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.

Atomic and Molecular Data for Fusion

Editors	H. W. Darwin and K. Katsonis
Publisher	Europhysics Journal, The Royal Swedish Academy of Sciences
Pages	1700
Price	$310.00
Reviewer	Clarence F. Barnett

In 1975 the International Atomic Energy Agency (IAEA) established a data center to provide the international fusion community with bibliographical and evaluated atomic and molecular data relevant to high-temperature plasmas. The present publication consists of invited reviews and contributed papers presented at the Second IAEA Technical Committee Meeting on Atomic and Molecular Data at Fontenay-aux-Roses, France, in May 1980. The first conference was held at the Culham Laboratory with the proceedings being published as *Phys. Rep.*, **37**, 53 (1978). The report title is a misnomer as the title should have been "Atomic and Molecular Data for Tokamak Plasmas." The uses and needs of atomic physics in mirror, high-beta, and inertial confinement plasmas were neglected. The objectives of the meeting and the subsequent publication of the papers were to

1. review the required and potentially useful atomic and molecular data for fusion
2. identify research groups who could contribute to the production, collection, and evaluation of useful data
3. establish close cooperation between data users in fusion and data producers in atomic physics
4. formulate specific recommendations to IAEA's atomic data program.

Four previous reports have been published as to the needs of fusion for atomic physics. The requirements have changed little over the past decade. After six years of experience with the data center, the IAEA staff should have been in a better position than a widely diverse group to know the fusion needs and those laboratories engaged in producing numerical data.

The proceedings were divided into three sections:

1. atomic and molecular problems in fusion research
2. state of the art of atomic and molecular physics
3. report of the working groups to the IAEA.

The reviews included the application of atomic physics to tokamak plasmas, discussion of atomic structure, collisions of electrons with highly charged ions, charge-exchange of multicharged ions with hydrogen, H_2, and inert gases, and plasma surface interactions. S. Suckewer presented an excellent summary of the use of atomic data in diagnostics of the Princeton Large Torus and Poloidal Divertor Experiment (PDX) tokamak plasmas. Quantitative knowledge of atomic structure and collision cross sections or rates has permitted an important contribution to the understanding of radiation cooling, radial ion temperature profiles (from Doppler broadening of forbidden spectral lines), plasma rotation, electron temperatures (from line intensity ratios), and the density of impurities in the plasma outer edge (using fluorescence spectroscopy). In high-temperature plasmas, the plasma physicist must not only be concerned with the effect that impurities have on plasma properties, but also must attempt to devise ways to prevent impurities from entering the hot plasma region. Two large-scale experiments were described in which the plasma impurity concentration was greatly reduced. In the Japanese Divertor Assembly experiment, the installation of a poloidal divertor reduced the impurity density by a factor of 2 to 4 with a corresponding decrease in radiated energy. In the United Kingdom Divertor and Injection Tokamak Experiment, a bundle divertor improved the plasma purity. No results were reported for the PDX or Germany's poloidal Axially Symmetric Divertor Experiments, which have provided significant additional experience with impurity removal since 1980.

The amount of numerical data required for an understanding of all the atomic processes that can occur in a high-temperature plasma containing impurity ions is enormous. Support of atomic physics programs relevant to fusion in the U.S. is based on the philosophy of performing benchmark-type experiments to confirm theory and establish scaling laws. With theory firmly confirmed, computed data will supply most of the needs. This is especially true for excitation and dielectronic recombination collisions, which are extremely difficult to measure. Unless new experimental techniques are developed, these data must rely on computational methods. Unless the international atomic physics community adopts the same or similar strategy to a systematic approach to the problems and identifying the most pressing current needs, the data base produced will be fragmentary and incomplete. Most of the reports were concerned with only theory or experiment and not with the interaction between them. Two reports that were well balanced between theory and experiment concerned charge-exchange of high-charged ions in hydrogen and H_2 presented by H. B. Gilbody and electron ionization of multicharged ions presented by D. H. Crandall. Since charge-exchange involves a three-body collision, accurate theoretical methods have been difficult to formulate. Developments in both semiclassical and in a full quantum treatment have resulted in computed cross sections that compare favorably with experimental data. A similar situation does not exist for electron ionization of highly charged ions. Present theory is only capable of predicting cross sections to within a factor of 2 of those found experimentally. Currently, in modeling of plasma properties such as ionization equilibrium, the practice has been to use ionization cross sections derived from the semi-empirical Lotz formula. Current research has shown that for ions in alkaline isoelectronic sequences the direct ionization process must have added to it inner shell excitation followed by autoionization and resonance recombination followed by double Auger autoionization.

