at Cornell University (CU), then as a research physicist at Naval Research Laboratory in Washington, D.C., and now at CU as a faculty member. His publications include theoretical research on equilibria and stability of intense charged particle beams, and experimental research on the physics and applications of both electron and ion beams. He has taught courses in intense charged particle beams at the University of Maryland in 1973, and at CU in 1979 and 1981.

Atomic and Molecular Physics in Controlled Thermonuclear Fusion

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Since the beginning of magnetically confined controlled thermonuclear research in 1952-1953, atomic physics processes have played an important role in the heating, energy loss, modeling, and diagnostics studies of high-temperature, low-density (10^{14}-cm^{-3}) plasmas. At the 1958 Second Geneva Conference on Peaceful Uses of Atomic Energy, Edward Teller warned that impurity ions in the plasma may affect the plasma parameters in a catastrophic manner. Moreover, neutral particles formed by charge-exchange in the plasma would traverse the magnetic confining field and sputter additional impurities from the surrounding walls. Indeed, this was the case with the United Kingdom's ZETA toroidal pinch in which impurity levels as high as 30% were measured in a helium discharge. In the ensuing years, little attention was paid to impurities and atomic physics, until the early 1970s when it was discovered that tungsten and gold from tokamak limiters and walls depressed the electron temperature in the plasma center. These observations initiated a renaissance in atomic physics research related to fusion. During the past decade, a worldwide experimental and theoretical research effort has been under way to provide the fusion community with atomic and molecular data relevant to plasma behavior and diagnostics.

This book contains the *Proceedings of the NATO Advanced Science Institute on Atomic and Molecular Physics of Controlled Thermonuclear Fusion* held at Santa Flavia, Italy, on July 19-30, 1982. A similar NATO institute was held in Gers, France, in August 1979 and the proceedings were published as *Atomic and Molecular Processes in Controlled Thermonuclear Fusion* by M. R. C. McDowell and A. M. Ferendeci. In the Preface, the aim of the Institute was stated to be "to bring together senior researchers and students in both atomic physics and fusion research, to survey atomic and molecular processes in fusion plasmas, and to review recent developments in theoretical and experimental research dealing with these processes." Much of the contents of the present proceedings are a survey of fusion and atomic physics as presented in the previous volume, the notable exception being chapters on inertial confinement. Formal presentations at the Institute were divided into three parts:

1. overview of the principles of magnetic and inertial confinement fusion research
2. theoretical and experimental methods of obtaining relevant atomic data
3. atomic and molecular physics of fusion research devices.

Obviously, only a cursory survey of each of these areas can be presented in a reasonably sized book. The reference listings at the end of each chapter contain an impressive 1222 references, which should provide an excellent tool for the newcomer in the field. However, a large fraction of the references are unavailable in most university or industrial laboratories.

Computation of electron ionization cross sections of positive ions within a factor of 2 is one of the most difficult tasks of atomic collision theory, and until recently few experimental measurements were made with multicharged ions. Modelers and diagnosticians in plasma physics were content to use the semiempirical Lotz formula. Recent work showed that in addition to direct ionization, one must also include inner shell excitation followed by autoionization and recombination into doubly excited states followed by Auger emission of two electrons. In these proceedings, the theory as of 1982 was briefly reviewed by McDowell and the experimental status by Dolder and Drawin. Comparison of theory and experimental measurements of Ti^{3+} indicates that the contribution of autoionization is a factor of 5 to 10 greater than that for direct ionization. Measurements with other ions suggest that the relative contribution of the autoionization processes increases with the ion charge and with some light ions the contribution is small. Most of the ionization cross-section data are obtained using crossed beam techniques. Another method used for higher charge states is to measure the reaction rate coefficient in a high-temperature plasma and compare the results to the crossed beam data integrated over a Maxwellian electron velocity distribution. These proceedings did not discuss this technique, which may be the only method in which data for very highly charged states (i.e., Fe^{20+}) can be obtained. At the present time, theory is only capable of reliably predicting ionization cross sections within a factor of 2. The complications introduced by inner shell phenomena in the ionization cross section may also influence the electron excitation cross section of multicharged positive ions.

Also of importance to the understanding of high-temperature plasma behavior is dielectronic recombination collisions, which are difficult to calculate and measure. In this process an incoming electron directly excites an orbital electron and is simultaneously captured into an excited state. Thus, a doubly excited state of the ion is created that is stabilized by the spontaneous emission of a photon. The importance of this process lies in the fact that not only is energy radiated from the confining volume but the average charge state decreases, implying the need of additional energy to heat the plasma to the desired temperature. Throughout the written proceedings, the only place that dielectronic recombination is discussed is a three-page description by Drawin. In all probability dielectronic recombination was discussed at great length during the course, but does not appear in the scientific program.

