Positronium Scattering from Hydrogen and Helium Atoms at Low Energies

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Synopsis The low-energy elastic scattering of Ps(1s)-H(1s) and Ps(1s)-He(1s) is studied using the confined variational method (CVM) and explicitly correlated Gaussians (ECGs) as basis functions. As an extension of the previous work (EPL, **99** 43001 (2012)), we calculate the phase shifts for the elastic Ps(1s)-H(1s) scattering for partial waves $1 \leq \ell \leq 4$ below the excitation threshold of Ps(n = 2). For the Ps(1s)-He(1s) scattering, phase shifts and pick-off annihilation rates for partial waves $\ell \leq 3$, and also momentum-transfer cross sections are evaluated for incident energies up to the excitation threshold of Ps(n = 2).

Ps scattering from atoms and molecules is fundamentally important for understanding the mechanism of interaction between Ps and ordinary matter. With the development of energy-tunable ortho-Ps beams, the Ps scattering has been paid more and more attention. However, the Ps-atom scattering problem is one of the most challenging problems in atomic collision theory due to the composite structure of both projectile and target. The main question is how to accurately handle the electron-positron and electron-electron correlations and the electron exchange between Ps and target. The Ps-He scattering has been investigated both theoretically [1, 2] and experimentally [3, 4]. However, serious conflicts exist between different experiments and also between different theoretical approaches at low energies. Although there is no experimental study of the Ps-H scattering, it has been extensively investigated by numerous theoretical groups since the 1970s [5] (and the reference therein). Being the simplest among the Ps-atom scattering systems, it is promising to obtain accurate results and to compare among various methods.

The main purpose of this work is to study the low-energy elastic scattering of Ps(1s)-He(1s) below the Ps(n = 2) excitation threshold using CVM and ECGs [6]. As an extension of previous work [7] on the *S*-wave Ps(1s)-H(1s) elastic scattering at low energies, we calculate the phase shifts for the Ps(1s)-H(1s) scattering for partial waves $1 \leq \ell \leq 4$. The motivation of the Ps(1s)-H(1s) calculation is to evaluate the contribution of the mixed symmetry terms to phase shifts for the partial waves $\ell > 2$ and to resolve the convergence problems that exist in the calculation of Woods *et al.* for $^{1,3}D$ in the S-matrix complex Kohn variational method (SMCKVM). Additionally by comparising with SMCKVM, the CVM reliability and accuracy for different partial waves are verified in the 0-5 eV energy range. For the Ps(1s)-He(1s) scattering, we compute phase shifts and pick-off annihilation rates for partial waves $\ell \leq 3$, and momentum-transfer cross sections for incident energies up to the excitation threshold of Ps(n = 2) in order to resolve existing discrepancies between theory and experiment at very low energies.

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