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This book is a comprehensive introduction to electron–atom collisions, covering both theory and experiment. The interaction of electrons with atoms is the field that most deeply probes both the structure and reaction dynamics of a many-body system. The book begins with a short account of experimental techniques of cross-section measurement. It then introduces the essential quantum mechanics background needed. The following chapters cover one-electron problems (from the classic particle in a box to a relativistic electron in a central potential), the theory of atomic bound states, formal scattering theory, calculation of scattering amplitudes, spin-independent and spin-dependent scattering observables, ionisation and electron momentum spectroscopy. The connections between experimental and theoretical developments are emphasised throughout.

Graduate students and researchers in atomic, molecular, and chemical physics will find this text a valuable introduction to a subject of central importance.

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IAN E. McCARTHY

The Flinders University of South Australia

ERICH WEIGOLD

Australian National University

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Preface

The advancement of knowledge of electron–atom collisions depends on an iterative interaction of experiment and theory. Experimentalists need an understanding of theory at the level that will enable them to design experiments that contribute to the overall understanding of the subject. They must also be able to distinguish critically between approximations. Theorists need to know what is likely to be experimentally possible and how to assess the accuracy of experimental techniques and the assumptions behind them. We have aimed to give this understanding to students who have completed a program of undergraduate laboratory, mechanics, electromagnetic theory and quantum mechanics courses.

Furthermore we have attempted to give experimentalists sufficient detail to enable them to set up a significant experiment. With the development of position-sensitive detectors, high-resolution analysers and monochromators, fast-pulse techniques, tuneable high-resolution lasers, and sources of polarised electrons and atoms, experimental techniques have made enormous advances in recent years. They have become sophisticated and flexible allowing complete measurements to be made. Therefore particular emphasis is given to experiments in which the kinematics is completely determined. When more than one particle is emitted in the collision process, such measurements involve coincidence techniques. These are discussed in detail for electron–electron and electron–photon detection in the final state. The production of polarised beams of electrons and atoms is also discussed, since such beams are needed for studying spin-dependent scattering parameters. Overall our aim is to give a sufficient understanding of these techniques to enable the motivated reader to design and set up suitable experiments.

Theorists have been given enough detail to set up a calculation that can be expected to give a realistic description of an experiment. For scattering this level of detail is only given for methods that take into account the whole space of reaction channels, which is necessary in general to describe

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experiments. These are mainly the recently-developed momentum-space methods, based on the solution of coupled integral equations, which have given an excellent account of experiments in a sufficient variety of cases to support the belief that they are generally valid and computationally feasible. Calculations of ionisation have not in general reached this stage of development, although kinematic regions are known where reactions are fully understood within experimental error. These reactions are extremely sensitive to the details of atomic structure and constitute a structure probe of unprecedented scope and sensitivity.

While reactions are the subject of the book, an essential ingredient in their understanding is the calculation of atomic structure. There is a chapter describing many-body structure methods and how to obtain the results in a form suitable for input to reaction calculations. This aims at an understanding of the methods without giving sufficient detail to set up calculations.

There is a chapter summarising background quantum mechanics from the undergraduate level and developing aspects such as angular momentum, second quantisation and relativistic techniques that are not normally taught at that level.

For certain mathematical functions and operations it is necessary for the physicist to know their context, definition and mathematical properties, which we treat in the book. He does not need to know how to calculate them or to control their calculation. Numerical values of functions such as $\sin x$ have traditionally been taken from table books or slide rules. Modern computational facilities have enabled us to extend this concept, for example, to Coulomb functions, associated Legendre polynomials, Clebsch–Gordan and related coefficients, matrix inversion and diagonalisation and Gaussian quadratures. The subroutine library has replaced the table book. We give references to suitable library subroutines.

We would like to acknowledge the help of Dmitry Fursa, Jim Mitroy and Andris Stelbovics in reading and criticising parts of the manuscript, Igor Bray and Yiajun Zhou for special calculations, and particularly Win Inskip for her patience, good humour and expertise in typing.

Ian McCarthy
Erich Weigold

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