In striking contrast to Marcel Duchamp's *Nude Descending a Staircase* (1912) where the figures represent successive points in time, seen as coexisting in the fourth dimension, Picasso's painting culminates with a superimposed set of three-dimensional projections of an object in four spatial dimensions. One is seeing the object simultaneously from (a sampling of) all possible perspectives rather than from only one as in classical painting.

Einstein did not appreciate the value of four-dimensional geometry in 1905 but came to it only later, with the help of Hermann Minkowski and Marcel Grossmann. Poincaré's influence was significant here but not so crucial; in fact Einstein rejected the "conventionalist" philosophy that led the Frenchman to the view that no uniquely determined geometry governs the world—you may choose whichever one is most convenient. Poincaré even proposed a "principle of relativity" but failed to grasp the consequences that Einstein drew from it.

Miller's point is that both Einstein and Picasso discarded the empiricist view—"what you see is what you get"—in favor of the realist–intellectualist view—thinking, not seeing, leads to the truth. The purpose of science is not to provide the most economical representation of the facts (as Ernst Mach claimed), and the purpose of art is not to provide the most accurate representation of what we can see (Why compete with photography?). The purpose of both science and art is to discover the reality that lies hidden behind the appearances.

This reality must, of course, conform to the highest aesthetic standards. Thus, as Einstein pointed out at the beginning of his 1905 relativity paper, the basic defect of classical electromagnetic theory is that it fails to give a *symmetrical* description of electromagnetic induction, one that is independent of the frame of reference of the observer.

In addition to giving detailed accounts of Einstein's discovery of relativity and Picasso's creation of *Demoiselles*, Miller provides fascinating biographies of both men. Both were isolated from most human concerns by their preoccupation with discovery; for instance, both attracted women whom they felt free to discard at will. Picasso had more lovers than Einstein did, but it was Einstein who "had the kind of male beauty that, especially at the beginning of the century, caused such havoc." (This anonymous quote, on page 50, provides part of the subtitle for the book.)

I strongly recommend this book to anyone interested in physics or art: It enhances a reader's understanding of the connection between art and science. It also underscores the breadth and pervasiveness of an epoch's intellectual ferment.

## Adventures in the Atomic Age: From Watts to Washington

Glenn T. Seaborg
with Eric Seaborg
*Farrar, Straus, and Giroux, New York, 2001. $25.00 (352 pp.). ISBN 0-374-29991-9*

Glenn Seaborg, discoverer of plutonium, Nobelist, and the only scientist to have an element (seaborgium-106) named for him during his lifetime, is surely the most prolific scientific diarist of the 20th century. Part of his journal, covering his 10 years as chairman of the Atomic Energy Commission, contains 18 000 pages. That and his scrupulously kept diary (begun when he was 14 years old) attest to and explain (in part) Seaborg's great strength as a nuclear chemist: He simply worked harder than anyone else! I never could understand why some who worked with him at the Chicago plutonium laboratory ("Metallurgical" Laboratory) thought he worried too much about the Nobel Prize; everybody knew all along that he would win one!

His memoir, *Adventures in the Atomic Age: From Watts to Washington*, written with his son, Eric, a professional writer (who completed the memoir after his father's death in June 1999), is a fascinating distillation of these journals: We learn about Glenn's origins as the grandson of Swedish immigrants, his career as the discoverer of transuranium elements; his tenure as respected and often envied boss of chemical research at the Metallurgical Laboratory, his chancellorship of the University of California, Berkeley, his stint as chairman of the Atomic Energy Commission, and more.

