3P068 Double ionization of He by (e,3-1e) at large momentum transfer

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[Introduction] Although kinematically complete experiments of the double ionization at large momentum transfer would provide direct information on electron correlation in the target initial state, such studies are scarce [1], possibly due to extremely small cross sections involved. Recently, Popov et al. [2] have suggested that (e,3-1e) experiments at large momentum transfer can also be used to study electron correlation in the target initial state. Thereafter Bolognesi et al. [3] have reported an (e,3-1e) experiment of He at a momentum transfer of about 6 a.u. using 580 eV incident electron. The present study aims at investigating (e,3-1e) reactions at larger momentum transfer (~9 a.u.) and at higher impact energy (2080 eV) both experimentally and theoretically.

[Experiment] (e,3-1e) experiments detect two fast outgoing electrons produced by electron-impact double ionization in coincidence, measuring a fourfold differential cross section (4DCS) for the kinetic energies and solid angles of emission of the two detected electrons, (E_1, Ω_1) and (E_2, Ω_2). Although the emission direction of the third electron Ω_3 is unknown, its kinetic energy E_3 can be determined with the aid of the law of conservation of energy; $E_0 - IP^{2+} = E_1 + E_2 + E_3$, where E_0 is the incident electron energy and IP^{2+} is the double ionization threshold energy.

The (e,3-1e) experiment of He was carried out using a multichannel apparatus that employs a spherical analyzer and two position-sensitive detectors [4]. Briefly, in the experiment two fast outgoing electrons having equal energies (E_1=E_2) and making equal polar angles of 45° with respect to the incident electron beam axis are detected in coincidence. The three-dimensional (e,2e) or (e,3-1e) data were collected over a binding energy range up to 150 eV. Although absolute cross section can not be determined experimentally, relative strengths of the individual transitions are maintained in the experiment. Thus, the experimental momentum profile for the single ionization transition to the He^+ ground state (n=1) was normalized to plane-wave impulse approximation calculations using a configuration-interaction description of the He target wavefunction. The resulting scaling factor has been subsequently applied to the experimental profiles for the single ionization transition to the He^+ excited state (n=2) and for double ionization. In this way all the experimental profiles have been placed on the absolute scale.

[Theoretical calculation] According to an (e,3-1e) model proposed by Kozakov and Popov [5], the four-body system can be divided into two subsystems; one formed by the two fast electrons taking part in the knock-out electron-electron collision, and another by the residual He^{2+} ion and the slow electron. With this model (e,3-1e) cross section was calculated using several target He wavefunctions. In the calculations effects of the interaction between the first and second subsystems were examined using the eikonal wave impulse approximation, but it has been found that the effects are negligibly small.

[Results and discussion] Fig. 1 shows a binding energy spectrum of He, obtained at an impact energy of 2080 eV. The inset shows the region of the binding energy spectrum where transitions to the excited ion states and doubly ionized continuum. Note that the inset is expanded by a factor of 40. Experimental (e,3-1e) momentum profiles for various kinematical conditions have been generated by plotting the corresponding signal intensity as a function of the recoil momentum of the second subsystem ($\boldsymbol{q} = \boldsymbol{p}_3 + \boldsymbol{p}_{He} = \boldsymbol{p}_0 - \boldsymbol{p}_1 - \boldsymbol{p}_2$).

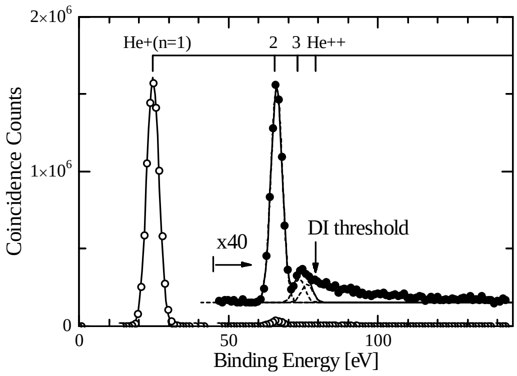

Fig. 1. Binding energy spectrum of He.

Fig. 2 shows an example of the (e,3-1e) experimental momentum profiles, which has been obtained for (a) E_1=E_2~996 eV and E_3~10 eV, and (b) E_1=E_2~991 eV and E_3~20 eV. Also included in the figure are associated theoretical calculations using three He wavefunctions. From comparison between experiment and theory, it has been found that (e,3-1e) momentum profile is very sensitive to the target electron correlation as expected. In fact, the experimental profile shape is reproduced well by calculations using highly correlated wavefunctions such as that developed by Pluvinage [6] (Pl in Fig. 2). However, there is noticeable intensity difference between experiment and theory; the calculation underestimates the experimental cross sections significantly, by a few times of magnitude. The same trend persists for the n=2 transition, though the intensity difference is smaller. In order to account for the observed intensity difference, development of a theory based on the second Born approximation is now in progress.

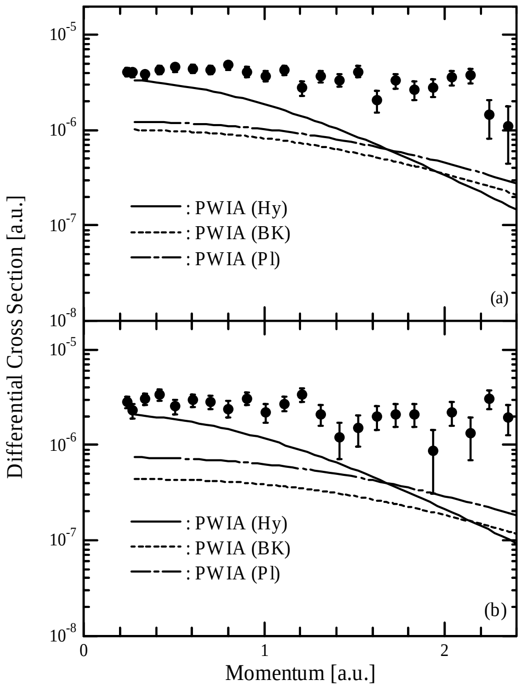

Fig. 2. Experimental and theoretical (e,3-1e) momentum profiles of He: (a) E_1=E_2 ~ 996 eV, E_3 ~ 10 eV and (b) E_1=E_2 ~ 991 eV, E_3 ~ 20 eV.

[References]

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