This monograph describes the theory and practice of electron spectrometry using synchrotron radiation.

The book is in three parts. After a short review of background theory, neon is used to elucidate the principles of the photoelectron and Auger spectra. The second part of the book looks at experimental aspects, including characteristic features of electrostatic analysers, detectors, lenses, disturbances, and optimization, and then illustrates theory and experiment with details of experiments. The third part provides useful reference data, including wavefunctions, special theory, polarization and special aspects of instrumentation. A detailed reference list completes the volume. The study of electron spectrometry using synchrotron radiation is a growing field of research driven by the increasing availability of advanced synchrotron radiation light sources and improved theoretical methods for solving the many-electron problems in atoms. This balanced account will be of value to both theorists and experimentalists working in this area.

Atomic, molecular and chemical physicists, and physical chemists will find this book of interest.

CAMBRIDGE MONOGRAPHS ON ATOMIC, MOLECULAR AND CHEMICAL PHYSICS

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Electron Spectrometry of Atoms using Synchrotron Radiation

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Contents

Corrigenda and Addenda

Page 4 eq.(1.3b): replace ∇_i by ∇_i^2

Page 12 after (iv) and page 323 add: A. Dalgarno and H.R. Sadeghpour, Phys.Rev. A46 (1992) R3591; K. Hino et al., Phys. Rev. A48 (1993) 1271

Page 78 eq.(3.1c): replace $^{2S+1}L^o$ by $^{2S+1}L^e$

Page 82 line 7 and p.91 line 29: replace 'substrates' by 'substates'

Page 83 eq.(3.9e): replace + by –

Page 84 eq.(3.14b): multiply with 2

Page 98 after [UDM94] add: J. Ullrich et al., J.Phys.B 30 (1997) 2917 (Topical Review); R. Dörner et al., Physics Reports 330 (2000) 95

Page 151 and page 407 add: J.E. Pollard et al., Rev. Sci. Instrum. 52 (1981) 1837; J. Ullrich et al., J.Phys.B 30 (1997) 2917

Page 238 Figure 5.22 and discussion must be revised; see B. Schmidtke et al., J. Phys. B 33 (2000) 2451 and 5225

Page 292 eqs. (7.39): replace (-) by (-1)

Page 321 eqs. (8.13), (8.14a) and page 322 line 16 from below: replace $e^{k\,r}$ by $e^{i\,k\,r}$

Page 323 part 8.1.3: note that 'H' means 'H_{atom}'

Page 328 eq. (8.37): replace in { } 'zero' by the angular momentum 'ℓ'

Page 331 eqs.(8.48), (8.49): replace 'np' by '2p'

Page 354 denominator in eq. (8.110c) must be the same as in eq. (8.128)

Page 356 eq. (8.117b): replace summation index 'α' by 'κ'

Page 397 eq.(10.63c): replace E_{kin}^o by $E_{kin,i}^0$

Page 415 replace [Aug95] by [Aug25]

Page 420 [KFe92]: replace 'Feht' by 'Fehr'; [KJG95]: replace Vol. '15' by '75'

Page 422 [PNS82]: replace Hordgren by Nordgren

Dear Reader,

You hold in your hand a book on electron spectrometry using synchrotron radiation which is rather unusual in three respects. First, it is restricted to the study of atoms and indeed only to selected topics in atomic photoionization. However, due to their simplicity atoms provide a natural introduction to the field of electron spectrometry using synchrotron radiation, and an extension to photoprocesses in molecules and/or other applications of electron spectroscopy is straightforward. Second, it is a mixture of experimental and theoretical aspects where the latter are formulated from the viewpoint of an experimentalist. In this context I would like to point out that the close interplay between experiment and theory is one of the most striking and stimulating features of this field of research. Third, specific themes are repeated in Parts A, B, and C, but with increasing specialization. Redundancy ensures that, depending on their backgrounds, readers may start at any place.

The particular organization of the material presented in the three different parts results from my personal experience of working over the years with undergraduate, graduate, and Ph.D. students. This book is based on seminars and lectures given at the University of Freiburg, Germany, and on lecture series presented at the University of Aarhus, Denmark (1976), the University of Lausanne, Switzerland (1983), the University of Lincoln, Nebraska, USA (1987), and the Los Alamos (New Mexico, USA) Summer School (1988). Hence it is my sincere wish to thank all my students and colleagues for their fruitful discussions on these occasions since their contributions have helped me considerably from the didactical point of view to prepare the material. Naturally, I have also been greatly influenced by the many colleagues who have taught me physics, given me advice, and have stimulated me by exchange of ideas. My sincere thanks go to Professor Werner Mehlhorn who introduced me to the broad field of electron spectrometry, encouraged me to do experiments with synchrotron radiation, and has continuously supported my research in this field.

Electron spectrometry of atoms using synchrotron radiation has become an increasing and important field of fundamental physics within the last two decades. The increasing availability of dedicated facilities with tunable synchrotron radiation has allowed detailed exploration of the atom–photon interaction which must take into account the electron–electron interactions, usually termed electron correlations. The parallel experimental and theoretical developments have permitted rather sophisticated investigations of the response of the atomic many-electron

system to photon impact over the whole range of energies, from outer-shell excitations to deep inner-shell ionizations. New development of even more advanced light sources (wigglers, undulators, free electron lasers), more dedicated instruments (electron, ion, fluorescence spectrometers adapted to operation with monochromatized synchrotron radiation, and the inclusion of coincidence techniques), as well as new theoretical approaches attacking the many-particle problem, make it evident that the zenith of this rapidly expanding field still lies in the future.

One of the most important experimental tools for the investigation of the structure and dynamics of an atom interacting with a single photon is electron spectrometry using synchrotron radiation, and this special field will be treated in this book. It is not my aim to compete with the many excellent presentations already published on this subject. Instead, as already expressed above, I will present material which I have found to be important when introducing students to this field. The book is split into three parts of increasing difficulty. In Part A a general introduction to the field is given, followed by a detailed analysis of the photoelectron and the K–LL Auger spectrum of neon. Emphasis is placed on a clear and compact presentation without too many formulas. Hence, it should be well suited for students interested in this field and/or looking for an interesting application of quantum mechanics. In Part B the experimental aspects of electron spectrometry are described, including the characteristic features of electrostatic analysers, detectors, lenses, disturbances and optimization. Further, recent examples of electron spectrometry with synchrotron radiation are presented in order to elucidate the power of results obtainable with this method. These topics are addressed to both those physicists who want to use electron spectrometers, whether or not for applications different from those described here, and those who wish to learn more about recent results on the photoionization of free atoms with synchrotron radiation. Part C provides all the information necessary to complete the discussions of Parts A and B. Even though these topics are essential for specialists in this field, they are also general enough to be of importance to the non-specialist, but interested, reader.

I hope that this book fulfils the expectations of its readers. I would finally like to thank many colleagues for fruitful comments and discussions on the manuscript, in particular, Dr Stephen J. Schaphorst and Maureen Storey, and Barbara Müller and Helga Müller for their help in preparing the book and last, but not least, my wife Annemarie and our daughters Verena and Sigune for their patience and understanding when I have spent much of my time in the preparation of this book.

Volker Schmidt

Freiburg
1996