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ABSTRACTS of CONTRIBUTED PAPERS

vol. I

Edited by: Josef Anton, Henrik Cederquist, Mats Larsson, Eva Lindroth, Sven Mannervik, Henning Schmidt and Reinhold Schuch

ELECTRON ENERGY-LOSS SPECTRA OF THE $(n-1)d^9ns^2np$ AUTOIONISING STATES OF Cd ($n=5$) AND Zn ($n=4$)

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We have experimentally investigated the $(n-1)d^9ns^2$ electronic configuration of Cd ($n=5$) and Zn ($n=4$) using their single inner-electron excitation spectra of the np autoionising states. This is of fundamental interest because electronic configurations mentioned above are avoided in the ground states of atoms given in the Periodic table of elements.

The apparatus used is a cross-beam electron spectrometer, described elsewhere [1]. For this purpose we utilized its energy-loss mode of operation. The crucible of the metal-vapour source was made of stainless steel in the case of Cd, but in the case of Zn the crucible was made of titanium, which is completely resistive to Zn vapour [2]. The measurements were performed at temperature of 580 K for Cd (purity 99.95%), while the temperature was increased to 750 K for Zn (purity 99.9%). In both cases the shape of the autoionising spectra was not temperature sensitive bellow the values given above.

The zero scattering angle ($\theta=0$) was determined with uncertainty of 0.5°. Typical overall energy resolution (as FWHM) was 50 meV for Cd, but approximately 140 meV for Zn to compromise with satisfactory signal intensity. Position of the feature in the elastic scattering attributed to the n^3P excitation threshold (3.737 eV for Cd, and 4.03 eV for Zn) was utilized for calibration of the energy scale.

We have recorded energy-loss spectra of autoionising states for both Cd and Zn atoms. For Cd, spectra are recorded at incident electron energy (E_0) from 15 eV to 60 eV (θ up to 40°). Also, the spectra of Zn at E_0 from 20 eV to 100 eV (θ up to 10°) have been measured.

Using J_c-j coupling scheme, where J_c and j represent total angular momenta of the ion core and np electron excited from $(n-1)d$ subshell, respectively, the 12 components for both the Cd and Zn autoionising $(n-1)d^9ns^2np$ multiplets can be predicted.

These autoionising states of Cd are positioned 2.6 eV above the first ionisation threshold (IP) in the range from 11.605 to 13.014 eV, while those of Zn are 1.6 eV above its IP in the range from 10.989 to 11.892 eV. We estimated remarkable lower probability for electron impact excitation of the $(n-1)d^9ns^2np$ autoionising states of Zn with respect to that of Cd.

To decompose features in the energy-loss spectra, we assumed the lines are obtained as convolution product of a symmetric Shore function [3] by the Gaussian apparatus function with corresponding FWHM. In some cases log-normal function is applied to reproduce obvious asymmetry of lines in the spectra. The lines of Zn are close one to another (within 0.9 eV), so detailed decomposition of the spectrum was more difficult than in the case of Cd.

References

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PHOTONIC, ELECTRONIC AND ATOMIC COLLISIONS IN FRONT OF CHARGED METALLIC TIPS

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Strong electric field near a metallic tip in environmental conditions enables producing of photons, free electrons that trigger new collision processes and both positive and negative air-ions.

