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Strong dynamical screening of the $(e,2e)$ processes for electron impact ionization of helium in the perpendicular plane symmetric geometry

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Abstract. We apply BBK, DS3C model and the new modified Sommerfeld parameters of the present DS3C model to calculation of the triple differential cross sections (TDCS) for electron impact ionization of helium in the perpendicular plane symmetric geometry. The results of the present are compared with the measurements and those of other theoretical models. It was found that the present results give a better description for the experimental data and the dynamical screening effects are strong in this geometry. The influence of the Sommerfeld parameters on the triple differential cross sections is also analyzed and discussed in the perpendicular plane geometry.

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Key words: perpendicular plane geometry, doubly-symmetric, sommerfeld parameter

1 Introduction

Electron-impact atom ionization provides a very interesting diversity of phenomena because of the wide range of kinematical situations available to the three-body final state. The incident electron knocks out the target electron with the remainder of the target atom acting as an inert core. An $(e,2e)$ [1–8] reaction is the measurement of the electron-impact ionization process where both the existing electrons are detected in coincidence. It is a measurement almost at the limit of what is quantum mechanically known and its description presents a substantial challenge to theory. Over the past 30 years, significant progress has been made on the theoretical side, with several theories demonstrating excellent agreement with a variety of experimental data yielding multiple differential cross sections for He [9–12], for a variety of outgoing electron geometries and kinematics, and from near threshold to relatively high

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impact energies in the coplanar geometry. But in the non-coplanar geometry constitute a major challenge for theoretical models for many years.

A significant advance in the theory of electron impact ionization has been the use of the asymptotically correct Coulomb three-body wavefunction for ejected and scattered electrons in the field of the residual ion by Brauner, Briggs and Klar(BBK), The BBK model [1] is valid for both symmetric and asymmetric geometries at intermediate energy. Unfortunately, the BBK model is not in agreement with the measurements at low energies because the normalization factor corresponding to the repulsive e-e interaction goes exponentially to zero as the total energy above threshold of the two electrons goes to zero. This exponential decrease also causes the magnitude of the cross section to decrease exponentially. So, Berakdar [13] corrected the deficiency of the BBK wavefunction, while still maintaining the philosophy behind it, by the introduction of effective Sommerfeld parameters in the two-body factors in the BBK wavefunction, and the results turn out to be in good agreement with experimental findings over a wide range of both the coplanar and the non-coplanar geometry.

In our earlier paper [4], we calculated the TDCS for electron impact ionization of helium in a symmetric non-coplanar energy-sharing geometry at incident energies from 27.6 eV to 84.6 eV using the DS3C model presented by Berakdar found the results not excellent agreement with the measurement [14, 15]. Berakdar has successfully derived an approximate analytical solution of the quantum-mechanical three body Coulomb continuum problem. However, his work is not very perfectly in the non-coplanar geometry or perpendicular plane geometry.

Hence, in this paper, we apply BBK, DS3C model and the new modified Sommerfeld parameters of the DS3C model to calculation of TDCS for electron impact ionization of helium in the perpendicular plane symmetric geometry.The results of the present are compared with the absolute measurements and those of other theoretical models. The influence of the Sommerfeld parameters on the triple differential cross sections is also analyzed and discussed in the perpendicular plane.

2 Theory

In atomic units, the TDCS for the $(e,2e)$ process, is given by

$$\mathrm{TDCS}=(2\pi)^4\frac{k_1k_2}{k_0}\left|\frac{3}{4}|f(\vec{k}_1,\vec{k}_2)-f(\vec{k}_2,\vec{k}_1)|^2+\frac{1}{4}|f(\vec{k}_1,\vec{k}_2)+f(\vec{k}_2,\vec{k}_1)|^2\right|, \tag{1}$$

where k_0, k_1 and k_2 are the momenta of the incident, the scattered and the ejected electrons, respectively. The direct amplitude reads

$$f(k_1,k_2)=\langle\psi_f^-|V_i|\phi_i\rangle \tag{2}$$

with

$$V_i=-\frac{2}{r_1}+\frac{1}{|\vec{r}_1-\vec{r}_2|}+\frac{1}{|\vec{r}_1-\vec{r}_3|}, \tag{3}$$