

Electron momentum spectroscopy studies on atom and molecules using monochromated electrons

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Abstract. A recently developed electron monochromator has been used in noncoplanar symmetric electron momentum spectroscopy studies on atomic argon and molecular cubane. This (e,2e) monochromator typically produces beam currents of 30 μ A, at better than 98% focus to the inner Faraday cup, into the interaction region. Contemporary work has concentrated on incident electron beam energies in the range 500-1800 eV. At these energies the overall coincident energy resolution is usually in the range 0.50-0.62 eV (FWHM). Binding energy spectra, at different values of recoil momenta, for both argon and cubane, highlight the performance of the spectrometer and will be presented. In addition, selected momentum distributions (MDs) for the respective valence orbitals in both argon and cubane will also be given. These MDs are compared against theory calculations made within either a distorted wave impulse approximation (argon) or plane wave impulse approximation (cubane) reaction mechanism framework. For the argon calculations Hartree-Fock orbitals were employed, while for cubane an extensive range of density functional theory basis sets were used. Some of the ramifications of the present results will be discussed.

1. INTRODUCTION

Electron momentum spectroscopy (EMS), or (e,2e) coincidence spectroscopy, is now a well developed tool for the investigation of the dynamic structure of atoms and molecules, including electron correlation effects, due to its unique ability to measure the orbital momentum profile for binding-energy-selected electrons[1]. Furthermore, within the distorted wave impulse approximation (DWIA) or plane wave impulse approximation (PWIA)[2], this measured momentum cross section may be directly compared with the calculated spherically averaged momentum distribution (MD) of a specific atomic or molecular orbital, once the appropriate angular-resolution function has been folded in. Hence EMS is also a powerful technique for evaluating the quality of theoretical wave-functions in quantum chemistry[3,4]. More recently, it has been used[3,4] to extract accurate and reliable chemical molecular property information for organic molecules and, finally, we note EMS is also a very important technique for testing the validity of the reaction mechanism description in different theoretical models.

Each of the above roles of EMS will be briefly considered in this short paper. In this particular task we have been aided by the development of an (e,2e) monochromator which has significantly improved our achievable energy resolution, thereby allowing us to unambiguously extract the MDs from the measured binding energy (ϵ_b) spectra. Specific examples of results for EMS studies on argon (Ar) and cubane (C₈H₈) are detailed later in Sections 4 and 5.

2. EXPERIMENTAL DETAILS

The present experiments were conducted with a noncoplanar symmetric electron-coincidence spectrometer. This spectrometer and the techniques used in the present investigation have been described at length previously[1] and so we do not go into further detail here. We note, however, that there has been three major developments to the coincidence spectrometer since the earlier description. They are, (i) the computer hardware and operating system have been upgraded, (ii) the collision region is now differentially pumped and (iii) an electron monochromator has been brought on-line[5].

Electron Momentum Spectroscopy Physics Of Atoms And Molecules

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Electron Momentum Spectroscopy Erich Weigold, Ian McCarthy, 2012-09-27 This book gives a complete account of electron momentum spectroscopy to date It describes in detail the construction of spectrometers and the acquisition and reduction of cross section data explaining the quantum theory of the reaction and giving experimental verification *New Directions in Atomic Physics* C.T. Whelan, Reiner M. Dreizler, J.H. Macek, H.R.J. Walters, 2012-12-06 The last few years have seen some remarkable advances in the understanding of atomic phenomena It is now possible to isolate atomic systems in traps measure in coincidence the fragments of collision processes routinely produce and study multicharged ions One can look at bulk matter in such a way that the fundamental atomic character is clearly evident and work has begun to tease out the properties of anti matter The papers in this book reflect many aspects of modern Atomic Physics They correspond to the invited talks at a conference dedicated to the study of New Directions in Atomic Physics which took place in Magdalene College Cambridge in July of 1998 The meeting was designed as a way of taking stock of what has been achieved and it was hoped as a means of stimulating new research in new areas along new lines Consequently an effort was made to touch on as many directions as we could in the four days of the meeting We included some talks which overviewed whole subfields as well as quite a large number of research contributions There is a unity to Physics and we tried to avoid any artificial division between theory and experiment We had roughly the same number of talks from those who are primarily concerned with making measurements and from those who spend their lives trying to develop the theory to describe the experiments