Electrical corona is well known physical phenomenon [1]. We used the home made high voltage (5 kV) cascade, with a tungsten tip at the end, to obtain a negative corona discharge in air. Optical spectrum of the negative corona is recorded in the wavelength region from 275 nm to 425 nm using Jobin Yvon grating spectrometer. Lines in the spectrum are identified as predominantly nitrogen the 2nd positive group ($C\ ^3\pi_u \rightarrow B\ ^3\pi_g$). The $C\ ^3\pi_u \rightarrow B\ ^1\pi_g$ (at 380.5 nm) transitions in N_2, and the $B\ ^2\Sigma_u \rightarrow X\ ^2\Sigma_g$ (at 391.4 nm) in N_2^+ are also identified. In a separate experiment we found that intensity of the ozone line (at 308.95 nm) increases with respect to the N_2 line at 315 nm if the potential applied increases from 3.5 kV to 5 kV [2]. High voltage power supply (Quantum Electronics Corp., 0-10 kV, 1 mA) was utilized for producing a positive corona discharge in the air. Optical fiber spectrometer SD-2000 (Ocean Optics Corp.) with a CCD camera as a detector was used in UV mode of operation to record the optical spectrum of the corona. Very similar UV spectra of negative and positive coronas confirm generally accepted opinion that molecules surrounding the charged metallic tip emit the UV radiation. Physical processes in an alternating corona are a combination of those in DC coronas. Free electrons and both negative and positive air-ions oscillate in the RF field with the mean free path lower than the distance from the metallic surface. As a result, collisions between atomic particles are predominant with respect to the particle-surface collisions.

The measurements referred by Akishev *et al* (references in [3]) suggest soft x-ray radiation produced by collisions of electrons against the tip surface. This is not confirmed in measurements by Aints *et al* [3] that performed in different experimental conditions.

A Gerdian type detector of air-ions, designed and built in our laboratories, is utilized for detection of the ions in vicinity of electrically polarised metallic tips. Electronic circuit with AD549LH operational amplifier enables high sensitivity of the detector (50 ion cm^{-3}). We found very high efficiency of metallic tips to produce "small" air-ions.

Experimental verification of the Fauler-Nordheim equation for current density of the "cold" electron emission was possible when surface radius of 30 nm was obtained on the tip. Very strong electric fields ($\approx$10 GVm^{-1}) in front of the tip can be obtained in this way.

Atomic-size tip is possible to obtain if the metallic nanowire appears during mechanical break junction. We designed the set-up for demonstration of the quantum conductance, using commercial electro-mechanical relay. For this purpose we gild the electrodes and applied potential difference of 100 mV between them. We found not only quantum conductance, but also tunneling of electrons through the potential barrier close to the tip surface. Light emission from the nanowire during the last stage of the contact, just before formation of the one-atom tip, is reported by Garcia and Costa-Kramer [4]. Unfortunately, this is not confirmed in our measurement performed using the Jobin Yvon double monochromator with the aim to detect radiation generated by surrounding air molecules or by the fundamentally finest gold tip itself.

References

[1] L.B.Loeb, 1965 *Electrical Coronas: Their Basic Physical Mechanisms* (Berkeley: University of California Press).
[2] D.M.Filipović, 1998 *Research Experiments in Atomic and Quantum Physics*, Faculty of Physics, University of Belgrade.
[3] M.Aints, K.Kudu, A.Haljaste and T.Plank, J.Phys.D: *Appl.Phys.* **34** (2001) 905.
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THE THIRD CRITICAL MINIMUM IN ELASTIC ELECTRON-ARGON SCATTERING

A. Milosavljević[1], S. Telega[2], D Šević[1], J. E. Sienkiewicz[2] and B. P. Marinković[1]

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2) Department of Applied Physics and Mathematics, Gdańsk University of Technology, Narutowicza 11/12, 80-952 Gdańsk, Poland

The critical minima are defined by the points on the plane constituted by the scattering angle and incident energy axis where differential cross section (DCS) attains its smallest value. These minima appeared to be the most sensitive test for both experimental procedures and theoretical models, and for comparison of experimental and theoretical results as well. Moreover, the critical minima are closely correlated with the total polarization of scattered electrons [1]. However, very few of the published data have been focused on this phenomenon.

Panajotović *et al* [2] published the first detailed experimental search for the critical minima in electron-argon scattering. They found two critical points below 100 eV. These results are in good accord with the most recent calculations of Sienkiewicz *et al* [3].

