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Fully differential cross section for four body charge transfer process

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Synopsis: Recently experimental fully differential cross sections (FDCS) have been reported for double capture in proton helium collisions which disagree with existing theoretical calculations by two orders of magnitude. We introduce here a theoretical model for charge transfer processes which is fully quantum mechanical and takes all post collision interactions (PCI) between the particles into account exactly. The results of this model are in much better agreement with experimental data.

Atomic processes in which two electrons change state are much more difficult to treat theoretically than single electron transitions. In this work we will examine both double capture and single capture for proton-helium collisions. In case of double capture, [1] the proton captures both of the electrons from helium and leaves the collision as a H^- ion. For single capture, the proton captures one electron from helium and leaves the other electron in the ground state. Recently Schulz *et al.* [2] performed experiments for double and single capture for proton energies of 25keV, 50keV and 75keV. Here we will introduce the 4BT-PCI (4-body transfer-post collision interaction) model which treats all the post collision interactions in the final state exactly. The initial state interactions are taken into account by using the Eikonal initial state wave function [3].The exact T-matrix [4] is given by

$$T_{fi} = \langle \chi_f^- | V_i | \beta_i \rangle + \langle \chi_f^- | W_f^\dagger | (\psi_i^+ - \beta_i) \rangle, \qquad [1]$$

where β_i is the asymptotic initial state wave function, χ_f^- is an approximate final state wave function, W_f is the final state perturbation which is determined by the choice for χ_f^-, V_i is the initial state interaction potential between the proton and helium atom, and ψ_i^+ is the exact initial state wave function. The approximation we propose for the final state wavefunction for double capture is given by

$$\chi_f = CW_P \; \phi_{H^-} \; C_{t-e_1} \; C_{t-e_2} \,. \qquad [2]$$

Here CW_P is a coulomb wave for the scattered projectile in the field of the He ion, ϕ_{H^-} is a variational wavefunction for a hydrogen ion, and C_{t-e} is the coulomb distortion factor [4] between the residual target nucleus and a capture electron .

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The asymptotic initial state is given as

$$\beta_i = PW_p \; \xi_{\text{He}} \qquad [4]$$

Where ξ_{He} is the ground state wave function for the helium atom (20 parameter hylleraas wave function) [1] and PW_p is a plane wave for the incident projectile.

Similarly for single capture the final state wave function is given by

$$\chi_f = CW_P \; \phi_H \; \psi_{He^+} \; C_{e_1-e_2} \; C_{p-e_1} \; C_{t-e_2} \qquad [5]$$

where $C_{e_1-e_2}$ represents the interaction between the captured electron and the bound electron, C_{p-e_1} represents the interaction between the projectile and the bound electron, and C_{t-e_2} represents the interaction between the target nucleus and the captured electron. The final state wave function for the hydrogen atom ϕ_H and the helium ion ψ_{He^+} are hydrogenic and know exactly. Here nine dimensional integration is performed which is computationally very expensive.

Theoretical results will be compared with absolute experimental measurements.

References

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