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To cite this version:

HAL Id: jpa-00227255
https://hal.archives-ouvertes.fr/jpa-00227255
Submitted on 1 Jan 1987

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ON THE DETERMINATION OF COMPTON PROFILES BY ELECTRON INDUCED K-SHELL IONIZATION(1)

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Abstract: - In a coincidence experiment we have measured the double differential cross section for K-shell ionization of Cu and Ag by electrons with energies of $E_0 = 140$ and $200$ keV. The results obtained are in accordance with those of a former experiment. A comparison with theory reveals a fairly good agreement with the calculations by Das at least for emitted electron energies in the vicinity of the Möller peak, while the predictions by Cooper and Kolbenstvedt exhibit a complete different behaviour. Finally, own calculations are presented that are based on a field theoretical approach in which the double differential cross section factorizes into a Compton profile and a kinematical factor.

1. Introduction

Measurements of double differential inner-shell ionization cross sections are important in the attempt to understand better the basic inelastic electron-atom interaction of ionization and to draw conclusions on the momentum distribution of the bound electron. Until now measurements of K-shell ionization of targets with intermediate atomic number by electron bombardment at relativistic energies have only been performed for a few targets, two different impact energies and some energies of the scattered electron [1,2]. A comparison of these data with theoretical results of Das [3] and Cooper and Kolbenstvedt [4] exhibit considerable discrepancies especially for large scattering.

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angles and particularly for heavier atoms. The two theoretical approaches yield predictions that differ at certain kinematical conditions by orders of magnitude. Some improvement is observed from a modified calculation by Das and Chakraborty [5].

We have tackled therefore the problem from the theoretical and experimental side. Making use of the work by Eschwey and Manakos [6] we derived approximately an expression for the double differential cross section that factorizes into a Compton profile, which represents the integral over the momentum distribution of the bound K-shell electron, and a part that contains the kinematical relevant quantities. Furtheron we have measured the cross section differential in electron energy and angle by observing either the scattered or ejected electron in coincidence with the K X ray.

2. Experimental Procedure and Results

In the present experiment electrons were accelerated to kinetic energy of 140 and 200 keV and struck a thin self-supporting target of Cu or Ag with a thickness of about 50 μg/cm² placed at the center of the scattering chamber. Electrons scattered at 40° or 45° with respect to the incident beam direction were momentum analyzed in a magnetic spectrometer and detected by a silicon surface barrier detector. Characteristic K X rays produced at 90° with respect to the incident electron beam passed out of the scattering chamber through a thin mylar window and were detected by a Si(Li) detector. A fast-slow coincidence system with a timing resolution of about 20 ns was used to measure the coincidence rate between the X rays and the electrons, which is directly proportional to the double differential cross section \( \frac{d^2\sigma}{d\Omega_1 dE_1} \). The coincidence counting rate was normalized to the total K-shell ionization cross section and to the elastic scattering Mott cross section.

The results of the experiment are shown in Fig.1 for an electron bombarding energy of 140 keV and electrons detected between 40 and 100 keV at an angle of 45°, and in Fig.2 for 200 keV impact energy on Ag and emitted electrons at 40°. The data of Ref. [1] are indicated by open squares. The three lines denote the various theoretical approaches by Das (solid line), Cooper and Kolbenstvedt (dotted line) and us (dash-dotted line). Because of the broad energy resolution of the magnetic spectrometer (\( \Delta p/p = \pm 17\% \)), it is necessary to fold the theoretical cross section over the measured transmission curve for the spectrometer in order to obtain a theoretical value which can be directly compared with the experimental points.
3. Discussion

The data shown in Fig.1 reveal a fairly good agreement with the results of Quarles and Faulk [1]. Furtheron it becomes apparent from the now wider spread experimental points that the overall behaviour of \( \frac{d^2\sigma}{d\Omega dE_1} \) as function of \( E_1 \) is in general described better by the predictions of Das than those of Cooper and Kolbenstvedt. This may be due to the fact that Coulomb wave functions were not used by Cooper and Kolbenstvedt to describe the low energy electron, which becomes of importance for the high or low energies. The not completely satisfying agreement of our data with the calculations by Das may be attributed to the potential in which the inner-shell electron is supposed to move, and we are currently investigating whether an approach using a more realistic model [5] yields better agreement. Our calculation of the longitudinal part of the cross section as well as the approximations...
made and the limits of validity will be presented in detail in a forthcoming paper. Using theoretical values of the Compton profile [7] the dash-dotted curve is obtained which exhibits a behaviour similar to the one calculated by Das. It should be mentioned, however, that the exchange has not been included in our calculations. The fact that the transverse part of the cross section has been neglected ought to be without significance at these impact energies. It is presently investigated in how far this method can be used to determine experimentally Compton profiles for inner-shell electrons even for medium and heavy elements.

References