J. At. Mol. Sci.
doi: 10.4208/jams.041811.050911a

Vol. **3**, No. 1, pp. 49-58
February 2012

Electron impact excitation cross sections of the $1s2s\ ^3S$ metastable state of helium

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Received 18 April 2011; Accepted (in revised version) 9 May 2011
Published Online 28 September 2011

Abstract. The differential and integral cross sections for the excited states $1s2p\ ^3P$, $1s3s\ ^3S$, $1s3p\ ^3P$ and $1s3d\ ^3D$ of helium from the metastable state $1s2s\ ^3S$ are calculated using the relativistic distorted wave method. A systematical comparison is made with the available experimental and theoretical results. Better agreement is found when the present results are compared with previous calculations and experiments for the integral cross sections. For differential cross sections, our results are in general agreement with the experimental data compared with the previous theoretical values.

PACS: 34.80.Kw, 34.80.Dp, 32.80.Hd
Key words: relativistic distorted-wave method, electron impact excitation, differential cross sections

1 Introduction

Excitation out of the metastable levels of rare gases is an important mechanism in a wide variety of phenomena. Accurate cross sections for electron impact excitation out of the metastable levels of rare gases are important for modelling and understanding processes that occur in gas discharge lasers, industrial plasmas, astrophysical plasmas, and electron-beam pumped lasers. Besides long lifetimes and the metastable states of rare gas atoms are known for having rather large electron impact excitation cross sections compared with the ground states. The behaviour of the cross sections for excitation out of the metastable levels has been found to be quite different from the behaviour of the cross sections for excitation out of the ground levels. For example, it is well known that excitations out of the ground state of helium corresponding to dipole-allowed transitions generally show large cross section values, whereas excitations corresponding to dipole-forbidden transitions have smaller cross sections. Yet some excitations out of the 2^3S metastable level of helium corresponding to dipole-allowed transitions

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have been shown to have smaller cross sections than excitations corresponding to dipole-forbidden transitions [1–3]. In the case of the 2^3S metastable level of helium, much theoretical [4–14] and experimental [1, 2, 15–19] work has been done on calculating and measuring both differential and integral cross sections for electron excitation out of these excited levels.

On the theoretical side, Flannery *et al.* [4] calculated the differential and total cross sections for the excitations of the states $2^{1,3}P$, $3^{1,3}S$, $3^{1,3}P$ and $3^{1,3}D$ from the metastable states $2^{1,3}S$ of helium using a ten-channel eikonal approximation. Khayrallah *et al.* [5] calculated the differential and total cross sections for the excitation of the state 3^3S from the state metastable 2^3S of helium in the Glauber approximations. Gupta *et al.* [6] reported the differential cross sections of helium from the metastable state 2^3S to the state 3^3S in the two-potential modified Born approximation. Berrington *et al.* [7] calculated total cross sections from the ground state 1^1S and the metastable states 2^3S and 2^1S of helium to the higher $n = 2$, 3 states by 11-state R-matrix. Mathur *et al.* [8], Mansky *et al.* [9] and Franca *et al.* [10] calculated the differential and total cross sections for the excitation of helium from the metastable state 2 ^3S to the states 2^3P, 3^3S, 3^3P and 3^3D using a distorted-wave approximation, the semiclassical multichannel eickonal method and the first-order many-body theory, respectively. Bray *et al.* [11] calculated the differential and total cross sections for the excitation of the states 2^3P, 3^3S, 3^3P, 3^3D, 4^3S, 4^3P, 4^3D and 4^3F of helium from the metastable states 2^1S and 2^3S using the convergent close-coupling method. Cartwright *et al.* [12] reported the differential and total cross sections for excitation from the metastable states 2^1S and 2^3S to the states $2^{1,3}P$, $3^{1,3}S$, $3^{1,3}P$ and $3^{1,3}D$ using the first-order many-body theory and the distorted wave approximation. Verma *et al.* [13] calculated the differential and total cross sections of helium from the metastable state 2^3S to the higher states $n^{1,3}S$ and $n^{1,3}P$ ($n = 2$, 3, 4). Bartschat *et al.* [14] studied electron impact excitation of helium from the ground state 1^1S and the metastable state 2 ^3S to the higher $n = 2$, 3 states using the R-matrix with pseudo-state.

On the experimental side, Muller-Fiedler *et al.* [15] performed a crossed-beam experiment to measure the differential cross sections for excitation from the metastable state 2^3S to the states 2^3P, 3^3S, 3^3P and 3^3D. Rall *et al.* [16] measured the excitation cross sections of the states 3^3S, 3^3P, 3^3D, 4^3S, 4^3D, 5^3D and 6^3D from the metastable state 2^3S of helium. Lagus *et al.* [17] measured the excitation cross sections of the states 3^3S, 3^3P, 3^3D, and 4^3D from the metastable state 2^3S of helium using a fast metastable atomic beam target. Piech *et al.* [1] measured the excitation cross sections out of the metastable state 2^3S of helium into the the states 2^3P, 3^3S, 3^3P, 3^3D, 4^3S, 4^3P, 4^3D, 5^3S and 5^3D using a laser-induced fluorescence technique. Piech *et al.* [2] also used the optical method to measure the excitation cross sections of the states 2^3P, 3^3S, 3^3P, 3^3D, 4^3S, 4^3P, 4^3D, 5^3S, 5^3P, 5^3D, 6^3S, 6^3P, 6^3D, 7^3S, 7^3P, 7^3D, 8^3S, 8^3P and 8^3D from the metastable state 2^3S of helium. Boffard *et al.* [18] measured the excitation cross sections of the states 3^3S, 3^3P, 3^3D, and 4^3D from the metastable state 2^3S of helium at high electron energies. Uhlmann *et al.* [19] performed using a magneto-optical trap technique to measure the excitation cross sections of the state 2^3P from the metastable state 2^3S.

For excitation cross sections of measure, there are some discrepancies among different experimental results because of using different experimental methods. But all experimental