Atoms, Molecules and Optical Physics 2 Ingolf V. Hertel, Claus-Peter Schulz, 2014-10-22 This is the second volume of textbooks on atomic molecular and optical physics aiming at a comprehensive presentation of this highly productive branch of modern physics as an indispensable basis for many areas in physics and chemistry as well as in state of the art bio and material sciences It primarily addresses advanced students including PhD students but in a number of selected subject areas the reader is lead up to the frontiers of present research Thus even the active scientist is addressed This volume 2 introduces lasers and quantum optics while the main focus is on the structure of molecules and their spectroscopy as well as on collision physics as the continuum counterpart to bound molecular states The emphasis is always on the experiment and its interpretation while the necessary theory is introduced from this perspective in a compact and occasionally somewhat heuristic manner easy to follow even for beginners *Relativistic Theory of Atoms and Molecules II* Pekka Pyykkö, 2012-12-06 Relativistic effects are of major importance for understanding the properties of heavier atoms and molecules This book is still the only comprehensive bibliography on related calculations The material is organized by subject into tables containing a concise characterization Together with Volume I *Lecture Notes in Chemistry Vol 41* ISBN 3 540 17167 3 the literature until 1992 is now covered and 6577 references with titles are given in the two books The book will provide a convenient reference for theoretical chemists and atomic and molecular physicists interested in the properties of

heavier elements Contents Introduction One particle problems Quantum electrodynamical effects Multielectron atoms methods Multielectron atoms results Symmetry Molecular calculations Solid state theory Relativistic effects and heavy element chemistry Corrections to Volume I Some comments on notations and terminology List of acronyms and symbols Bibliography

Polarization and Correlation Phenomena in Atomic Collisions Vsevolod V. Balashov, Alexei N. Grum-Grzhimailo, Nikolai M. Kabachnik, 2013-03-14 Polarization and Correlation Phenomena in Atomic Collisions A Practical Theory Course bridges the gap between traditional courses in quantum mechanics and practical investigations The authors goal is to guide students in training their ability to perform theoretical calculations of polarization and correlation characteristics of various processes in atomic collisions The book provides a concise description of the density matrix and statistical tensor formalism and presents a general approach to the description of angular correlation and polarization phenomena It illustrates an application of the angular momentum technique to a broad variety of atomic processes The book contains derivations of the most important expressions for observable quantities in electron atom and ion atom scattering including that for polarized beams and or polarized targets in photo induced processes autoionization and cascades of atomic transitions Spin polarization and angular distributions of the reaction products are described including the angular correlations in different types of coincidence measurements The considered processes exemplify the general approach and the number of examples can be easily extended by a reader The book supplies researchers both theoreticians and experimentalists with a collection of helpful formulae and tables and can serve as a reference book Based on a highly regarded course at Moscow State University and elsewhere the book provides real guidance on theoretical calculations of practical use

Atoms, Molecules and Photons Wolfgang Demtröder, 2006-03-06 The detailed understanding of matter its phase transitions and its interaction with radiation could be only reached after its microscopic structure determined by the kind of atoms or molecules as basic constituents of matter had been investigated This knowledge allowed the controlled optimization of characteristic properties of matter Atomic physics therefore represents not only an area of important fundamental research but has furthermore many applications which have essentially formed our present technical world The understanding of materials and their use in daily life has major impact of our culture and our attitude towards nature and our environment This textbook is aimed as an introduction to the microscopic world of atoms molecules and photons It illustrates how our knowledge about the microscopic structure of matter and radiation came about and which crucial experiments forced an extension and refinement of existing classical theories culminating in the development of quantum theory which is now accepted as the basic theory of atomic and molecular physics The book therefore starts with a short historical review about the role of experiments for correcting erroneous ideas and proving the existence of atoms and molecules The close interaction between experiments and theory has been one of the main reasons for the rapid development of atomic physics in the 19 and 20 centuries

Nuclear Science Abstracts, 1976

State-of-the-art Reviews On Energetic Ion-atom And

Ion-molecule Collisions Dzevad Belkic, Igor Bray, Alisher Kadyrov, 2019-10-17 This book is based upon a part of the invited and contributing talks at the 25th International Symposium on Ion Atom Collisions ISIAC biennial held on July 23-25 2017 in Palm Cove Queensland Australia To aid the general reader all the authors tried to present their chapters in the context of the development of the addressed particular themes and the underlying major ideas and intricacies Some chapters contain new results that have not been previously published elsewhere Whenever possible the authors made their attempts to connect the basic research in atomic and molecular collision physics with some important applications in other branches of physics as well as across the physics borders It is hoped that the material presented in this book will be interesting and useful to the beginners and specialists alike The contents and expositions are deemed to be helpful to the beginners in assessing the potential overlap of some of the presented material with their own research themes and this might provide motivations for possible further upgrades Likewise specialists could take advantage of these reviews to see where the addressed themes were and where they are going in order to acknowledge the fruits of the efforts made thus far and actively contribute to tailoring the directions of future research Overall this book is truly interdisciplinary It judiciously combines experiments and theories within particle collision physics on atomic and molecular levels It presents state of the art fundamental research in this field It addresses the possibilities for significant and versatile applications outside standard atomic and molecular collision physics ranging from astrophysics surface as well as cluster physics chemistry hadron therapy in medicine and to the chemical industry It is then as Volume 2 fully in the spirit of the Aims and Scope of this book series by reference to its Mission Statement

