Electron impact ionization of He(1s2s ^{3}S) and He$^-$(1s2s2p ^{4}P)

Matthieu Génévriez*[1], Jozo J. Jureta*, Pierre Defrance*, Xavier Urbain*

*Institute of Condensed Matter and Nanosciences, Université Catholique de Louvain, Louvain-la-Neuve, Belgium

Synopsis We present experimental cross section for electron impact single and double ionization of He(1s2s ^{3}S) and for ionization of He$^-$(1s2s2p ^{4}P). The experiment has required the development of a novel source producing a fast, intense beam of He(1s2s ^{3}S) with high purity, based upon the photodetachment of He$^-$. The results for single ionization of He(1s2s ^{3}S) solve a long-lasting discrepancy between theory and experiment, while the results for double ionization are the first determination of the cross section for these processes.

Helium is considered a benchmark for the study of electron correlation and, as such, has been the subject of much investigation on both theoretical and experimental grounds. In the case of single and double electron-impact ionization, good agreement has been reached for the ground states of He and He$^+$. However, data for the first excited state He(1s2s ^{3}S) and for the helium negative ion He$^-$ suffer either from major discrepancies between theory and experiment, or simply do not exist in the literature.

We have measured the absolute cross section for electron impact single and double ionization of He(1s2s ^{3}S), and double ionization of He$^-$(1s2s2p ^{4}P). To do so, we have designed a novel source of metastable helium atoms, based upon the production of a fast, intense beam of He$^-$ and its subsequent photodetachment. It overcomes the fundamental limitation of other production techniques, plagued with the presence of non-negligible fractions of other excited states (^{1,3}S, ^{1,3}P), as it produces a beam of pure He(1s2s ^{3}S) with contamination limited to He(1s^2) and as low as 5%. The flux of metastable atoms also keeps up with the highest fluxes achieved with other techniques. The cross section measurements are performed using the animated crossed beam technique of Defrance *et al.* [1].

The results for single ionization of He(1s2s ^{3}S), presented in Fig. 1, are in excellent agreement with the calculations of Fursa and Bray [2]. They also lie significantly lower than the only other experiment available for this energy range [3], thus solving a long-lasting discrepancy. Calculations using the frozen-core approximation (see, *e.g.*, [4]) deviate from the present results at higher energies, highlighting the importance of doubly excited states.

The results for double ionization of He(1s2s ^{3}S) and He$^-$ represent the first determination of these cross sections. Surprisingly, the cross section for double ionization of He(1s2s ^{3}S) has roughly the same magnitude as that of He(1s^2 ^{1}S), although the former lies 19.8 eV above the latter. The cross section for double ionization of He$^-$ is very high when compared to typical values, as may be expected from such a weakly bound system (77 meV), and does not match the universal formula of Rost and Pattard [5], thus hinting towards the importance of indirect double ionization mechanisms. Surely, there is room, and need, for theoretical input in order to understand the mechanisms underlying these intricate processes.

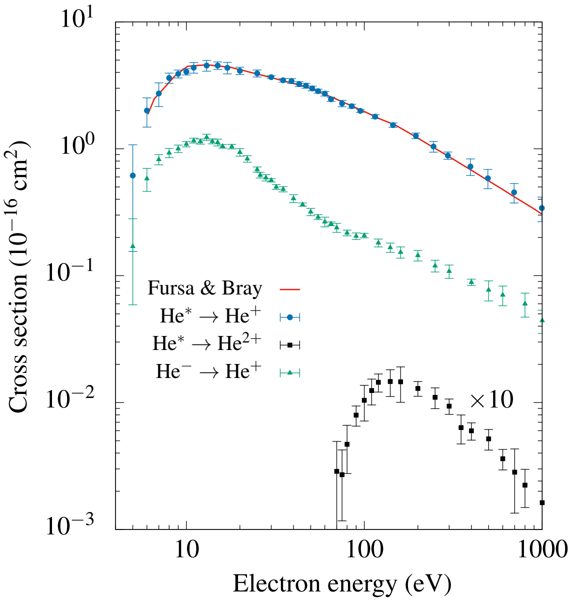

Figure 1. Cross section for electron impact single and double ionization of He(1s2s ^{3}S), and double ionization of He$^-$. The cross section for double ionization of He(1s2s ^{3}S) is multiplied by 10 for clarity.

References

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[1]E-mail: matthieu.genevriez@uclouvain.be