Practically all of the cross sections and rates listed by the working groups as relevant are the same as previously reported. One exception is the need for diagnostics of alpha particles formed as a reaction product in deuterium-tritium plasmas operating at reactor-like conditions. With the copious production of alpha particles, the question arises as to whether the 3.5-MeV alpha particles will be lost from the confinement region by double electron capture collisions before transferring their energy to the plasma. D. Post has suggested that the velocity or energy distribution of the thermalizing alpha particles may be determined by injecting into the plasma a beam of He^0 or Li^0 at a few million electron volt energy and measuring the flux and energy of the escaping He^0 formed in the reaction $Li^0 (He^0) + He^{++} \rightarrow Li^{++}(He^{++}) + He^0$. This diagnostic technique will require intense He^- or Li^- sources and knowledge of the relevant He^0 or Li^0 cross sections.

The reports of the working groups are a disappointment. No attempt was made to distinguish between data required or needed and the data base that exists at the present time. A summary of the status of the data in each area would add substantially to the proceedings. Twenty-three elements plus an unknown number of molecules are listed as requiring a large data base to satisfy the requirements of fusion. Without a large increase in support, such a task is improbable. One of the working groups assigned required accuracies of ±20% or a factor of 2 to the collisional data. The fact that the accuracy must be either ±20% or a factor of 2 implies that these limits are guesses, and they are misleading to the atomic physics community. Only when sensitivity computations are made for each process can a meaningful maximum error be assigned to a cross section or rate. For example, if radiation from an impurity contributes only a fraction of 10^{-5} of the total radiant energy, it is unnecessary to know the excitation cross section to within 20%. Throughout the proceedings, no report was presented of the theory and measurement of dielectronic recombination rates and cross sections except for the brief discussion by Dabau on satellite lines found in plasmas. Probably, this process is one of the most important interactions occurring in high-temperature plasmas and the omission is inexcusable. In summary, the meeting suffered from the proverbial theme of asking a 77-man committee to design an atomic physics program relevant to fusion.

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.

Plasma Physics for Thermonuclear Fusion Reactors

Editor	G. Casini
Publisher	Harwood Academic Publishers P.O. Box 786 Cooper Station, New York, New York 10276
Pages	491
Price	$75.00
Reviewer	Robert A. Gross

This book is a compilation of lecture notes prepared by 11 European scientists for an introductory course on plasma physics. The course was given at the Joint Research Center of the Commission of the European Communities, Ispra, Italy Establishment, from October 1979 to January 1980. The purpose of the lectures and this book is to provide scientists and engineers who are working on technology problems of fusion with some basic information on plasma physics of controlled fusion. The material covered is nearly exclusively devoted to magnetic fusion, and in particular the tokamak confinement concept. The intellectual level of this material varies widely, but most of it should be understandable by scientists or engineers who have received good basic undergraduate training. The contents of this book are summarized in the following.

"Introduction into Fusion Plasma Physics" by F. Engelmann, from FOM-Instituut voor Plasmafysica, Rijnhuizen, Jutphaas, the Netherlands (16 pages, 16 references) is, apparently, a very shortened version of the introductory lectures given by the author. The deuterium-tritium fusion reaction is briefly described together with the physics requirements needed to achieve fusion power conditions. Magnetic confinement principles are sketched and fusion ignition is described. Some fusion reactor conditions are mentioned. There are no derivations. Results are stated, and in this very short introduction it is difficult to separate what is truly fundamental from what is empirical and subject to change.

"Features and Comparison of Magnetic and Inertial Confinement Reactors" by B. Brunelli from Fusione Centro di Frascati, Italy (33 pages, 7 references) summarizes very