Book Review

Hydrogen. The Essential Element

by John S. Rigden
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This book provides a view of the development of modern physics based upon fundamental research on hydrogen by experimental and theoretical physicists. John Rigden presents this seminal research of twentieth century physics in a clear and concise manner. At the same time, he weaves in the enticing historical events that began with early quantum theory and advanced to recent validations of quantum electrodynamics, weighing theory against extremely precise measurements of hydrogen atomic spectral parameters. The centrality of hydrogen to the studies of Balmer, Bohr, and Sommerfeld is carried through to the modern day research on Bose-Einstein condensates by Nobel Prize winners Cornell, Wieman, and Ketterle.

The early chapters of the book will be quite familiar to chemists, as the struggles are described of early twentieth century physicists attempting to understand the nature of the hydrogen atom. The atomic structure of hydrogen provided by Niels Bohr and his idea of the quantized atom was grudgingly accepted by some because it could explain the data from the bright line spectrum of hydrogen. Some of the frustration felt by many physicists of the time is so aptly expressed by the quotation of Otto Stern (p. 39) who threatened to leave physics if “that crazy model of Bohr” turned out to be correct. Also described are the changes made to the Bohr model as more precise spectral data were obtained. This is exemplified by the work of Arnold Sommerfeld, who introduced elliptical orbits for the hydrogen electron and by doing so brought together relativity theory and quantum mechanics. Although more satisfactory than the Bohr model in explaining the appearance of doublets in the spectral lines it was clear that the Bohr-Sommerfeld theory of atomic structure would soon be replaced by newer concepts.

The author next turns to the importance of fundamental constants and their careful measurement. In chapter 6, a relatively short chapter, he emphasizes this point in relationship to the dimensionless fine-structure constant. At the end of the chapter is the story of Hans Bethe and the joke he and two accomplices played on the physics community by publishing a paper in *Naturwissenschaften* concerning a fictitious value for this very constant. It is also interesting to note that Bethe’s apparently playful and

good sense of humor indirectly involved him as a "non-contributing" author in another paper referred to as the "Alpha Beta Gamma paper", published in 1948 by George Gamow and a graduate student Ralph Alpher (p. 213).

The work of Pauli, Heisenberg, and Schrödinger and others who usher in the age of wave mechanics is then presented. One of the many interesting anecdotes included is a meeting between Bohr and Schrödinger as detailed by Werner Heisenberg (p. 83). It appears that Schrödinger visited the home of Bohr in Copenhagen during the Fall of 1926, to converse about quantum jumps and atomic structure. After many days and nights of discus- sion Schrödinger became ill and remained in bed, while Mrs. Bohr cared for him with food and tea. Niels Bohr on the other hand sat on the edge of the bed, continuing to argue.

Chemists should be particularly interested to read about Harold Urey(Chapter 10). Not only is Urey cited for his work on the discovery of deuterium, but for his great generosity.

The discovery and development of NMR is described in chapters 12 through 14. The pioneering work of I.I. Rabi, (the subject of another book by Rigden , *Rabi: Scientist and Citizen*, Harvard University Press, 2000), of Edward M. Purcell, and of Felix Block is presented with interesting details of the earliest experiments. One is particularly struck by the lack of funding even at the great universities at that time. For example, Purcell had to scrounge surplus magnets (p.143), and Block had to use the majority of his research money to purchase an oscilloscope worth $300. What a striking difference this is to the cost of doing NMR research today!

This section (chapters 15 and 16) details the importance of the Lamb shift in the hydrogen atomic spectrum and its interpretation by quantum electrodynamics.

The author does a particularly fine job in explaining the complicated theoretical discussion in lay terms. Perhaps chemists will not be familiar with the events that unfolded after 1947 and the Shelter Island Conference. The story is just as fascinating as those preceding.

At the end of chapter 16 is a paragraph that I think best describes this book in the author's own words:

> "In arriving at insights into nature's bountiful imagination, we are fortunate that nature gave us the simple hydrogen atom. Its one electron with its nucleus of one proton or one deuteron has stimulated the feeble imaginations of scientists to probe behind the common sense appearance of things and to soar to ever new heights of understanding. The concepts that have emerged from the laboratory have proven their power in synthesizing disparate realms of experience. At the same time, these concepts continue to challenge and boggle the best minds. As

> we look to the future, the hydrogen atom will continue to help us meet the challenge of embracing the natural world with understanding and, in the process, to understand better the place of humankind within the larger scheme of things."

In the chapters that follow, experiments and concepts involving radio astronomy, galactic mapping, the atomic clock, and big bang cosmology are discussed, along with the people and their personalities whose work helped formulate the ideas that led to the discoveries. Again the author focuses these stories through the hydrogen lens. Antimatter and particle physics, Bose-Einstein condensate, and exotic hydrogen-like atoms are all discussed in the closing chapters. This material introduces the reader to some of the current research that fascinates today's physicists: Why the absence of antimatter? How can the study of Rydberg atoms help unravel more mysteries of atomic structure? Will Bose-Einstein condensates provide insight to the domains between the microscopic quantum and macroscopic classical domains?

John Rigden does an excellent job in putting the human quality into the technical material so that it is both entertaining and informative. I found this book good reading and highly recommend it to anyone who wants to discover why hydrogen is the essential element.