DIFFERENTIAL CROSS SECTIONS FOR FRAGMENTATION OF POSITRONIUM

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In a recent experiment [1] the longitudinal energy distribution of the ejected positron from positronium (Ps) ionization in Ps(1s)+He(1^1S) collisions has been measured. The measurements have been made at energies of ≤33eV where excitation of the He(1^1S) is either impossible or very unlikely. Consequently, we need only concentrate upon collisions in which the atom remains unexcited. Here, we report impulse approximation (IA) calculations for the process.

If the ejected positron has a velocity $\mathbf{v_p}$ making an angle θ_p with respect to the incident direction, then its longitudinal energy is $E_{pl} = E_p \cos^2\theta_p$ where $E_p = \frac{1}{2}v_p^2$ is the total energy of the positron. The measured cross section is then

$$\frac{d\sigma}{dE_{pl}} = \frac{d\sigma^+}{dE_{pl}} + \frac{d\sigma^-}{dE_{pl}} \tag{1}$$

where $d\sigma^\pm/dE_{pl}$ is given by

$$\frac{\pi}{\sqrt{E_{pl}}}\int_{E_{pl}}^{E_m} \frac{d^2\sigma}{dEd\Omega_p}\left(E_p, \cos\theta_p = \pm\sqrt{\frac{E_{pl}}{E_p}}\right)\frac{dE_p}{\sqrt{E_p}} \tag{2}$$

The experiment collects positrons ejected into both the forward (+) and backward (-) scattering cones. In (2) $d^2\sigma/dEd\Omega_p(E_p, \cos\theta_p)$ is the double differential cross section (DDCS) with respect to the positron energy and ejection angle, and E_m is the maximum energy available to the emitted positron. The DDCS is obtained by integration of the triple differential cross section $d^3\sigma/dEd\Omega_e d\Omega_p$ over the angles of the ejected electron.

In our IA, and in atomic units,

$$\frac{d^3\sigma}{dEd\Omega_e d\Omega_p} = \frac{v_p v_e}{4v_0}\left|f^{IA}\right|^2 \tag{3}$$

where

$$\begin{aligned} f^{IA} &= 2\langle\phi_{\boldsymbol{\kappa}}^-(\mathbf{t}) \mid e^{-i\mathbf{q}\cdot\mathbf{t}/2} \mid \phi_a(\mathbf{t})\rangle f_{el}^+(\bar{v}^+, q) \\ &\quad + 2\langle\phi_{\boldsymbol{\kappa}}^-(\mathbf{t}) \mid e^{i\mathbf{q}\cdot\mathbf{t}/2} \mid \phi_a(\mathbf{t})\rangle f_{el}^-(\bar{v}^-, q) \\ \boldsymbol{\kappa} &= \frac{1}{2}(\mathbf{v_p} - \mathbf{v_e}) \\ \mathbf{q} &= 2\mathbf{v_0} - \mathbf{v_p} - \mathbf{v_e} \\ \bar{v}^+ &= \mathrm{Max}\left(\mid 2\mathbf{v_0} - \mathbf{v_e} \mid, v_p\right) \\ \bar{v}^- &= \mathrm{Max}\left(\mid 2\mathbf{v_0} - \mathbf{v_p} \mid, v_e\right) \end{aligned} \tag{4}$$

In (3) and (4) $\mathbf{v_0}$ is the velocity of the incident Ps(1s) and $\mathbf{v_p}(\mathbf{v_e})$ is the velocity of the ejected positron (electron). In (4) $f_{el}^\pm(\bar{v}, q)$ is the amplitude for elastic scattering of a free positron (+)/ electron (-) by the atom, where the positron/electron is incident with speed $\bar{v}$ and scattered with momentum transfer of magnitude q. The amplitude $f_{el}^+(f_{el}^-)$ has been calculated in the static (static-exchange) approximation. The wave functions $\phi_{1s}(\phi_{\boldsymbol{\kappa}}^-)$ represent the initial 1s state (final ionized state) of the Ps.

We shall report results calculated using (4) at the conference.

References

[1] S. Armitage *et al*, Phys. Rev. Lett. **89** 173402 (2002); G. Laricchia *et al*, Nucl. Instr. Meth. B **221** 60 (2004)