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PHYSICS

POSITRON IMPACT EXCITATION CROSS SECTION OF HELIUM

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Abstract

We have computed excitation cross section (ECS) of Helium (2^1S - 2^1P and 2^3S - 2^3P) by positron impact using coupled channel optical (CCO) method. Here we have compared the calculated ECS results for singlet-singlet excitation with other available theoretical data. The results are found in excellent agreement with convergent close coupling (CCC) and distorted wave approximation (DWA) calculations. For triplet-triplet transition, we have compared our results with available experimental results also. However some discrepancies suggested that more theoretical work is required in future.

Introduction

The recent study of atomic collision provides the most energetic means available to the physicists for understanding various branches of science and advanced technology. The positron plays most significant role in compare with electron in atomic collision physics. Helium plays a vital role in various fields. Helium is lighter than air due to this, airships and balloons are inflated with it for lift. It is used as a protective gas in growing silicon and germanium crystals, in titanium and zirconium production, and in gas chromatography, because it is inert. Helium is used to cool the superconducting magnets in modern MRI scanners, laser technology. The use of Helium reduces the distorting effects of temperature variations in the space between lenses in some telescopes. On the account of above use, we can say that Helium is very fruitful for human being. Harris *et al* [1] have discussed the importance of projectile interactions in DCS for simultaneous excitation -ionization of Helium using four body distorted wave model. The theoretical calculations have been performed by a number of different methods, the distorted wave approximation (DWA) of Cartwright and Csanak [2], the R matrix Pseudo states with the calculations (RMPS) of Bartschat [3] and convergent close coupling (CCC) method of Ralchenko *et al* [4]. In contrast to the corresponding ground state, there are significant discrepancies for metastable Helium between recent experiments and calculations. It is very interesting to note that a long standing discrepancy between the theoretical predictions and experiments exist for the ionization of metastable Helium. It reflects the difficulty of giving an accurate theoretical description for the dynamic of positron scattering by excited targets. The measurement for positron Helium scattering has provided an interesting challenge to test the present CCO calculations with best available results. We have already reported the results of Hydrogen using CCO calculations [5] at DAE-BRNS symposium held at IUAC New Delhi in 2009.

Theory

The CCO method involves the solution of the set of coupled integral equations

$$\langle k_i i|T|jk_j\rangle = \langle k_i i|V+V^Q|jk_j\rangle + \sum_{l_\epsilon P}\int d^3k\langle k_i i|V+V^Q|lk\rangle$$

$$X\left[E^+ - \epsilon_l - \frac{1}{2}k^2\right]^{-1}\langle k_l|T|jk_j\rangle \qquad \ldots\ldots(1)$$

where

$$\langle k_i i|T|jk_j\rangle = \langle k_i i|V|\phi_j^{(+)}(k_i)\rangle$$

is the T matrix element.

The differential cross section for scattering from channel j to i at an angle 'θ' is given by

$$\frac{d\sigma_{ij}}{d\Omega} = (2\pi)^4\frac{k_i S^2}{k_j f^2}\sum_{m,m'}|\langle k_i; n'l'm'|T|nlm; k_j\rangle|^2 \qquad \ldots\ldots(2)$$

The excitation cross section (ECS) can be calculated by integrating the above DCS over all scattering angles. Using the notation of

Carthy *et al* [6], the polarization potential V^Q for continuum excitation of helium reads

$$\langle k_i i|V^Q|jk_j\rangle$$

$$= \int d^3k'\int d^3k\ (a_s + b_s P_r)\langle k_i i|V|\phi^{(-)}(k<)k>\rangle$$

$$X\left[E^{(+)} - \frac{1}{2}(k^2 + k^{1^2})\right]\langle k_>\phi^{(-)}(k<)|V|jk_j>\rangle \qquad \ldots\ldots(3)$$

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Where $\phi^{(-)}$ (k<) is Coulomb wave, orthogonalized to the bound state in the same amplitude factor, which represents the slower electron. The spin coefficients a_s and b_s are given by McCarthy and Stelbovics [7]. The half on shell polarization potential is given by the appropriate angular momentum projection of V^Q,

$$V_{l''l'l}(K) = \sum_{m''m'} C^{l''l'l}_{m''m'm} \int d\hat{K} \langle k_i l | V^Q | j k_j \rangle i^{-l''} . Y_{l''m''}(\hat{K})$$

……… (4)

Where $K = k_i - k_j$, the orbital angular momentum quantum numbers l', m' and l, m belong to the target states i and j, respectively, and $C^{l''l'l}_{m''m'm}$ denotes the Clebsch – Gordan coefficients. For the optical potential the target states are represented by the appropriate Hartree-Fock configuration. $V_{l''l'l}(K)$ is calculated with on shell values of k_j.

Results and Discussion

In this figure [1], we have shown the present results of CCO calculation with the DWA results [2] and CCC results [4] for the excitation of Helium metastable 2^1S state to 2^1P state. The results are found merged with other results below 30eV showing a very little difference among all. In the intermediate energy range the discrepancy appears between our results and DWA results, since the discrepancies of continuum of the methods are different from each other. However our results are in good agreement with CCC results throughout the whole energy range. Unfortunately, there is no available experimental measurement for comparison purpose.

Fig. 1: Excitation cross section for helium in singlet-singlet state

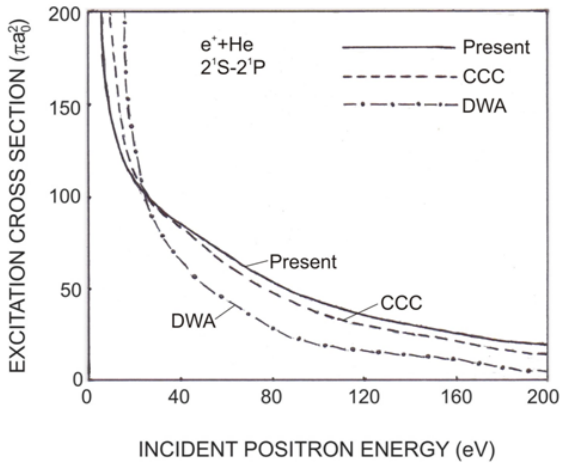
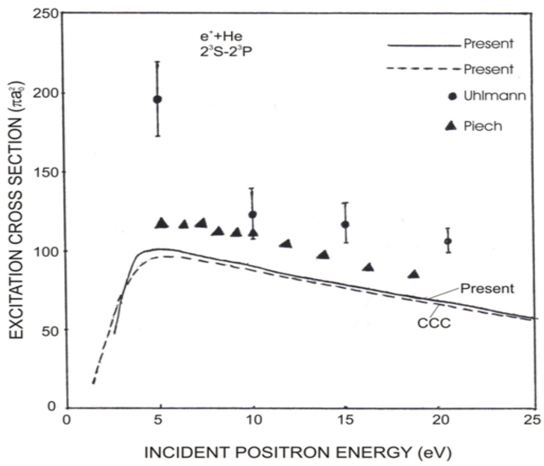


Fig. 2: Excitation cross section for helium in triplet-triplet state



The comparision of our CCO 2^3S – 2^3P excitation cross sections with the latest experimental measurements from Uhlmann *et al* [8] and Piech *et al* [9,10] as well as theoretical calculations of the CCC results from Ralchenko *et al* [4] are shown in figure [2]. It is important to note that these theoretical results are essentially identical to each other. However, there are remarkable quantitative discrepancies between the experimental measurements and the theoretical calculatins.

Conclusion

We have observed that polarization interaction plays a very important role for scattering cross section.

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