A coupled rearrangemnet channel analysis of positronium antihydride $Ps\overline{H}$

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Synopsis Ground and resonance states of $Ps\overline{H}$ are calculated with a coupled rearrangement-channel, four-body calculation. The structures of these states are examined with help of correlation functions and probabilities of finding two-body states in the total wavefunction. Asymptotic configurations of the ground and resonance states are determined from the tail behaviour of the correlation functions.

We report a theoretical investigation of positronium antihydride $Ps\overline{H}$ which consists of an antiproton ($\bar{p}$), an electron (e^-) and two positrons (e^+). The $Ps\overline{H}$ is a charge-conjugated system of the positronium hydride PsH. The $Ps\overline{H}$ has only one truly bound state below $\overline{H}$ (1s) + Ps (1s) threshold.

Resonance states of $Ps\overline{H}$ are of interest for the ongoing experiments of GBAR project [1] as intermediate states for rearrangement collisions, $Ps + \overline{H} \rightarrow e^- + \overline{H}^+$. Since below the dissociation threshold of $e^- + \overline{H}^+$ there exist several other dissociation thresholds, all possible channels for the rearrangement dissociation should be accounted for the branching ratio for the decay of the resonance state to various states.

To obtain a four-body wavefunction of $Ps\overline{H}$ including all coupled rearrangement channels, a Gaussian expansion method [2] is adapted. The role of the various rearrangement channels in our total wavefunctions provides an insight to the structure of the ground and resonance states.

The structure of $Ps\overline{H}$ is analyzed with help of a correlation function between two particles ('i' and 'j') defined as $C(r'_{ij}) = \langle \Psi \mid \delta(\mathbf{r}_{ij} - \mathbf{r}'_{ij}) \mid \Psi \rangle$ [3]. As shown in Fig. 1 (a),the correlation functions $C(r_{\bar{p}e^+})$ has the same slope as isolated $\overline{H}$ (1s) around the origin, while the middle-long range tail of $C(r_{\bar{p}e^+})$ shows a large deviation from the $\overline{H}$ (1s). Since the bound state lies only 1 eV below the $\overline{H}$ + Ps threshold, the expected configuration of the ground state may be a molecule-like structure. The asymptotic form of the correlation function between $\overline{H}$ and Ps should be proportional to $\exp(-\kappa r)$ where $\kappa = \sqrt{2\mu\varepsilon}$ (μ is a reduced mass and ε is binding energy). This asymptotic slope, however, appears over 20 bohrs and its amplitude is $\sim 10^{-11}$ which indicates that in the ground state coexistence of atomic/molecular structure is remarkable. The Ps formation is manifested by $C(r_{e^+e^-})$ and $C(r_{e^+e^+})$ in which the $C(r_{e^+e^-})$ has the same slope as isolated Ps (1s) and the $C(r_{e^+e^+})$ almost overlaps with $C(r_{e^+e^-})$, as shown in Fig. 1 (b).

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The coexistence of molecular and atomic structures in $Ps\overline{H}$ is an intriguing feature of a quantum few-body system. The analysis of the four-body resonances in terms of the three-body resonant subsystem ($\overline{H}^+$, $e^-\overline{H}$) will also be presented. Since in the energy region of resonances the dissociation thresholds associated with various configurations exist, a hybridization of different configurations and a small asymptotic amplitude of wavefunction can seriously affect the interpretation of the decay.

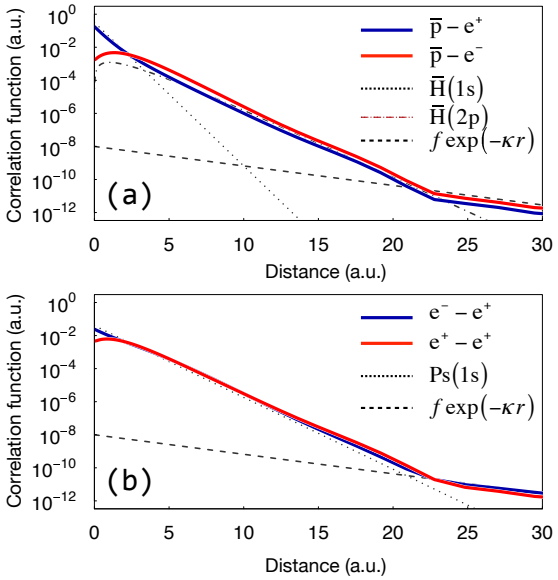

Figure 1. The correlation functions $C(r_{\bar{p}e^+/-})$ and $C(r_{e^+e^+/-})$ defined in text is shown together with that of isolated $\overline{H}$ (1s), $\overline{H}$ (2p), Ps (1s) and an asymptotic behavior ($f = 10^{-8}$ is a scaling constant).

References

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