BOOK REVIEWS

Selection of books for review is based on the editor's opinions regarding possible reader interest and on the availability of the book to the editor. Occasional selections may include books on topics somewhat peripheral to the subject matter ordinarily considered acceptable.

Treatise on Heavy Ion Science

Vol. 1: Elastic and Quasi-Elastic Phenomena (1984)

Pages 753 *Price* $95.00

Vol. 2: Fusion and Quasi-Fusion Phenomena (1984)

Pages 855 *Price* $95.00

Vol. 3: Compound System Phenomena (1985)

Pages 589 *Price* $89.50

Vol. 4: Extreme Nuclear States (to be published)

Pages 721 *Price* $92.50

Vol. 5: High Energy Atomic Physics (1985)

Pages 498 *Price* $79.50

Vol. 6: Astrophysics, Chemistry, and Condensed Matter (1985)

Pages 429 *Price* $69.50

Vol. 7: Instrumentation and Techniques (1985)

Pages 471 *Price* $79.50

Editor D. Allan Bromley

Publisher Plenum Publishing Company, New York

Reviewer Bernard L. Cohen

This is a monumental work of over 4000 pages in seven volumes covering every aspect of research involving the acceleration of heavy ions, i.e., nuclei with atomic weight >4 (alpha particles) with or without some attached electrons. Its editor, Allan Bromley, is a pioneer in this field and has done a remarkable job in producing this treatise. Each of the 43 articles is written by highly respected experts from all over the world. Each article, and often each section, has an introduction and a summary that can be easily understood by any nuclear physicist. Each article is a rather thorough review of its subject matter, with dozens (or hundreds) of references to the original literature. There is no apparent effort to sacrifice clarity or thoroughness in the interest of brevity, or to compromise quality to reduce costs. Each article has numerous figures and photographs, all of the highest quality.

Since almost any accelerator can accelerate heavy ions, it was only natural to do some experiments of this sort with the very early accelerators, and a new impetus grew out of fears that thermonuclear reactions between nitrogen nuclei in the atmosphere following a hydrogen bomb explosion might lead to destruction of the earth's atmosphere. Although this fear was soon allayed, the field continued to grow slowly, fueled largely by interests of chemists, through the 1960s. By the mid-1970s, many nuclear physicists and chemists concluded that the "cream had been skimmed" from research with low-energy hydrogen and helium ions that had dominated the field since its beginnings in the 1920s and turned to using their accelerators for heavy ions. With the interest generated, new machines were built expressly for heavy-ion acceleration, and in recent years this work has been the most active field of nuclear physics and chemistry research.

This research is reviewed in the first four volumes of the treatise. Volume 1 starts with a 132-page article by the editor, including ten pages of references, on the early history of heavy-ion nuclear physics. It follows with 155 pages on elastic scattering by a South African, 60 pages on Coulomb excitation by a Swiss, 105 pages on nuclear inelastic scattering by two Italians, 150 pages on one and two nucleon transfer reactions by two Americans, and 130 pages on cluster transfer reactions by two Japanese. This pattern of segmentation and thorough treatment by scientists from all over the world continues through the entire treatise.

In the above-mentioned reactions treated in Vol. 1, the two colliding nuclei largely retain their individual identity, with a transfer of a few nucleons at most from one to the other. Volume 2 treats the other type of reaction, in which the two colliding nuclei fuse into a single nucleus in the initial stages of the interaction. Over 600 pages (including 35 pages of references) of this volume are devoted to a review of damped nuclear reactions, in which there is a great deal of mass and energy transfer between the two colliding nuclei but some "memory" of their original form is retained. There is a tremendous amount of data on these, and a great deal of empirical systematics has been developed in the classical tradition of chemistry, but the problem is so complicated that basic understanding is quite limited.

