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Double Differential Cross-Section Measurements for Electron Impact Ionization of Helium

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The single ionizing collision with an incident electron and atom/molecules ends up two kinds of outgoing electrons called scattering and ejected electrons. As a feature of electron impact ionization these two electrons are indistinguishable. Double differential cross-sections can be obtained by the measurements of energy and angular distributions of one of the two outgoing electrons by a detector. In this perspective, we used He target that is reasonable to expect to understand ionization mechanisms of atomic systems. We have measured double differential cross-sections for asymmetric geometry for different kinematical situations. The experiments are carried out on a newly developed electron spectrometer constructed in Afyonkarahisar, Turkey.

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1. Introduction

Over the past two decades there has been an increasing effort to fully understand the process of single ionization in electron–atom/molecule collisions from experimental and theoretical perspective. Much of this interest is focused on doubly differential cross-section studies for atomic and molecular structure. The literature contains the results from numerous experimental measurements [1–11]. Röder et al. presented a combined experimental and theoretical study of double differential cross-section (DDCS) for electron impact ionization of helium over a wide range of incident energies [5]. For incident energies of 100 eV and 200 eV the measurements of Röder et al. are in good agreement with Müller–Fiedler et al. [4, 8] but to lesser degree with much earlier measurements of Shyn and Sharp and the measurements of Opal et al. [2]. Opal et al. measured the DDCS for several simple gases including He at 50–2000 eV incident electron energies with angular range of 30–150°. The measured energy range for ejected electrons was 4–200 eV. Experimental DDCS of helium shows differences in the shape of angular and energy distributions. Biswas and Sinha have calculated the DDCS of helium at high energy in the framework of eikonal approximation while for the ejected electron a Coulomb wave is considered [6]. The DDCS can be measured using a cross beam type experiment where beam and target particles cross perpendicularly.

The DDCS is represented by

$$\frac{d^2\sigma}{d\Omega_a\, dE_a}. \tag{1}$$

In Eq. (1), for DDCS kinematics are defined by Ω (solid angle) and E (energy). DDCS, differential in energy and direction of one of the outgoing electrons, can be obtained through the measurement of the energy and angular distributions of outgoing electrons with only one detector.

In this paper, we report double differential cross-sections measured by using an apparatus originally developed for coincidence measurements of ejected and scattered electrons i.e. triple differential cross-sections Ref. [12]. The same apparatus can also collect data on angular distribution of ejected or scattered electrons simply disabling the coincident circuit. We take He atom as typical atom couple that is reasonable to expect to understand the ionization process in terms of the quantum mechanical description.

2. Experimental setup and details

The apparatus used to measure the DDCSs is described in Refs. [13, 14]. Therefore the apparatus is described only briefly here. The main components of the apparatus are two electrostatic hemispherical energy analyzers, an electron gun, the Faraday cup and the components for shielding interaction region and electronic control units for data acquisition. An electron beam produced by electron gun is directed into a gas target. Ejected electrons emitted at an angle of θ_b are energy analyzed by a hemispherical electrostatic analyzer and detected by a channel electron multiplier (CEM). DDCSs for He were measured for selected ejected electron energies by manually adjusting the analyzing voltage and recording the scattered signals.

The electron beam was produced by an electron gun that during the present measurements has been operated at 100, 200, and 300 eV energy and at currents about 3 μA. The diameter of the electron beam at the scattering center was around 2 mm. The electron beam current was continuously monitored by a Faraday cup placed on the axis of the electron gun at 50 mm from the scattering center. The effusive gaseous beam was let into the chamber via a needle orthogonal to the electron beam.

3. Results and discussion

DDCSs of ejected electrons from He by electron impact have been measured by a crossed beam method. The incident energies used were 100, 200, and 300 eV. The energy and angular range of ejected electrons measured were 20 and 40 eV for 100 eV impact energy; 10, 20, 40, 60, 70, 80, and 100 eV for 200 eV impact energy; 20 and 40 eV for 300 eV impact energy. The angular range of ejected electrons was measured between 40–140°. Figure 1 shows the DDCS results of He. The results show a smooth systematic variation with both energy and have a maximum around 60° at 200 and 300 eV incident electron energies. This maximum becomes stronger as the incident energy increases.

