Single Ionization of Helium toms in the collision of fast protons

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Synopsis The ionization of helium atoms by fast protons has been studied by using Faddeev-Watson formalism. The non-relativistic triple-differential cross sections (TDCSs) and the double differential cross sections (DDCS) are calculated for 1.5 MeV protons.

The investigation of the single ionization of helium atom by a charged particles is a powerful tool to study three interacting body interaction. Ion impact ionization of helium atoms has been studied both experimentally and theoretically [1, 2]. Multiple ionization arising in ion-atom/ion collisions are one of the most fundamental processes in atomic and molecular physics and finds important applications in plasma kinematics problems, planetary upper atmosphere, mass spectrometry and etc.

The ionization process in proton-helium collision is one of the simplest case to investigate such interactions of the many-electron atomic systems. Roberts [3] have been investigated the application of the Faddeev-Watson multiple-scattering series to the ionization of helium atoms by proton impact. In the present work, the triple and double differential cross sections are calculated for the interaction of protons with atomic helium by considering all terms of Faddeev-Watson multiple-scattering series.

The single ionization of helium atom has been considered from its ground state by impact of incident charged particles with initial momentum K_i relative to the atomic center of mass, leaving a passive electron, which remains bound in the ground state of the target's core. To treat this process theoretically using a three-body model, in ionization channel as:

$$P+(T+2\mathrm{e}^-)\rightarrow P+(T+e^-)+e^- .$$

Involving a projectile P of charge Z_P and mass M_P incident on a target consisting of an electron e of charge Z_e and mass M_e bound to a residual ion T with charge Z_T and mass M_T, where one of the electrons is ionized and the other one remained to the target nucleus. The non-relativistic triple-differential cross sections (TDCSs), is simply given by:

$$\frac{d^3\sigma}{dEd\Omega_e d\Omega_f}=n_e 16\pi^4 \mu_{Te}\mu_P^2 \frac{k_e K_f}{K_i}|<f\ |\Im_I\ |i>|^2$$

where n_e, μ_{Te}, μ_P and k_e are, respectively, the number of equivalent electrons in the target, the reduced mass of the ionized electron, the is the reduced of mass of the system in the initial channel and the absolute momentum vector of the ejected electron with respect to the target nucleus. In addition, K_f, K_i are the absolute final and initial wave vector for the relative motion of Z_P with respect to Z_T in the center of mass frame, respectively. Also, $<f|\Im_I|i>$ is the transition matrix between the initial and final states. The double differential cross sections (DDCS) at an ejected electron velocity is given by:

$$\frac{d^2\sigma}{dEd\Omega_e}=\int\frac{d^3\sigma}{dEd\Omega_e d\Omega_f}d\Omega_f .$$

The TDCS is shown in Fig. 1 for 1.5 MeV protons incident on Helium atoms, with $\theta_e=0^o$ for the various scattering angles and 800eV as the ejected electron energy.

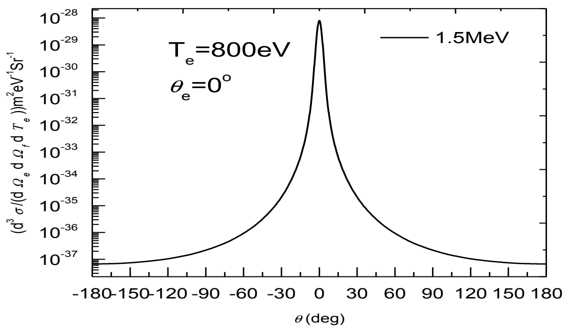

Fig. 1: TDCS for 1.5 MeV Protons incident on Helium, at $\theta_e=0^o$.

The DDCS are shown in Fig. 2 for 1.5 MeV Protons incident on Helium, at $\theta_e=0^o$, that we compare with the theoretical and the experimental DDCS for various ejected electron energies. We observe that the agreement between the data Faddeev-Watson formalism, by the DWBA, IA [3] and experimental data [4].

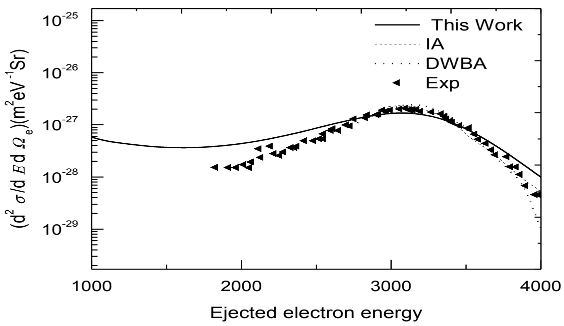

Fig. 2: DDCS for 1.5 MeV Protons incident on Helium, at $\theta_e=0^o$.

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