POSITRONIUM FORMATION IN POSITRON - NOBLE GAS COLLISIONS

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Recent advances in the experimental study of positron (e⁺) scattering by the noble gases have prompted us to re-investigate the problem from a theoretical viewpoint. Over a decade ago, M.T. McAlinden and H.R.J. Walters [1] calculated ground state Positronium (Ps) formation cross sections for e⁺-Noble gas collisions using the truncated coupled-static approximation. These calculations assumed electron capture from the outer shell, with the exception of argon, where inner shell electron capture was also considered. More recently, e⁺–helium collisions were investigated within the coupled-pseudostate framework by C.P. Campbell *et al* [2]. In this work, Ps formation in the 1s, 2s and 2p states was examined and an estimate of the contribution from higher excited states was made. There is substantial experimental data on e⁺–noble gas collisions, the most recent being that of Laricchia *et al* [3] from University College London. For e⁺ impact on argon, they obtained a double peak structure in the Ps formation cross section while for krypton and xenon the second peak was replaced by a shoulder structure. The double peak and shoulder structures were considered to be due to excited state Ps formation and it was felt that a theory should be developed which took this into account.

Our approach is to expand the collisional wave function Ψ in terms of atom states, ψ_a, Ps states, ϕ_b, and ion states, ψ_d^+, as

$$\Psi = \sum_a F_a(\mathbf{r}_p)\psi_a(\mathbf{x}_1,\ldots,\mathbf{x}_N) + A\sum_{b,d} G_{bd}(\mathbf{R}_1)\phi_b(\mathbf{t}_1)\psi_d^+(s_1;\mathbf{x}_2,\ldots,\mathbf{x}_N)$$

where $\mathbf{R}_i \equiv (\mathbf{r}_p + \mathbf{r}_i)/2$, $\mathbf{t}_i \equiv \mathbf{r}_p - \mathbf{r}_i$, $\mathbf{r}_p$ ($\mathbf{r}_i$) is the position of the positron (ith electron), $\mathbf{x}_i \equiv (\mathbf{r}_i, s_i)$, s_i is the spin coordinate of the ith electron, and A is the electron antisymmetrization operator. Both the total electronic spin and the positron spin will be separately conserved in the collision and therefore the positron spin need not be explicitly specified.

Due to the complexity of the resulting equations, we make a number of simplifications, which result in a set of coupled equations corresponding to the Distorted-Wave Born Approximation.

To simplify the calculations, we retain only the ground state of the target atom, however, we consider Ps formation in the 1s, 2s, 2p, 3s, 3p, and 3d states and use a $1/n^3$ scaling rule to estimate Ps formation in higher states. We allow for electron capture from both the outermost atomic shell and the first inner shell.

We shall report results obtained for total Ps formation from positron collisions with helium, neon, argon, krypton and xenon. These will be compared with the experimental data obtained by Laricchia *et al* [3].

References

[1] M.T. McAlinden and H.R.J. Walters, Hyperfine Interact. **73**, 65 (1992).

[2] C.P. Campbell, M.T. McAlinden, A.A. Kernoghan and H.R.J. Walters, Nucl. Instrum. Methods **143**, 41 (1998).

[3] G. Laricchia, P. Van Reeth, M. Szłuińska and J. Moxom, J. Phys. B **35**, 2525 (2002).