This graduate/research level text introduces the theory of multi-electron transitions in atomic, molecular and optical physics, emphasizing the emerging topic of dynamic electron correlation.

The book begins with an overview of simple binomial probabilities, classical scattering theory, quantum scattering and correlation, followed by the theory of single electron transition probabilities. Multiple electron transition probabilities are then treated in detail. Various approaches to multiple electron transitions are covered including the independent electron approximation, useful statistical methods and peturbation expansions treating correlation in both weak and strong limits. The important topic of the dynamics of electron correlation is a central theme in this book. The text contains a comprehensive summary of data for few and many electron transitions in atoms and molecules, including transitions on different atomic centers, fast ion-atom and electron-atom interactions, and recent observations using synchrotron radiation. Emphasis is given to methods that may be used by non-specialists.

This text provides a pedagogic introduction to graduate students and researchers new to this developing field, but will also serve as a valuable reference for atomic, chemical and optical scientists interested in correlation and multi-electron transitions.

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Electron Correlation Dynamics in Atomic Collisions

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Dedicated to

Meredith Mallory, Jr.

Contents

Preface

One of the central questions of science is: how are complex things made from simple things? In many cases larger systems are more complicated than their smaller subsystems. In biology and chemistry the issue is how to understand large molecules in terms of atoms. In atomic physics one may strive to understand properties of many electron systems in terms of single electron properties. The general theme is interdependency of subsystems, or 'correlation'.

Correlation may be regarded as a conceptual bridge from properties of individuals to properties of groups or families. In atoms and molecules correlation occurs because electrons interact with one another – the electrons are interdependent. This electron correlation determines much of the structure and dynamics of many electron systems, i.e., how complex electronic systems are made from single electrons. Complexity is the more significant idea, but complexity may be seldom, if ever, understood. Correlation is the key to complexity.

Understandably, much has been done on the correlation of static systems. There are many excellent methods and computer codes to evaluate energies and wavefunctions for complex atomic and molecular systems. However, the dynamics of these many electron systems is less well understood. Hence, the dynamics of electron correlation is a central theme in this book.

The dynamics of electron correlation may affect single electron transitions. However, this effect is sometimes difficult to separate from other effects. Correlation is usually dominant in multiple electron transitions for fast collisions since there is not enough time for the collision partners to interact more than once. This means that multiple electron transitions in fast collisions provide an unobstructed view of the dynamics of electron correlation.

Since there are numerous processes that depend on the transition of more than a single electron, multiple electron transitions are of interest in their own right. Also recent advances in the production of highly charged ions and in synchrotron radiation provide new experimental tools for studying multiple electron transitions.

So the motivation for this book is to look at an emerging topic that is of interest in its own right and that impacts on a question of broad scientific interest, namely, the question of correlation (or the many body problem, or the construction of complex atomic systems ...).

The audience for whom this book is intended includes specialists in the field, graduate students and engineers. The first chapter includes a review of basic concepts in simple probability, classical scattering theory and a brief introduction to quantum mechanics. Then a background in one electron transitions in atomic and molecular transitions is developed. The third chapter addresses the formulation of interactions in many electron atomic and molecular systems. Later chapters deal with interactions of many electron targets with charged particles, with projectiles carrying electrons, and with photons.

An effort has been made to include practical methods for analysis and interpretation of data which can be used without extensive theoretical background or large computer codes. While much of this book focuses on relatively simple fast interactions, examples for intermediate and slow interactions related to chemistry, biology and condensed matter are also included. The emphasis in this book is on ideas and techniques that are simple enough for a beginning graduate student to pick up quickly and interesting enough to attract the attention of a person with a little curiosity.

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