In this work we present the results of the experimental investigation of DCSs for elastic electron-argon scattering in the ranges of 40°-126° and 90-150 eV where the third critical minimum should be expected. We have performed independent relative measurements of both angular and incident energy dependence of DCS, which allowed us to use only one single point for absolute calibration. To cover the energy and angular ranges of the present experiment, relevant relativistic *ab initio* calculations were carried out. The theoretical approach is based on the Dirac-Hartree-Fock method. Exchange between incident and target electron is calculated exactly. Target polarization is described by an *ab initio* potential taken from relativistic polarized orbital calculations.

The experimentally obtained and theoretically calculated DCSs between 88 eV and 150 eV are presented in figure 1.a and 1.b, respectively. The position of the third critical minimum in elastic scattering of electrons by argon was experimentally found to be at 129.4 ± 0.5 eV and 119.4° ± 0.5°, while the calculated values are 118.0 ± 0.5 eV, 118.9° ± 0.3°. In figure 1.c, the obtained high angle minimum position versus incident electron energy is presented. The theoretical curve is shifted for 12 eV towards higher energies according to the difference in the obtained critical energy position.

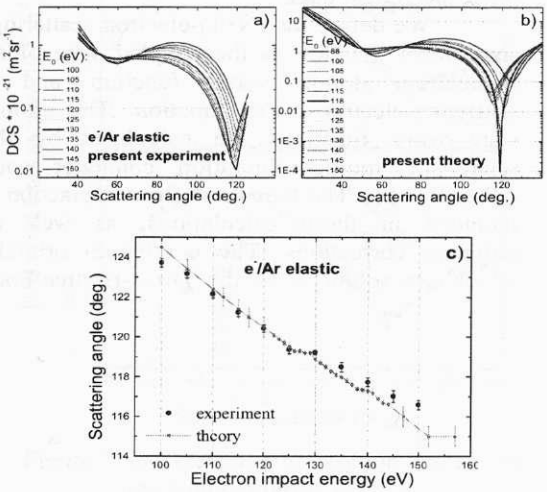

Figure 1: Elastic electron-argon scattering: a) absolute DCSs – experiment; b) absolute DCSs – theory; c) High-angle minimum position versus incident energy.

References

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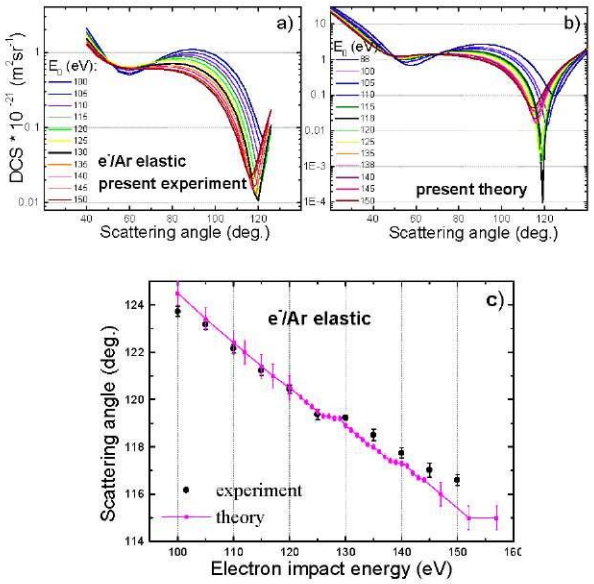

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THE ENERGY DEPENDENT DIFFERENTIAL CROSS SECTIONS FOR ELASTIC ELECTRON-ARGON SCATTERING

