects on the support of basic science are discussed by other authors as well.

John Polanyi discusses the history of the concept of the transition state and describes how he has studied this fleeting species through the use of infrared chemiluminescence, trajectory calculations (it is useful to note that modern molecular-dynamics studies of proteins grew out of these trajectory studies of simple chemical reactions), and lasers. Whereas we used to be able to infer only the nature of the transition state from the experimental measurements, we are now able to perform spectroscopy on this species, which has an imaginary frequency.

The focus of Dudley Herschbach's chapter is somewhat different from that of the others in the volume. He covers three areas in which Pauling has played an important role—electronegativity, hybridization, and resonance—and explains how these processes affect his own work. Hershbach uses the concept of electronegativity to help categorize the observed dynamics of a wide range of chemical reactions and describes how electronic structure governs the dynamics of the reaction. He then discusses the way to orient a pendular molecule and the importance of vector correlations in obtaining more information from the experimental measurements of reaction dynamics. In his conclusion, he discusses his new approach to the electronic structure of atoms and molecules with a few electrons based on dimensionality and scaling arguments. That this area of research arose from his desire to design a homework problem for a first-year graduate course in quantum mechanics shows the important coupling between teaching and research.

The last chapter covers real-time laser femtochemistry and is something of a disappointment as it is a reprint of a 1988 review published in *Chemical and Engineering News* by Zewail and Richard Bernstein, who died in 1990. Zewail merely provides two pages of additional comments (despite his note that over 400 articles have been published in the area of femtochemistry during the past five years) and ten pages of references.

It would have been nice to include chapters on modern electronic structure theory and modern theoretical dynamics studies. These would have helped to tie the structural aspects of Pauling's work to the dynamics discussed in the second half of the book, and the editor would not have had to look far among Pauling's students or his own Caltech colleagues to find those who could cover these areas.

Still, the book is enjoyable, and the quality of the production is excellent, with significant use of color. The biographies and often informal photographs of these world-class scientists at the end help to place them in a historical perspective and provide some insight into the character of these unique individuals. The perspectives provided by their essays can give us all hints about how to think about problems and come up with ingenious solutions. Although much of the book is inherently technical, there is also an underlying aspect of scientific philosophy that is worth learning.

David Dixon
DuPont Central Research and Development Experimental Station, Wilmington, DE 19880–0328

Axons, Ions, and Dons

Chance and Design. Reminiscences of Science in Peace and War. ALAN HODGKIN. Cambridge University Press, New York, 1992. xii, 412 pp., illus. $59.95.

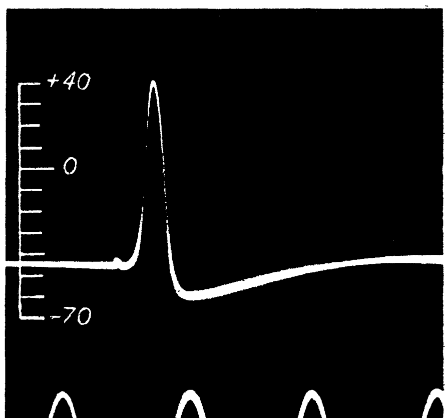
All students of excitable membranes know that Hodgkin and Huxley discovered voltage-dependent sodium and potassium permeability changes in the membrane of squid giant axons and showed how their properties explain propagation of action potentials. This fundamental biophysical work dominates an early chapter of every textbook of neurobiology. It set the tone for all subsequent voltage-clamp studies on ionic channels and, although now 40 years old, still receives hundreds of citations each year and inspires the most challenging questions of channel molecular biology.

Alan Hodgkin's autobiography has three contrasting sections. The first moves from a gentle English childhood to life as a university student and starting as a fellow at Trinity College, Cambridge. In the second, England is thrown into war. Scientists turn every energy to technical projects in a tense climate of austerity and urgency. The third blends discoveries, holidays, and meetings in postwar years until Hodgkin and Andrew Huxley go to Stockholm to share the 1963 Nobel Prize in Physiology or Medicine. There is neither the competition and intrigue of Watson's *Double Helix* nor the sharp commentary of Medawar's *Memoirs of a Thinking Radish*. Rather we sample the flavor of private life and the climate of science in Cambridge. Drive and ambition and even the science itself move to the back seat as a quieter recollection takes over, bolstered by quotations from personal letters—friends, romances, holidays, and arts as well as science. Throughout, vignettes of ordinary and extraordinary people, their habits, oddities, and opinions, are sketched with dry humor. These light impressions suggest the theme that life flows through sequences of odd encounters and as much depends on chance as on design.

Childhood is a period piece of peaceful opportunity. Visits to many Quaker aunts, grandmothers, and other relations abound with children playing in ample gardens flowing down to rivers. Insects, flowers, and birds are early attractions. An eager naturalist, the young Hodgkin takes up ornithology more seriously, and holidays of rock-climbing and adventure in remote places become important. A 1932 stay in Germany reveals dangers of Nazism, and student days in Cambridge promote political debate, particularly about Communism.

Research students are on their own in Cambridge. At the age of 20, Hodgkin personally buys parts to assemble an oscilloscope and, without a supervisor, embarks on successful and significant research, proving the local-circuit theory of nerve impulse conduction with frog nerve. His work eventually earns him a teaching fellowship at Trinity College and a Rockefeller Foundation fellowship for a year with Herbert Gasser in America. A few weeks in the summer of 1938 with Kenneth Cole and Howard Curtis are notable both for the chance to use the squid giant axon and because Hodgkin discovers that collaboration is more fun than working alone. Additional money from the Rockefeller Foundation allows him to build up his own equipment in Cambridge, and the next summer he and Huxley try their hand at intracellular recording from squid giant axons. Almost at once they obtain the quite unexpected and very important result that the action potential overshoots zero potential by many tens of millivolts.

Within three weeks of this great discovery, Hitler invades Poland, the Plymouth squid boat is commandeered for mine sweeping, and a darker era begins. Hodgkin becomes part of a team developing 10-centimeter airborne interception radar. We read about design of magnetrons, aerials, scanning systems, and displays as the group is shuttled from one unlikely location to another, working exposed in winter without heat and flying hazardously in quickly outfitted aircraft to test and refine each concept. Much depends also on the quality of components and on the ability of the wartime industry to deliver and install hundreds of sets. There are many details of dates, ideas, successes, and failures. The seven-days-a-week effort is physically and



"Action potential and resting potential recorded between inside and outside of axon with capillary filled with sea water. Time marker 500 Hz. The vertical scale indicates the potential of the internal electrode in millivolts, the sea water outside being taken as zero potential." [From *Chance and Design*; Hodgkin and Huxley, *Nature* **144**, 710–711 (1939)]