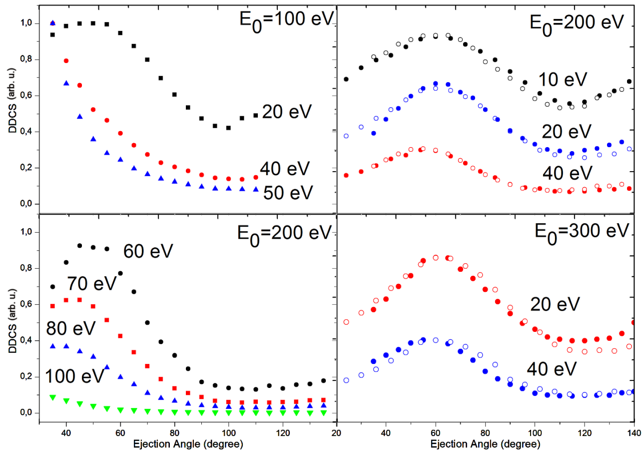

Fig. 1. DDCS spectra for 100, 200, and 300 eV electron impact ionization of He. The DDCS results of He for 100 eV impact energy at 20, 40, 50 eV ejected electron energies, for 200 eV impact energy at 10, 20, and 40, 60, 70, 80, 100 eV ejected electron energies and for 300 eV electron impact energy for 20 and 40 eV ejected electron energy. The present experimental data is shown within filled symbols and the experimental data of Müller–Fiedler et al. is shown within non-filled circles.

At high and intermediate incident electron energies, the high energy ejected electron is emitted in the forward direction. The lower energy ejected electrons are mostly ejected isotropically in all directions. Ejected electrons with higher energies produce some structure in the cross-section due to a binary collision between the incident electron and an electron from the target of He.

The results obtained for 200 and 300 eV impact energy are drawn in comparison with experimental data of Müller-Fiedler et al. [4, 10]. The DDCS results are found to be in good agreement with the experimental data of Müller-Fiedler et al. [4, 10] for both lower and higher ejected energies.

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References

[1] H. Ehrhardt, M. Shultz, T. Tekaat, K. Willmann, *Phys. Rev. Lett.* **22**, 89 (1969).

[2] C.B. Opal, E.C. Beaty, W.K. Peterson, *At. Data* **4**, 209 (1972).

[3] T.W. Shyn, W.E. Sharp, *Phys. Rev. A* **19**, 557 (1979).

[4] R. Müller-Fiedler, K. Jung, H. Ehrhardt, *J. Phys. B* **19**, 1211 (1986).

[5] T. Rösel, P. Schlemmer, J. Röder, L. Frost, K. Jung, H. Ehrhardt, *Z. Phys. B* **23**, 329 (1992).

[6] R. Biswas, C. Sinha, *Phys. Rev. A* **51**, 3766 (1995).

[7] Y. Yun-Fei, C. Zhang-Jın, *Acta Phys. Sin.* **8**, 0167 (1999).

[8] M.V. Kurepa, L. Vuskovic, *J. Phys. B* **8**, 2067 (1975).

[9] D.V. Fursa, I. Bray, *Phys. Rev. A* **52**, 1279 (1995).

[10] R. Muller-Fiedler, P. Schlemmer, K. Jung, H. Ehrhardt, *Z. Phys. A* **320**, 89 (1985).

[11] M.V. Kurepa, L. Vuskovic, *J. Phys. B* **8**, 2067 (1975).

[12] Z.N. Ozer, M. Ulu, B. Aktas, M. Dogan, *Acta Phys. Pol. A* **123**, 363 (2012).

[13] O. Sise, M. Dogan, I. Okur, A. Crowe, *J. Phys. B, At. Mol. Opt. Phys.* **43**, 185201 (2010).

[14] M. Dogan, M. Ulu, O. Sise, *J. Electron. Spectrosc. Relat. Phenom.* **161**, 58 (2007).