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POSITRONIUM FORMATION BY SCATTERING OF INTERMEDIATE ENERGY POSITRONS FROM ALKALI ATOMS

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ABSTRACT

The differential and total cross sections for the formation of ground state positronium by scattering of intermediate energy positrons from lithium and sodium are calculated using both the first Born and the distorted wave Born approximation. The first Born approximation cross sections show very little post-prior discrepancy. Because of computational economy, the "post-form" of the distortion is used.

1. INTRODUCTION AND THEORY

Because of a single valence electron in their outermost shells, the alkali atoms can be treated as almost hydrogenlike systems for electron capture processes. The core potential of the target can be replaced by a suitable pseudopotential. In these calculations, the ion core potentials are represented by Hellmann type potentials.[1] The corresponding bound state wave functions of the active electrons are obtained using the variational method. Six term trial wave functions are used for both Li and Na. The valence electron energy is -0.1959 a.u. for Li and -0.1826 a.u. for Na. The initial state i and the final state f are represented by ψ_i and ψ_f, respectively, in the First Born Approximation (FBA) and by χ_i^+ and χ_f^-, respectively, in the Distorted Wave Born Approximation (DWBA). The T-matrix elements representing the scattering amplitudes are:

$$T = \langle \psi_f \, | V_i | \, \psi_i \rangle \qquad \text{(FBA prior)},$$

$$T = \langle \psi_f \, | V_f | \, \psi_i \rangle \qquad \text{(FBA post)},$$

$$T = \langle \psi_f \, | V_i - U_i | \, \chi_i^+ \rangle \qquad \text{(DWBA prior)},$$

$$T = \langle \psi_f \, | V_f - U_f | \, \chi_i^+ \rangle \qquad \text{(DWBA post)}.$$

The differential cross section (in a.u.) in all cases is given by

$$\frac{d\sigma}{d\Omega} = \frac{\nu_i \nu_f}{(2\pi)^2} \frac{k_f}{k_i} |T|^2$$

where ν_i and ν_f are the initial and the final reduced masses of the system, $\hbar\vec{k}_i$ is the initial momentum of the projectile and $\hbar\vec{k}_f$ is the final relative momentum of the positronium. V_i and V_f are the interactions in the initial and the final channel, respectively, and U_i and U_f are the corresponding distortion potentials. As in previous application[2] of DWBA, terms up to third order in potential are kept in $|T|^2$ here. Details of the calculations will be published elsewhere.

2. RESULTS

Integrals are simplified by the fact that the projectile is much

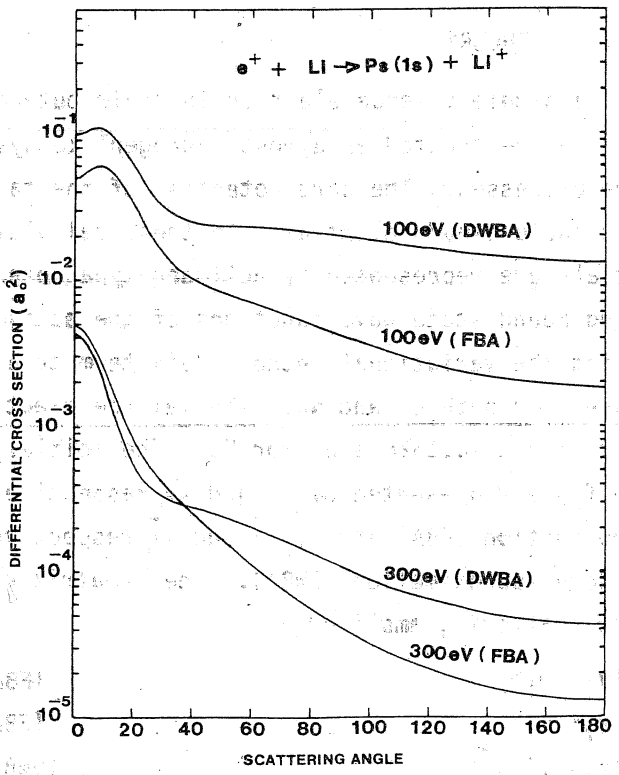

Figure 1. FBA and DWBA differential cross sections for the process $e^+ + Li \rightarrow Ps(1s) + Li^+$ at positron impact energies of 100 eV and 300 eV.

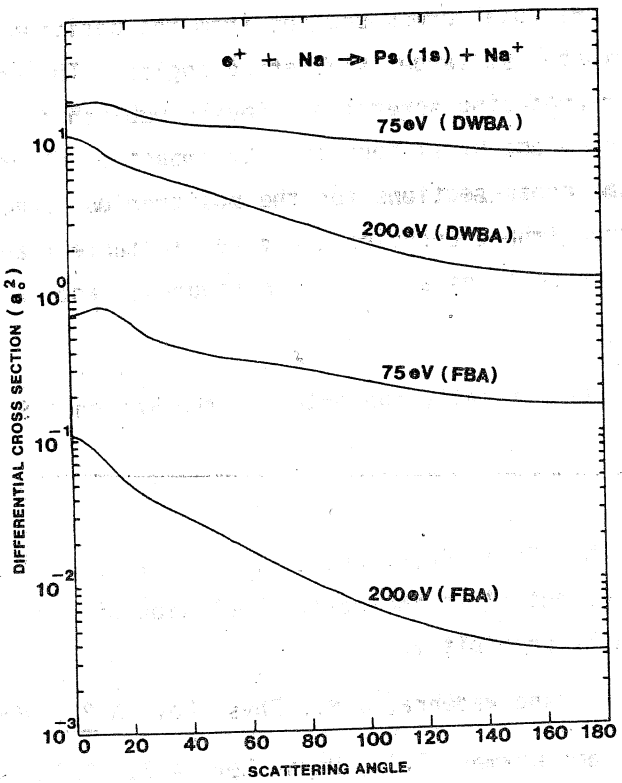

Figure 2. FBA and DWBA differential cross sections for the process $e^+ + Na \rightarrow Ps(1s) + Na^+$ at positron impact energies of 75 eV and 200 eV.

less massive than the target. Feynman identity is used to reduce all the integrals in the transition amplitudes to one or two dimensional analytical forms which are evaluated numerically. The present results show that the distortion part provides a large contribution to the total Ps formation cross section. It is also noticed that the

TABLE I. Total cross sections for positronium formation.

Target atom	Positron energy (eV)	σ_{FBA} (prior) (a.u.)	σ_{FBA} (post) (a.u.)	σ_{DWBA} (post) (a.u.)
Li	100	8.432(-2)	8.430(-2)	2.810(-1)
	300	1.832(-3)	1.833(-3)	2.255(-3)
Na	75	3.569	3.568	1.388(2)
	200	1.726(-1)	1.727(-1)	3.738

The notation a(b) means a x 10^b

contribution to the total cross section from the positron-ion core interaction dominates at larger scattering angles. The computer code was checked by reproducing several previously published[2],[3] FBA and DWBA results for Ps and H(1s) formation by impact of e^+ or p^+ on H(1s). The total cross sections for the positronium formation at different positron impact energies are given in table I and the differential cross sections are shown in figures 1 and 2.

3. ACKNOWLEDGMENT

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4. REFERENCES

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