INTEGRATED CROSS SECTIONS FOR ELECTRON EXCITATION OF THE $4d^{10}5p$ STATE OF THE Ag ATOM

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Abstract. We have investigated the electron-impact excitation of the combined (two fine-structure levels) resonant $4d^{10}5p\,^2P_{1/2,3/2}$ state in silver from the ground $4d^{10}5s$ state both experimentally and theoretically. Measurements are presented for the combined level while the relativistic distorted wave (RDW) calculations were carried out for each level separately and for the combined level as well. Both the experimental and theoretical results were obtained in the incident electron energy (E_0) range from 10 to 100 eV with experimental scattering angles (θ) from 10^o up to 150^o. Experimental absolute differential cross sections (DCSs) were determined through normalization of the relative DCSs at 10^o to our previous small angle experimental DCS values. The integrated cross sections which include integral (Q_I), momentum transfer (Q_M), and viscosity (Q_V) cross sections were determined by numerical integration of the absolute DCSs.

1. INTRODUCTION

In this paper, we continue our study of the combined resonant $4d^{10}5p\,^2P_{1/2,3/2}$ state of the silver atom excited from the ground state by electron impact [1]. Those results at small scattering angles show that the measured differential cross sections were generally in quite good agreement with the relativistic distorted-wave (RDW) calculations especially at higher energies and smaller scattering angles. Thus, we established the experimental DCSs at 10^o as a base for the normalization of our present relative measurements of the DCSs which are extended over a wide range of scattering angles up to 150^o for experiment and up to 180^o for theory. The energy range remains the same (from

10 to 100 eV). In this way, we obtained absolute DCS values which were extrapolated to 0^o and 180^o and numerically integrated to obtain the integral (Q_I), momentum transfer (Q_M) and viscosity (Q_V) cross sections. Since the observed excited state has two fine-structure levels with total angular momentum J = 1/2 and 3/2 which cannot be distinguished in the present experiment, measured results are presented for the excitation of the combined level. RDW calculations were performed for both fine-structure levels and for the combined excitation.

2. EXPERIMENT

The apparatus used is a conventional crossed-beam electron spectrometer described in more detail in our recent papers dealing with electron scattering by silver and lead atoms [1-3]. In the crossed beam arrangement the electron beam is formed in a system of cylindrical electrostatic lenses and hemispherical energy selectors. The scattered electrons are detected by a rotating analyzer that covers an angular range from −30^o to 150^o, in the plane perpendicular to the atomic beam. The analyzer is of the same construction as the electron monochromator except that it has a channel electron multiplier as a single-electron detector at the end.

A silver vapour beam was produced by heating a Knudsen-type oven crucible containing silver metal by two separate coaxial heaters. The working temperature was about 1300 K, the background pressure was of the order of 10^{-5} Pa, the overall energy resolution (FWHM) was typically 160 meV while the angular resolution was 1.5^o. The position of the true zero scattering angle was determined before each angular distribution measurement by checking the symmetry of the scattered electrons at negative and positive scattering angles (usually from −10^o to +10^o). Due to the change of effective interaction volume versus scattering angle, the effective path length correction factors Veff [4] determined for the present experimental conditions were applied and corrections of the measured scattered intensities was made. The obtained relative DCSs were put on an absolute scale by normalization to the absolute DCSs for the same excitation process at 10^o [1]. Our experimental integrated cross sections are obtained by the extrapolation of the absolute DCSs to 0^o using our previously reported results at small angles and to 180^o using the appropriate RDW calculation followed by numerical integration. Integral (Q_I), momentum transfer (Q_M) and viscosity (Q_V) cross sections are defined as:

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$$Q_I = 2\pi \int_0^\pi DCS(\theta) \sin\theta \; d\theta \tag{1}$$

$$Q_M = 2\pi \int_0^\pi DCS(\theta) \left[1 - \left(1 - \frac{\omega}{E_0} \right)^{1/2} \cos\theta \right] \sin\theta \; d\theta \tag{2}$$

$$Q_V = 2\pi \int_0^{\pi} DCS(\theta)\left[1-\left(1-\frac{\omega}{E_0}\right)\cos^2\theta\right]\sin\theta \, d\theta \qquad (3)$$

where *DCS(q)* is absolute differential cross section, *w* is excitation energy and E_0 is electron impact energy. The details of the RDW method for calculating the DCSs were given in [1] and references therein.

3. RESULTS AND DISCUSSION

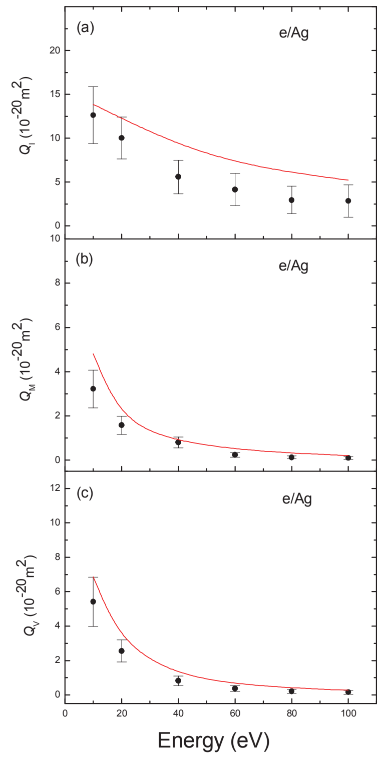

Figure 1. (a) Integral, (b) momentum transfer, and (c) viscosity cross sections for electron impact excitation of the $4d^{10}5p^2P_{1/2,3/2}$ state of the silver atom. Filled circles with error bars denote the present experimental results. The solid line shows the combined DCSs calculated by the RDW method.

In Figure 1 we show the results for the integral (Q_I) (a), momentum transfer (Q_M) (b) and viscosity (Q_V) (c) cross sections for electron excitation of the $4d^{10}5p^2P_{1/2,3/2}$ state of silver. Experiment confirms a slow decrease of Q_I, Q_M and Q_V with increasing incident electron energy as is also predicted by theory. One can see that reasonably good agreement was achieved between experiment and theory concerning the shape of the energy dependences of all integral cross sections but theory gives slightly larger values of all integral cross sections at all electron energies though they lie within the limits of the error bars in several cases. The main reason for this behaviour is the fact that the present calculated DCSs are higher than the normalized measured ones over the whole angular range.

Considering excitation of the $4d^{10}5p^2P_{1/2,3/2}$ fine structure levels, it should be mentioned that there is also the $4d^95s^2D_{5/2}$ state with an energy of 3.749 eV which is intermediate to these fine-structure doublet (with energies of 3.664 eV and 3.778 eV, respectively). One should expect that there must be some contribution from the excitation of this level in our measurements. However, since this excitation from the ^2S ground level to the ^2D state belongs to the electric quadrupole transition, we suppose that its contribution to the excitation cross sections of the resonance ^2P states is negligible. Also, as we already reported in our previous paper [1], the DCS for the combined levels can be represented as a sum of DCSs for excitation of the individual levels.

4. CONCLUSION

Electron impact excitation from the ground state of silver has been studied both experimentally and theoretically. Measurements have been performed at 10, 20, 40, 60, 80 and 100 eV electron energies and scattering angles from 10° to 150°. Calculations were also carried out for the same energies and scattering angles up to 180°. We conclude that good agreement is achieved between the present two sets of data especially at higher energies.

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