Atomic Physics of Highly Charged Ions Erhard Salzborn, Paul H. Mokler, Alfred Müller, 2012-12-06 This book contains the invited lectures and contributed papers presented at the V International Conference on the Physics of Highly Charged Ions which was held at the Justus Liebig University at Giessen 10-14 September 1990 This conference was the fifth in a series after Stockholm 1982 Oxford 1984 Groningen 1986 and Grenoble 1988 to deal with a rapidly growing field which comprises the spectroscopy of highly charged ions and their interactions with photons electrons atoms ions and solids Most of the matter of the universe is in the ionized state Investigations dealing with hot plasmas on earth have been greatly furthered by thermonuclear fusion research The increasing maturity of this programme has revealed the fundamental role of highly charged ions in fusion plasmas Today it is clear that a detailed knowledge of the production mechanisms of highly charged ions and their interactions with other plasma constituents is an important prerequisite for a better understanding of the microscopic and macroscopic plasma properties The study of highly charged ions involves various branches of physics It was the aim of the conference to bring together physicists working in atomic collisions and spectroscopy in plasma physics and astrophysics as well as in solid state and ion source physics About 220 scientists from 20 nations attended the conference indicating the strong worldwide interest and the vitality of research in this field

International Conference on the Physics of Electronic and Atomic Collisions, 1989 **Advances in Atomic, Molecular, and Optical Physics**

,2011-09-29 *Advances in Atomic Molecular and Optical Physics* publishes reviews of recent developments in a field which is in a state of rapid growth as new experimental and theoretical techniques are used on many old and new problems Topics covered include related applied areas such as atmospheric science astrophysics surface physics and laser physics Articles are written by distinguished experts and contain both relevant review material and detailed descriptions of important recent developments International experts Comprehensive articles New developments *Advances in Atomic, Molecular, and Optical Physics* Paul R. Berman,Ennio Arimondo,Chun C. Lin,2011-10-03 *Advances in Atomic Molecular and Optical Physics* publishes reviews of recent developments in a field which is in a state of rapid growth as new experimental and theoretical techniques are used on many old and new problems Topics covered include related applied areas such as atmospheric science astrophysics surface physics and laser physics Articles are written by distinguished experts and contain both relevant review material and detailed descriptions of important recent developments International experts Comprehensive articles New developments *Scientific and Technical Aerospace Reports*, 1994 *Progress in Photon Science* Kaoru Yamanouchi,2017-05-26 This book features chapters based on lectures presented by world leading researchers of photon science from Russia and Japan at the first STEPS Symposium on Photon Science held in Tokyo in March 2015 It describes recent progress in the field of photon science covering a wide range of interest to experts in the field including laser plasma interaction filamentation and its applications laser assisted electron scattering exotic properties of light ultrafast imaging molecules and clusters in intense laser fields photochemistry and spectroscopy of novel materials laser assisted material synthesis and photon technology *Energy Research Abstracts* ,1994-02 *Nuclear Science Abstracts* ,1974-07

Supercomputing, Collision Processes, and Applications Kenneth L. Bell,Keith A. Berrington,Derrick S.F. Crothers,Alan Hibbert,Kenneth T. Taylor,2006-04-18 Professor Philip G Burke CBE FRS formally retired on 30 September 1998 To recognise this occasion some of his colleagues friends and former students decided to hold a conference in his honour and to present this volume as a dedication to his enormous contribution to the theoretical atomic physics community The conference and this volume of the invited talks reflect very closely those areas with which he has mostly been associated and his influence internationally on the development of atomic physics coupled with a parallel growth in supercomputing Phil's wide range of interests include electron atom molecule collisions scattering of photons and electrons by molecules adsorbed on surfaces collisions involving oriented and chiral molecules and the development of non perturbative methods for studying multiphoton processes His development of the theory associated with such processes has enabled important advances to be made in our understanding of the associated physics the interpretation of experimental data has been invaluable in application to fusion processes and the study of astrophysical plasmas observed by both ground and space based telescopes We therefore offer this volume as our token of affection and respect to Philip G Burke with the hope that it may also fill a gap in the literature in these important fields ***Australian Journal of Physics*** ,1998 ***Molecular Beams in Physics and Chemistry***

Bretislav Friedrich, Horst Schmidt-Böcking, 2021-06-19 This Open Access book gives a comprehensive account of both the history and current achievements of molecular beam research In 1919 Otto Stern launched the revolutionary molecular beam technique This technique made it possible to send atoms and molecules with well defined momentum through vacuum and to measure with high accuracy the deflections they underwent when acted upon by transversal forces These measurements revealed unforeseen quantum properties of nuclei atoms and molecules that became the basis for our current understanding of quantum matter This volume shows that many key areas of modern physics and chemistry owe their beginnings to the seminal molecular beam work of Otto Stern and his school Written by internationally recognized experts the contributions in this volume will help experienced researchers and incoming graduate students alike to keep abreast of current developments in molecular beam research as well as to appreciate the history and evolution of this powerful method and the knowledge it reveals **Canadian Journal of Physics** ,1996

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