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DIFFERENTIAL CROSS SECTIONS FOR INELASTIC ELECTRON SCATTERING BY CALCIUM ATOM

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ABSTRACT

Differential cross section data for inelastic electron scattering by Ca atom have been obtained using a crossed electron-atom beam technique in which the angular distribution for the inalastically scattered electron were measured. Measurements were obtained for the $4p^1P^0$ state (2.93 eV) at electron impact energies of 10, 20, 40 and 60 eV and within a scattering angle interval from 0^o to 150^o. Angular distributions of the scattered electron were converted into relative differential cross sections (DCS) by using the appropriate effective length correction factors. Absolute values have been obtained by normalizing generalized oscillator strengths (GOS) to optical oscillator strength (OOS) in minimum momentum transfer squared (K^2) limit.

Keywords: calcium, inelastic scattering, DCS

1. Introduction

Calcium atom plays an important role in both experimental ant theoretical studies of excitation and electron scattering by metal atoms or two-electron systems and interest for these investigations is growing in the recent years. Experimental studies on calcium atom usually include electron impact [1, 2, 3, 4], combined electron impact and laser excitation [5] and photoionisation [6, 7, 8, 9, 10, 11] but to the best of our knowledge, experimental differential cross sections for inelastic scattering have not been reported.

In this paper we present results for the measurements of differential cross sections for inelastic electron scattering by Ca atom. The angular distribution of the scattered intensity in the range from 0^o to 150^o was determined at electron impact energies of 10, 20, 40 and 60 eV. Our results are presented in absolute scale and compared with available theoretical data by Srivastava *et al* [12].

2. Experimental set-up

The apparatus used in the present experiment has been described in detail by Panajotović [13] and a shematic representation is shown in figure 1. In brief, the experiment was carried out by utilising a crossed electron-atom beam technique. A monoenergetic electron beam was perpendicularly crossed by an atomic beam and the angular distributions for the inalstically scattered electrons were measured.
A hairpin thermo-electron source was used and a electron beam was formed by an electron monochromator (system of cylindrical electrostatic lenses and hemispherical electrostatic energy selector). The inelastically scattered electrons were detected by a hemispherical electron energy analyzer with a channel electron multiplier as a single-electron detector at the end. Analyzer is of the same construction as the monochromator except that it can rotate around the atomic beam axis from -30^o to 150^o with respect to the incoming electron beam.