During the past three to five years, increased emphasis has been placed on the atomic physics in the plasma periphery of tokamak plasmas where the ion and electron temperatures are typically 50 to 500 eV. Diagnostic measurements have shown that many of the central plasma parameters are strongly influenced by the plasma boundary conditions. Considerable work has gone into the development of various types of limiters to control the flow of impurities into the plasma. Harrison has written an excellent summary of the plasma-boundary region including particle transport, divertors, relevant atomic reactions, and plasma/wall interactions. It is evident that some control must be exerted over this region if a tokamak reactor is to be a successful power generator.

A distinguishing feature of this book over its predecessor is that two chapters are devoted to inertial confinement. Fusion research in the field of inertial confinement began several years after the initiation of magnetic confinement. Since the plasma density is between 10^{16} and 10^{26} cm^{-3} with temperatures of tens of kilovolts and temperature gradients as high as 10^{10} K/cm, it is not surprising that the atomic physics and the associated problems in these plasmas are very different than those found in low-density plasmas. In one chapter, R. Moore presents an excellent summary of the atomic physics in high-density plasmas. The complexity of atomic physics in high-density plasmas can be illustrated by considering a pellet compressed by laser or particle impact. As the density increases, the ionization potential of the outer electron is lowered and the ratio of the ionization to plasma temperature decreases, implying a lowering of the excited state level. As the excited state level is lowered toward the normal ground state, less energy is required for excitation resulting in an increase in excited state population near the continuum. These excited states interact strongly with nearby ions and elaborate theories must be developed to model the interaction. A similar situation exists for electron-ion recombination. For low-density plasmas as found in magnetically confined plasmas, the two-body electron-ion recombination is proportional to n_e and three-body recombination varies as n_e^2. For high-density plasmas these relationships would result in complete recombination. Again, detailed theory must be developed to adequately describe recombination. In his conclusion, the author states "dense plasmas containing partially-stripped ions are very interesting from the atomic point of view." This chapter is highly recommended for those who want a brief concise account of atomic physics in high-density plasmas. Missing is a discussion as to the applicability of the existing theory to experimental results.

Normally, a reviewer does not comment on the mechanics of assembling a book and the subsequent publication. I would be remiss in my duties as a reviewer unless I made some comments on this book's structure. Apparently, neither the book editors nor publisher proofread the chapters submitted for publication. One receives the impression that the various submissions were just bound together. In one chapter I counted 49 typographical errors or other mistakes. Repetitions are present throughout the text with a graph of the rate coefficients of hydrogen appearing four times. In many places graphs of figures were taken from the original source without removing the extraneous lettering on the original. The references in this book and previous books are in a mixed format. Admittedly, these are trivial comments, but they are annoying and detract from the content of the book. For the past several years, debates have gone on as to whether conference proceedings should be published in permanent bindings and become part of the archival literature. Some technical societies, notably the American Nuclear Society, require all submissions to be refereed before publication in conference proceedings. A prime example of the widespread use of unrefereed material is that in a chapter of the present book 76% of the citations were unrefereed while in another chapter the percentage was 60%. Plasma physicists appear to be the worst offenders in this regard. This may be due to the fact that plasma physics is still a maturing science, or it may be a result of many reports finding their way into the open literature without the customary scientific scrutiny. If steps are not taken to curb this practice of publishing unrefereed papers in permanent form, the credibility of the scientific literature may be impaired. I highly recommend that in the future sufficient time and effort be expended to referee all contributions if conference proceedings are to become a part of the permanent literature.

The book will be valuable to those who want a general overview of the role of atomic physics in fusion research. Many review papers are available in the published literature that will provide greater insight into the theoretical and experimental status of atomic physics relevant to fusion. Since most of the material was covered in the preceding NATO institute proceeding, the main value of the present edition is the updated list of references and the inclusion of discussions on inertial confinement.

Clarence F. Barnett began his career in Oak Ridge National Laboratory (ORNL) in 1943 as a technical advisor for the electromagnetic separation of uranium. From 1951 to 1956, he was engaged in studying the interaction of particles with gases and surfaces. Shortly after joining the fusion effort in 1956, he was made director of the DCX-1 mirror plasma project. His responsibilities during 1962 to 1979 included directing the atomic physics and plasma diagnostic groups and as director of the Atomic Data for Fusion Data Center. During these years, he was instrumental in establishing the American Physical Society (APS) topical conferences on atomic processes in high-temperature plasmas and high-temperature plasma diagnostics. He is a fellow of the APS and the American Association for Advancement of Science. At the present time, he is a senior scientist on the ORNL Physics Division staff.