Volume 3 deals with deeper details of heavy-ion reactions. It starts with a paper on time-dependent Hartree-Fock calculations, which attempt to understand the phenomena from first principles—the nuclear force between each pair of nucleons. This, of course, requires approximations, but impressive progress has been made. The next paper covers statistical models for understanding how the residual nuclei formed in the heavy-ion reactions eventually decay. This is close to the interests of nuclear technologists, as these are the models used to predict the probability distribution of the number of neutrons per fission and the energies with which these neutrons are emitted. The next paper is on resonances in heavy-ion reaction cross sections that are superficially similar to the familiar resonances in neutron physics but must be very different because the latter represent excitation of a single nuclear state while each heavy-ion resonance involves excitation of numerous nuclear states. The fourth paper in Vol. 3 is on high angular momentum states. Heavy-ion collisions commonly involve 40 or more units of angular momentum, in contrast to the collisions in nuclear technology where the angular momentum is usually zero. The final two sections of Vol. 3 are on polarization phenomena and magnetic moments of short-lived nuclear states, subjects familiar to neutron physicists, but the experimental problems are much more difficult with heavy-ion reactions.

Volume 4, which has not yet been completed, is on extreme nuclear states. There are to be articles on heavy-ion induced fission, transuranium nuclei, super-heavy elements (relatively stable nuclei with atomic number $\lesssim 112$ that may some day be observed with heavy-ion reactions), and relativistic heavy-ion collisions (experimental and theoretical).

Volume 5 covers the entirely new area of *atomic* physics opened up by the fact that high-energy heavy ions (like fission fragments) are readily stripped of numerous electrons and that the fusion of colliding heavy ions leads to the temporary existence of atoms with atomic numbers up to at least 184 (from the collision of two uranium nuclei). This second aspect has attracted great interest because, due to the fact that the electron binding energy exceeds $2mc^2$ (where m is the electron rest mass), theory predicts the collapse of usual atomic physics for these high atomic numbers in a way that would shed new light on basic quantum electrodynamics. This theory is reviewed in the first paper (138 pages and hundreds of references), and the second (twice the number of pages and references) discusses the very substantial experimental problems involved in studying these phenomena. The third paper in Vol. 5 is on beam foil spectroscopy, studies of the light emitted by energetic heavy ions after passing through a thin foil that strips off a large and controlled number of electrons. This includes not only the wavelengths of the spectroscopic lines, but also their rate of emission, the oscillations of this rate with time (quantum beat phenomena), and Lamb shift experiments. This paper also includes applications to atomic theory, astrophysics, plasma physics, and fusion research.

Volume 6 covers other applications of heavy ions to nuclear astrophysics, hot atom chemistry, studies of stopping and range of energetic ions in matter, ion implantation, channeling through well-aligned crystals, electronic polarization in solids, radiation damage in solids, trace element analysis, and to fusion power—heavy-ion drivers for inertial confinement fusion. Perhaps the most pertinent paper for nuclear technologists is on radiation damage in solids since heavy-ion beams simulate the effects of fast neutrons but provide order of magnitude higher dose rates.

Volume 7 describes the various experimental techniques that have been developed for studies of heavy-ion physics and chemistry. These techniques include positive and negative ion sources, stripping foils for heavy-ion beams, very thin films for targets, focal plane detectors for magnetic spectrometers, heavy-ion identification using multiple detectors (with and without time-of-flight measurement), streamer chambers (a new type of visual track detector), and electromagnetic separators for recoiling reaction products. The treatise finally closes with a paper on the use of heavy-ion acceleration for ultrasensitive mass spectrometry. While none of these techniques is normally used in nuclear technology, they are recognizably derived from the same principles and early applications as more familiar experimental techniques.

All in all, this seven-volume treatise represents a very valuable review that should be available to all researchers in heavy-ion science. For many, their interests may be covered by one or two single volumes of the treatise; but for most, access to several of the volumes would be highly desirable. For most nuclear technologists, the bulk of this material would be of only passing interest, but the breadth of coverage is such that they would be almost certain to find something of value in their work.

Bernard L. Cohen is a professor of physics and of radiation health at the University of Pittsburgh. He is a former experimental nuclear physicist, was the 1974–75 chairman of the American Physical Society Division of Nuclear Physics, and received the 1981 American Physical Society Bonner Prize for research in nuclear physics. More recently, he has worked on environmental impacts of energy generation and radon problems. He served as chairman of the American Nuclear Society Division of Environmental Sciences in 1980–81 and received the American Nuclear Society Public Information Award in 1984.