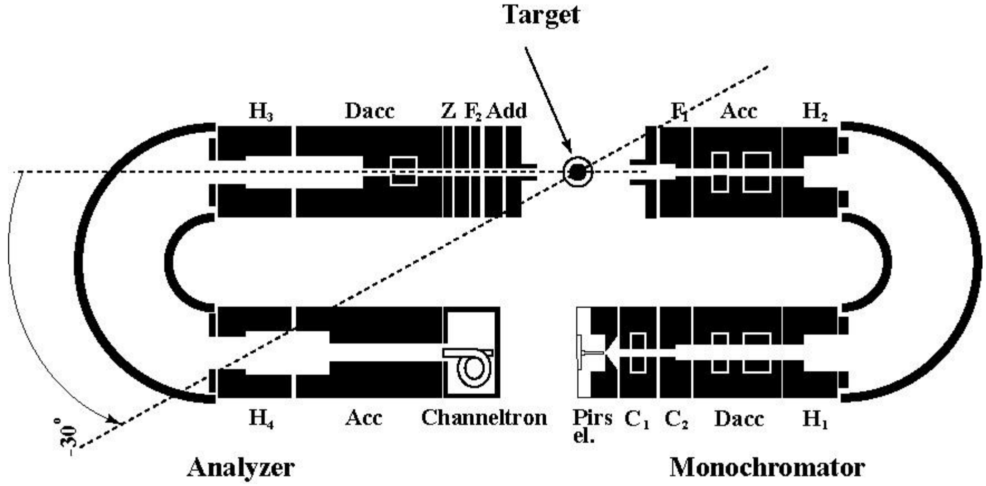

Fig. 1. *Electron optic system*

Atomic beam was produced by heating calcium metal in a wire-heating oven. Diagram of this new designed oven is shown in figure 2. The main modification is that the thickness of oven walls were reduced and additional shielding was performed. This design permits achieving of higher temperatures wich provide vaporisation of calcium sample and ensure reliable work for extended periods of time. The oven was heated to about 700-720 ^{o}C by two separate heaters, one for the top of the stainless steel crucible and nozzle and one for the body of the crucible. They provided a variable temperature differential between the top and bottom – the nozzle was maintained at higher temperature in order to prevent clogging. The heaters are wound in helical grooves on stainless steel heaters bearing. The temperature of the oven was controlled by two thermocouples, one installed at the top of the crucible and the second at the bottom. Transfer of heat and radiation losses from the oven are minimized and reduced by two (inner/outer) stainless steel shields located near the crucible and insulated by ceramic and one copper shield around the oven. The position of oven was adjusted by ceramic insulated stainless steel screws. External overheating of surrounding components was avoided by additional water-cooling.

The experiment was conducted in a vacuum chamber which was shielded magnetically by a double μ-metal shield. Magnetic field was bellow 2 x 10^{-7} T. Two diffusion pumps provided differential pumping of the vacuum chamber and electron-optics system. The background pressure was of the order of 10^{-4} Pa.

The energy-loss spectrum was obtained to verify the absence of double scattering. The scattered electron intensity was measured as a function of scattering angle. The detector was adjusted to record only electrons that had lost 2.93 eV. These measurements were carried out in the full angle interval and then detector was returned to a reference angle. It was a control that the measurements were made under identical conditions.

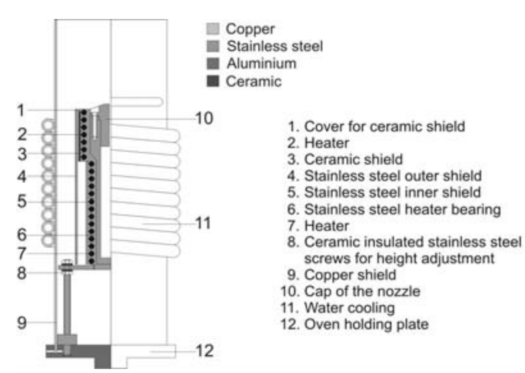

Fig. 2. *Scaled diagram of the oven*

The position of zero scattering angle was determined from the symmetry of angular distribvution of scattered electron from -10^o to +10^o. The measured signals were corrected into relative differential cross sections (DCSs) by using the appropriate egffective length correction factors and then the absolut values have been obtained. This procedure and a normalization procedure we had presented earlier [14].

3. Results and discusion

We have measured angular distribution of electron inelastically scattered by calcium atom for $4p^1P^0$ state at 10, 20, 40 and 60 eV electron impact energies. The scattering intensities were recorder from 0^o to 150^o in 10^o increments except for small scattering angles which is relevant for the normalization procedure. In this range the scattering intensities were recorder each 2^o .

