Low-energy scattering properties of ground-state and excited-state positronium collisions

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Synopsis
Low-energy elastic and inelastic scattering in the Ps(1s)-Ps(2s) channel is treated in a four-body hyperspherical coordinate calculation. Adiabatic potentials are calculated for triplet-triplet, singlet-singlet, and singlet-triplet spin symmetries of coupled electrons and coupled positrons, with total angular momentum \( L = 0 \) and positive parity. Preliminary estimates of the \( s \)-wave scattering length in the elastic Ps(1s)-Ps(2s) channel were obtained. Spin recoupling is implemented to obtain calculations of experimentally relevant scattering properties for different Ps spin states.

Ground-state Ps collisions have been extensively studied due to growing interests in the creation of a spin-polarized Ps Bose-Einstein condensate (BEC) [1, 2] and references therein. Experimental efforts have been made to probe BEC densities of atomic hydrogen by measuring the cold-collision frequency shift in the spectrum for ground-state and excited-state atomic collisions [3, 4]. For experimentalists to probe Ps BEC densities using the same techniques, knowledge of \( s \)-wave scattering lengths for ground-state excited-state atomic collisions should be well characterized. This recognition forms the motivation for this study.

The four-body Hamiltonian is investigated to study the interaction of two electrons and two positrons. The interactions considered in this study include only two-body Coulombic interactions; spin-spin, spin-orbit and relativistic interactions are neglected. This problem is solved using hyperspherical coordinates, which treats fragmentation pathways on an equal footing. The Hamiltonian is solved in a coupled electron and coupled positron spin basis in order to simplify the anti-symmetrization requirements of the total wavefunction. States with total orbital angular momentum \( L = 0 \) and positive parity are considered in this work in representing \( s \)-wave collisions.

From the adiabatic/diabatic potential curves, \( s \)-wave scattering properties were investigated in the Ps(1s)-Ps(2s) elastic and inelastic channels. Spin recoupling was implemented to represent experimentally relevant spin states of each Ps atom in a two-body collision, both in spin states coupled to total spin \( S_{\text{tot}} \) and uncoupled spin states specifying spin and spin projection quantum numbers for both Ps atoms. Scattering cross-sections are provided for the spin-flip conversion from the triplet to singlet spin states to give preliminary estimates of the spin-conversion rate.

\[ n(s) \]

\[ \sqrt{k/\hbar} \]

Figure 1. Adiabatic and diabatic potential curves for the singlet-triplet spin configuration shown on an effective principle quantum number scale for the first 6 channels.

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References
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