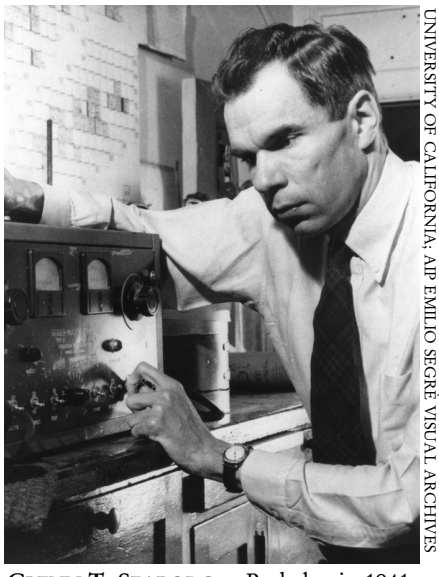
The book has great historical value. It is especially interesting to oldtimers like me, who knew and liked Glenn. Besides bringing Glenn the person into focus, the book clarifies many puzzling aspects of the nuclear enterprise. For example, the controversy over Glenn's *in absentia* letter to Robert Oppenheimer, in which Glenn reluctantly argued, "I have been unable to come to the conclusion that we should not develop the H-bomb." Oppenheimer's negligence in not sharing Glenn's views with the rest of the General Advisory Committee was a factor in Oppenheimer's loss of security clearance—an outcome that Glenn bitterly opposed.

We also learn that 41 of the nuclear weapons tests were aimed at the Plowshare Project (the peaceful uses of nuclear explosions). Although I was at Oak Ridge during this time, I had no idea that so many of the tests were part of the Plowshare program.

Aside from Glenn's massive contribution to chemistry, we read of his deepest views on arms control and nuclear power. Although, as the father of plutonium, he could hardly have said otherwise, his arguments favoring nuclear are cogent.

I admire Glenn very much for pushing the Comprehensive Test Ban Treaty—which President Clinton signed, but which the Senate has sidetracked. Glenn thought little of Star Wars, and he adduced the standard arguments against defensive missiles. In this respect, I believe he was shortsighted. Star Wars makes sense if, as many hope, the number of intercontinental ballistic missiles is eventually reduced to, say, 100 on each side. Some arms control experts (as well as Presidents George W. Bush and Vladimir Putin) seem to support this ultimate posture. I wish Glenn had expressed his views on such a long-range scenario.

In reviewing Glenn Seaborg's life, I can only stand in awe. The diligence and common sense displayed in this book are sui generis. The essence of the man is captured in his "Letter to a Young Scientist," which Eric Seaborg added as an appendix. Here Glenn Seaborg says, "A particularly necessary element in the makeup of a good scientist (is) simple hard work!"



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**GLENN T. SEABORG** at Berkeley in 1941.

Glenn's legacy to science is contained in that sentence. He was a great scientist, administrator, and public figure, whose remarkable success was largely attributable to hard work.

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## Molecular Electronic-Structure Theory

Trygve Helgaker, Poul Jørgensen, and Jeppe Olsen
*Wiley, New York, 2000. $300.00 (908 pp.). ISBN 0-471-96755-6*

The molecular electronic-structure problem lies at the heart of chemistry and of molecular physics. The full electronic Hamiltonian in the Born–Oppenheimer approximation can be solved exactly only for the hydrogen atom, but the development of powerful approximate methods over the past 70 years has invalidated P. A. M. Dirac's famous statement that "the underlying physical laws for understanding . . . all of chemistry are thus completely known, . . . it is only that application of these laws leads to equations much too complicated to be soluble."

A number of commercially available programs now exist that use different methods and approaches to solve for the ground-state electronic structure of small- to medium-sized molecules in the nonrelativistic limit. Some of these programs also extend to excitation properties, relativistic corrections, and semiempirical and density functional schemes. While many discussions are also available in the textbook, review, and journal literature concerning electronic-structure theory, in the authors' view, no "comprehensive, up-to-date, technical monograph" on the subject has been written.

*Molecular Electronic-Structure Theory*, by Trygve Helgaker, Poul Jørgensen, and Jeppe Olsen is, as is pointed out in its preface, precisely such a comprehensive monograph. Up to now, no single source has provided, in a unified form and with a unified, convenient notation, a comprehensive description of the actual methods for carrying out ab-initio electronic structure. This book will be useful to those workers who wish to use such calculations with more than "black-box" knowledge. In its 900 pages, it gives detailed, clear, numerically illustrated, and extensively discussed presentations of "all the important aspects of modern ab-initio non-relativistic wavefunction-based molecular electronic structure theory."