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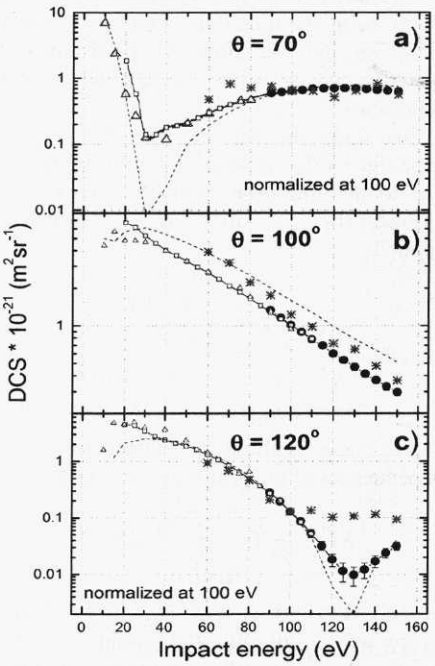
The elastic scattering of electrons by argon has been extensively studied and a large number of either theoretically or experimentally obtained differential cross sections (DCSs) is available. However, most of the previous measurements are reported as a function of scattering angle at fixed incident electron energies and few of them (Panajotović *et al* [1]) were performed in small energy steps. Even in this case, however, the normalization procedure and energy dependent experimental parameters could affect the extracted energy dependent DCSs.

Recently, Cvejanović and Crowe [2] reported the extensive measurements of DCSs for elastic electron-argon scattering that were performed as a continuous function of incident electron energy. They have investigated the possible broad resonance structures, similar to that observed in positron-argon scattering. The obtained DCSs appeared to be smooth over a wide energy range. Also, at some fixed scattering angles, they revealed extreme points. However, the upper energy limit of these measurements was 110 eV, which is below the third critical energy (see the other contribution at this ICPEAC).

We have measured the DCSs for elastic electron-argon scattering as a function of incident electron energy within the range of 90-150 eV in 5 eV steps, at fixed scattering angles from 70° to 120° in 10° increments. The most important energy dependent factors (electron beam current, analyzer lens transmission and detection efficiency) were keeping constant during the measurements.

In figure 1, the absolute DCSs at 70°, 100° and 120° are presented. Present curve is normalized at 100 eV with respect to the absolute DCS of Cvejanović and Crowe [2]. Also, for the angles of 70° and 120° (figure 1a and 1c) all DCSs are normalized to the same value at 100 eV. For 100° all DCSs appeared to be practically linear in logarithmic scale. The similar DCS shape has been obtained at the angles of 80°, 90° and 110° (not presented in this work) as well. However, the energy dependent DCSs at 70° and 120° are more complex, with deep DCS minima that correspond to the positions of the critical points in elastic electron-argon scattering.



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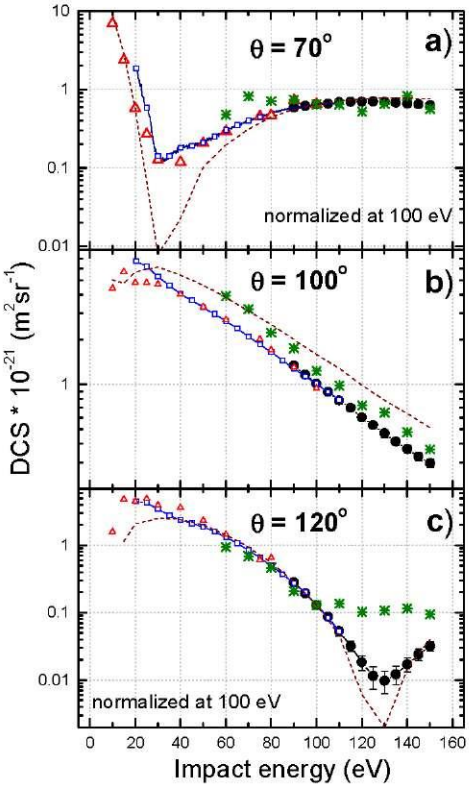

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GENERALIZED OSCILLATOR STRENGTHS FOR ELECTRON SCATTERING BY Ca ATOM AT SMALL ANGLES

S. Tošić[1], D. Šević[1], V. Pejčev[2], D. M. Filipović[3] and B. P. Marinković[1]

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Here we present generalized oscillator strengths (GOS) for the resonant $4p^1P^0$ state (2.93 eV) of calcium.

