

REVIEWS OF BOOKS

Hermann Haken and Hans Christoph Wolf
The Physics of Atoms and Quanta
Introduction to Experiments and Theory
(Third Corrected and Enlarged Edition)
Springer Verlag, Berlin 1993

"A thorough knowledge of the physics of atoms and quanta is clearly a must for every student of physics but also for students of neighbouring disciplines such as chemistry and electrical engineering". This sentence opens the preface to the first edition of Haken and Wolf's textbook. I obtained for the review the third, English edition of this book, corrected and enlarged, with 273 figures and 160 problems and solutions.

The book is a wonderful, modern lecture on atomic physics. This domain was born in the beginning of this century giving the principles to the Quantum Mechanics.

The book begins with short historical review on the fundamental problem of ancient atomism, the concept of the discontinuity of matter and energy. Experimental determination of mass of atom with different methods starting from Dalton's law of constant and multiple proportion, determination of Avogadro's number, gas and Boltzmann's constant together with a few experimental methods of the atom size determination starting from kinetic theory of gases, X-ray diffraction until ion traps form 3rd chapter.

The explanation of the necessity of introduction of atomic nuclei for understanding of attenuation of electrons by matter and passage of α particles through matter (Rutherford scattering) together with short description what nuclear radius means close 4th chapter.

After the creation of matter God created light, as we read in the Bible, so the description of light ought to be next. First the wave character of light is postulated via historical remarks. Let us mention the names used in the text — Huygens, Maxwell, Hertz. The problem of thermal radiation and the introduction of Planck's radiation formula together with its Einstein derivation introduce the reader to the World of Photons and Quanta. Photoelectric and Compton effects must follow. But at this point I would like to find something about photon counting — true particle character of photons can be clearly seen in the experiments in which photons are counted, i.e. by the possibility of investigation of photon statistics and next via production of non-classical states of light.

To keep the balance the description of wave character of electrons and interferometry with atoms follows. Only discussion of experiments, with de Broglie hypothesis as interpretation is presented at that point.

More theoretical chapter 7 introduces some basic properties of matter waves and its probabilistic interpretation together with the Heisenberg uncertainty relations.

Now students are ready for one of the biggest mystery — the spectroscopy of hydrogen atom (chapter 8). As the opening to this problem some general remarks what spectroscopy is are given. Then the optical spectrum of the hydrogen — discontinuity and the Balmer series, the Rydberg constant and the Rydberg formula follow. The Bohr postulates and the Bohr model of atom are described on the following 20 pages. I think that too much time of the reader/students is taken for, as we know, unsatisfying model, which, as we learn from history, was very quickly replaced by the quantum mechanics.

To keep up with the description of atoms more knowledge of mathematical bases is given in chapter 9. Problems of a particle in a box, the Schrödinger equation, the conceptual basis of quantum mechanics and the quantum mechanical oscillator are described.

The following chapters are concentrated on building up quantum descriptions of atomic structure:

10th chapter — quantum theory of the hydrogen atom deals with: motion in a central field; angular momentum eigenfunctions (together with pictures of the Legendre polynomials); radial wave functions in a central field; radial wave functions of hydrogen (with pictures).

11th chapter — lifting of the orbital degeneracy in the spectra of alkali atoms; shell structure; screening; the term diagram; inner shells.

12th chapter — orbital and spin magnetism; fine structure: magnetic momentum of the orbital motion, precession and orientation in magnetic field, spin and magnetic momentum of the electron, determination of the gyromagnetic ratio by the Einstein-de Haas method, detection of the directional quantization by Stern and Gerlach, fine structure and spin-orbit coupling, level scheme of the alkali-atoms, fine structure in the hydrogen atom, the Lamb shift.

These chapters, being classical ones, are very clear and rich in illustrations, as well as the ones which follow:

13th — atoms in a magnetic field: experiments and their semiclassical description, consisting of: directional quantization in a magnetic field, electron spin resonance, the Zeeman effect, the Paschen-Back effect, double resonance and optical pumping. In this chapter Authors stress more on the formal descriptions than on the more, in reality, rich experimental applications of phenomena, being foundations of modern applications — like laser physics.

Next chapter "Atoms in a magnetic field: quantum mechanical treatment" is purely theoretical one. In my opinion, whole treatment of atoms in magnetic field is a little bit too long — especially the semiclassical description.

Chapter 15 "Atoms in an electric field" starts from experiments and ends with a glance at the quantum electrodynamics. This is a very nice and concise description.

16th chapter "General laws of optical transitions" is a very good lecture of the problem, starting from symmetries and selection rules and ending on the problem of line widths and line shapes.

Many-electron atoms are treated in chapter 17. The following problems are described: the spectrum of the helium atom, electron repulsion and the Pauli principle, angular momentum coupling, magnetism of many-electron atom.

Next chapters are connected with the problem of 17th one. 18th chapter deals with the X-ray spectra, internal shells, 19th — with the structure of the periodic system and the ground states of the elements, excited state, many-electron problem, the Hartree-Fock method. Going into details of the atomic level structure, the nuclear spin and the hyperfine structure must be considered. This chapter contains also description of nuclear magnetic resonance and its medical application.

In the next chapter lasers and laser spectroscopy are described in extremely concise form.

Fundamentals of the quantum theory of chemical bonding end the book. Appendix and the solutions of problems then follow.