This text is focused and, within its focus, quite complete. In the first 15 chapters, it covers second quantization, exact and approximate wavefunctions, standard models, atomic basis functions, Gaussian basis sets, molecular integral evaluation, Hartree–Fock theory, configuration interaction theory, multiconfigurational self-consistent field theory, coupled cluster theory, and perturbation theory. The sixteenth chapter, roughly 100 pages long, many times the length of any of the others, is devoted to calibration of electronic structure models. In this chapter, a set of sample atoms and molecules is examined for various strengths and weaknesses. It also contains sections on errors in quantum mechanical calculations, equilibrium distances, equilibrium structures, dipole moments, atomic and molecular energies, atomization energies, reaction enthalpies, and conformational barriers.

The formal presentations and derivations are quite complete. Referencing is adequate. A particular strength of the text is the presence in each chapter of a set of comprehensive exercises accompanied by the solutions to those exercises. Most of these exercises are formal and manipulative, rather than numerical.

Although a number of electronic structure codes were used in the writing of this book, there is very little reference within the text to specific codes. Rather, the authors discuss the principles involved in electronic structure theory at the ab-initio level, and how those principles can be utilized in the derivation and optimization of algorithms for such calculations. Indeed, the authors suggest in their preface, "you will be able to write a computer program without too much difficulty." This is a strong statement, but both the detail and the precision of the text make it a correct statement. The book also has a useful list of acronyms and a very well-constructed index.

Because of the tight focus on ab-initio methodology and analysis of molecular ground state properties, the text misses some subjects that might have been expected. For example, both density functional theory and relativistic corrections are largely absent. (Density functional theory is discussed briefly in the last few pages, and some examples of relativistic corrections are given in the last chapter.) Because this is largely a book on formal derivations and methodology, several of the interpretative aspects that one might have expected are absent: There is no population analysis, no Bader analysis of bonding properties, no discussion of the Morokuma energy partitioning, no physical discussion of bonding properties. While the standard textbook analysis of Koopmans' theorem is extended to include electron affinities as well as ionization energies, the authors do not point out that the electron affinities are almost always substantially worse numerically than the ionization energies. Nor do they explain why this is true.

Other aspects that do not appear include semiempirical theories and energy derivative methods. Despite the extremely important work that these authors have done in the development and application of response theories for the calculation of excited state properties and molecular response properties, no extended discussion of the response properties appears in the text.

The specific problem of molecular electronic-structure theory and models requires analysis at many levels. On balance, this text provides what I believe to be a comprehensive, careful, meticulous, and clear development of the formalism of wavefunction-based ab-initio electronic-structure theory for molecules. It is the most complete and satisfying presentation of the actual armament involved in the computational approach to electronic structure that I have seen, and should be available to all students and researchers who wish to understand the basis of contemporary molecular electronic structure methods.

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## 100 Years of Planck's Quantum

Ian Duck and E. C. G. Sudarshan
*World Scientific, River Edge, N.J., 2000. $86.00 (545 pp.)*
*ISBN 981-02-4309-X*

Ian Duck and E. C. G. Sudarshan's *100 Years of Planck's Quantum* is an unusual hybrid of a reprint volume and a running commentary on the papers being reprinted. The authors, who are "interpreters" as much as editors, believe that one should have as a basis the actual words of the scientists as they went through their creative processes. At the same time, they are aware that history has selected the important from the unimportant, changing the emphasis from what the creators might have thought was important to what seems important in light of subsequent events. In some cases of course, the originators had it exactly right!

Duck and Sudarshan believe that their selection requires a continuing commentary to place the papers within a modern historical context. Their aim is clearly not to provide the reader with a historical document as such.