Angewandte Chemie International Edition

Absolutely Small

This book has an ambitious goal: to convey an intuitive understanding of quantum theory without the use of mathematical formulas, and, as a further bonus, to explain some aspects of everyday life by using quantum theory. As Fayer points out in the preface, the people reading this book will be either his colleagues (i.e., chemistry professors) who are curious to see how someone can write a serious book about quantum theory without mathematics, or people hoping to develop some understanding of phenomena that are still unclear to them.

I will review this book firmly from the former person's viewpoint, with the idea of having it as an aid for teaching first-year chemistry students. However, *Absolutely Small* is targeted at a broad audience of scientifically interested readers and should be considered as a popular science book. This view is supported by the attractive title, by the well-promoted aim of the book, by the enthusiastic quotes from distinguished scientists in various fields that are cited on the back cover, and, last but not least, by the attractive price of ca. 18 € for a 383-page hardcover book with many black-and-white illustrations.

The idea of the book is to allow the reader to understand quantum theory without using mathematics, instead enabling him or her to have an intuitive understanding of the subject. For many of us that sounds like a hopeless exercise—quantum theory courses always began by using partial differential equations, three-dimensional integrals, special functions, linear algebra, and the like. How can one avoid it?

Fayer does an excellent job, in particular for those phenomena of quantum theory that occur in organic chemistry. Of course, the book contains some equations, but these are very simple ones, and typically only lead to final results—moreover they are well explained. Fayer's trick to avoid equations is to explain figuratively, with the help of more than 100 illustrations, each of them well explained in caption and text.

The book is structured like many first-year quantum theory courses for students who are majoring in science subjects other than physics. The first seven chapters deal with the basics of quantum theory, starting with Schrödinger's cat and probability, and continuing through quantum-mechanical ("small") objects, and Heisenberg's uncertainty principle. He reviews waves using Michelson's interferometer as an example, and discusses the photoelectric effect, the wave–particle duality, and all the quantum-mechanical terms such as probability, eigenstates, momentum, and positional probability distributions, and comes back to Heisenberg's uncertainty principle, before he concludes this part with the solution of the "quantum racketball" problem (one-dimensional particle in a box). All that indeed with only very few simple equations, but with many illustrations and with clear explanatory text. I consider this to be the best part of the book, which is particularly useful for chemists without much inclination towards mathematics, and is also suitable for introducing quantum theory in a general chemistry course for students with insufficient mathematical background.

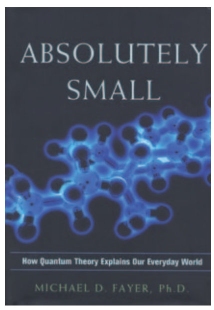
In Chapters 9–11 the Periodic Table is developed, starting from the experimental line spectrum of the hydrogen atom, then discussing the solution of the Schrödinger equation in terms of energy, orbitals, and electron probability densities. As in many other quantum theory courses, he develops the Periodic Table from the states of the hydrogen atom, not forgetting to introduce the Pauli exclusion principle, Hund's rule, and the Aufbau principle, also with a discussion of atomic sizes. While this part is important for chemists, other readers will probably consider it to be a bit too detailed, especially as the later chapters focus on applications involving only first- and second-row elements.

Chapters 12–14 deal with covalent bonding. Starting from quantum theory, this is much more intuitive to the reader than the "classical" approach based on ad-hoc electron pairs and the octet rule. Molecular-orbital diagrams are developed for diatomic molecules, and the bonding energy and bond order are discussed. Hybridization, and the resulting trigonal, tetrahedral, and finally linear bonding geometries are explained using the shapes of polyatomic molecules as examples.

Armed with this knowledge, Fayer tackles a couple of very prominent real-world problems in Chapters 15–19, while also using them to introduce more concepts of chemistry that are explained by quantum theory: what happens with ethanol in the body, and how different is that from methanol?—how does soap work?—what are hydrogen bonds, and why are hydrogen-bonded systems liquids at room temperature?—what is a fat, and why are *trans*-fats unhealthy?—how do greenhouse gases warm the atmosphere? Finally, he introduces electron delocalization in aromatic molecules, and explains how superposed orbitals form bands in solids and how materials conduct electricity.

The last chapter is the reprise of the book; it motivates the reader to "think quantum" when trying to explain phenomena of everyday life. At the end of the book, a glossary explains the most important terms of quantum theory in a simple manner.

Altogether, this is a fascinating and very entertaining book, packed with marvelous ideas about how to teach quantum theory to the general public,



Absolutely Small
How Quantum Theory Explains Our Everyday World. By Michael D. Fayer. McGraw Hill, New York 2010. 400 pp., hardcover, € 17.99.—ISBN 978-0814414880

and also to first-year students. Unfortunately, the book also contains some embarrassing errors. For example, where MO energies are introduced using the dissociation of H_2 as an example, the bonding MO becomes antibonding for short distances (that is, the internuclear repulsion is included in the MO energy), rather than converging towards the helium atom 1s energy. There are some other similar errors, which will hopefully disappear in the next edition of the book. It is therefore difficult to give a clear recommendation that this book should be used as accompanying material for an undergraduate student course without being complemented in class.

In conclusion, this book indeed presents an intuitive approach to quantum theory. It is a useful supplementary resource for undergraduate teaching, but a few misconceptions and mistakes of the first edition need to be corrected. As it is focused on chemistry, it is particularly useful as a source from which one can adopt ideas for undergraduate chemistry teaching, and it nicely illustrates how one can avoid classical concepts of the chemical bond and use quantum theory intuitively instead. Apart from its use in teaching, I strongly recommend this book merely because it is really fun to read.

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