The experiment was carried out using a crossed electron-atom beam technique in the electron spectrometer "ESMA", both described in more details elsewhere [1]. The calcium vapour beam was produced in a wire-heating oven at temperatures from 700 to 720°C. For this experiment we made some modifications in order to achieve higher temperatures than used for zinc measurements. The most basic modification was new oven with reduced thickness of walls. External overheating was avoided by additional water-cooling.

The position of zero scattering angle was determined from the symmetry of angular distribution of scattered electrons at negative and positive scattering angles. These measurements were carried out for scattered electrons that had lost 2.93 eV ($4p^1P^0$ state) at each 2 degrees from -10° to +10° and angular scale was corrected. The associated error in angular scale determination was ± 0.2°.

Then, angular dependencies of the scattering signal were multiplied by effective length correction factors to get relative differential cross sections (DCS). We have applied the correction factors of Brinkman and Trajmar [2], modified for our experimental conditions.

In order to put results on absolute scale, obtained relative DCSs were normalized through known value of the optical oscillator strength (OOS) by utilizing forward scattering function (fsf) [3] of the generalized oscillators strength of resonant state of calcium. This technique relies on the fact that the generalized oscillator strength tends to the optical oscillator strength as momentum transfer squared K^2 tends to zero. Due to this technique, at each impact energy, the smallest value of K^2 was obtained from 0° scattering angle. Fitted results were extrapolated to 0° scattering angle and corresponding GOS was normalized to the forward scattering function. The optical oscillator strengths used in this work is experimental value of Kelly and Mathur (1.79 ± 0.03) [4].

Generalized oscillator strengths for e-Ca scattering at small angles have been obtained for 10, 20, 40, 60 and 100 eV electron impact energies. Results are presented in function of K^2 in figure 1. As one can see, the position of the minimum of momentum transfer squared moves to smaller value when the electron energy increase. Also, the slopes of fitted data decrease with the increase of incident energy.

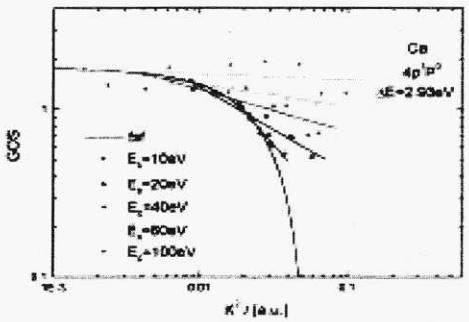

Figure 1.Generalized oscillator strengths for the $4p^1P^0$ state of calcium atom at 10, 20, 40, 60 and 100 eV impact energies

References

[1] R. Panajotović, PhD Thesis, University of Belgrade, Yugoslavia (1999)
[2] R. T. Brinkman and S. Trajmar, J. Phys. E: Sci Instrum. **14** (1981) 245
[3] N. B. Avdonina, Z. Felfli and A. Msezane, J. Phys. B: At. Mol. Opt. Phys. **30** (1997) 2591
[4] F. M. Kelly and M. S. Mathur, Can. J. Phys. **58** (1980) 1416

GENERALIZED OSCILLATOR STRENGTHS FOR ELECTRON SCATTERING BY Ca ATOM AT SMALL ANGLES

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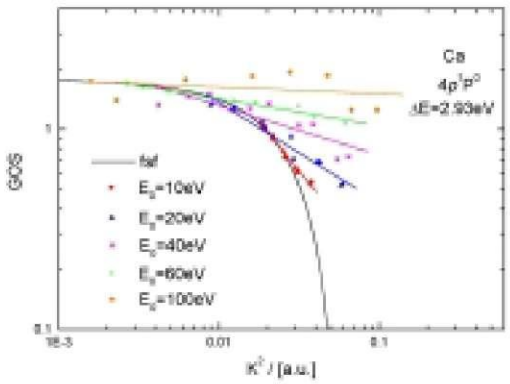

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