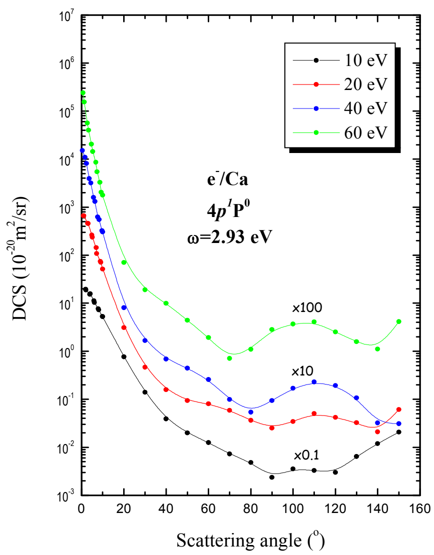

Fig. 3. *DCSs for excitation of the* $4p^1P^0$ *state of Ca.*

Our experimental results are presented in figure3.As one can see, at 10 eV DCS curve has a minimum at 90 ^{o}. At 20 eV two minima show up, one at 90 ^{o} and the other at 140 ^{o}. As the energy increases these minima becomes pronounced. The first one becomes deeper moving toward smaller scattering angles, from 90^o at 20eV to 70 ^{o}at 60 eV. At 60eV intensity of the DCS curve changes six orders of magnitude in the full range of scattering angles.

There are no experimental data to compare with our DCSs. The only comparision is possible with theoretical data of Srivastava *et al* [11]. Their calculation have been carried out in the relativistic distorted-wave approximation for the excitation of calcium from ground state to the $4p^1P^0$ for 30, 40 and 60 eV incident electron energies. Our results at 40 eV and 60 eV are compared with this calculated data and presented in figure 4. For both impact electron energies calculations agree very well with measured distributions of inelastic scattering. At 60 eV the shapes of angular distribution and the absolute values are in excellent agreement with theory. At 40 eV the agreement at small scattering angles ($\Theta < 40^o$) is also excellent while at higher angles calculated values are higher than experimental ones.

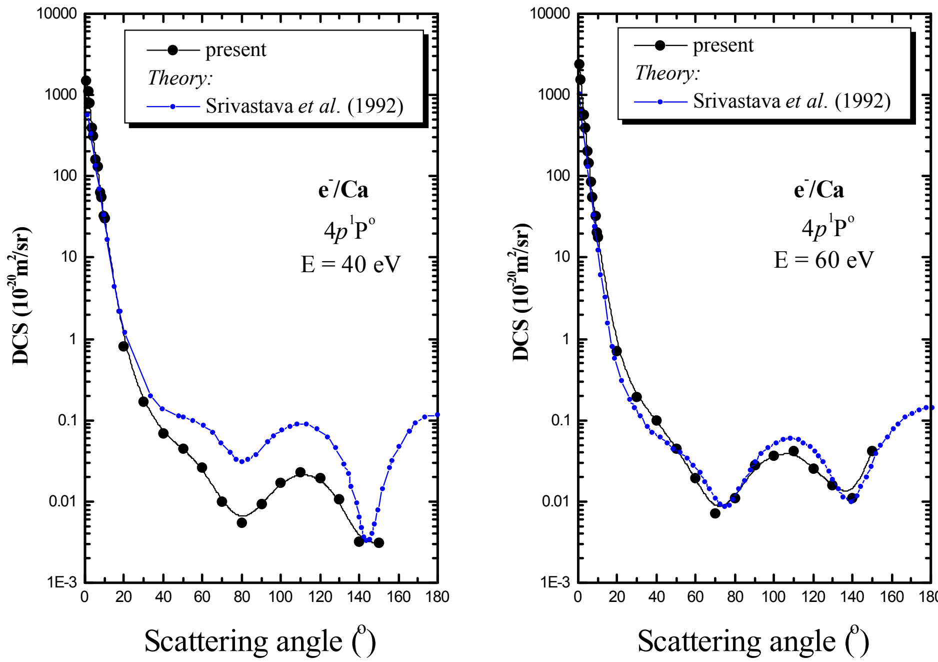

Fig. 4. *DCSs for excitation of the* $4p^1P^0$ *state of Ca; comparison with the calculation of Srivastava at al. (1992)*

4. Conclusions

Our aim was to provide differential cross section data for electron-calcium inelastic scattering. The results were obtained for 10, 20, 40 and 60 eV in the angular range of 0 ° to 150 °. Comparision with existing theoretical results shows that very good agreement exist between experiment and theory. Generally, there is a need for more theoretical and experimental work and we hope that our results will stimulate further scattering studies of calcium atom.

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