Differential cross sections for positronium formation in positron–hydrogen scattering

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Abstract

Positron scattering by hydrogen atom is an interesting system to test theoretical methods due to its simplicity. Recently, theoretical calculations have reported differential cross sections (DCS) for positronium (Ps) formation for this system. The present work utilizes the coupled-channel optical method (CCOM) that allows simultaneous treatment of the target channels and the Ps channels in the close-coupling method and the incorporation of the continuum effects via an optical potential to provide a comparative view of the DCS for Ps(1s) formation and Ps(2s) formation at energies ranging from 20 to 100 eV. A large 12-states and 15-states CCOM calculations have been undertaken and the results compared with other available data.

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1. Introduction

With the advent of major experimental breakthroughs in the last two decades [1,2], there has been growing theoretical and experimental interest in the positron scattering by atomic hydrogen [3–5]. In tandem, there has been a lot of progress in the theoretical studies of positron–hydrogen atomic system. One of the main reasons is the development of efficient computational techniques that has made it practical to do theoretical investigations with much ease [3,4,6].

Even though it is the simplest three-body Coulomb system, the difficulties inherent in studying scattering of positrons with hydrogen atoms are quite well known. The interactions governing the positron and electron scattering processes lead to different dynamic mechanisms: such as the Ps formation that characterizes the uniqueness of the positron-scattering problem.

With the judicious use of suitable array of pseudostates [3,4], various calculations have been performed to accurately profile quantitatively and qualitatively the observables for the $e^+\cdot\cdot\cdot H$ scattering system. These calculations of Mitroy (CC(28,3)) [3] and Kernoghan et al. (CC(30,3)) [4] are considered as the benchmark calculations for $e^+\cdot\cdot\cdot H$ with high quality data for the elastic, inelastic and Ps formation processes.

Since the late 1990s, there have been attempts to use the optical potential method to study this system. Among them is the CCOM used by Ratnavelu et al. [7–9] within the close-coupling (CC) formalism [10] to study the $e^+\cdot\cdot\cdot H$ scattering. The CCOM provides a novel approach [11] to include the neglect of higher discrete and continuum channels in the CC calculation. There have been other theoretical methods such as the distorted wave methods of Mandal et al. [12–14] which have investigated the Ps formation (Ps(1s), Ps(2s), Ps(2p)) DCS in the $e^+\cdot\cdot\cdot H$ case. As a perturbative method, the distorted wave method has the capability in predicting reliable results at intermediate and higher energies. In view of the recent calculations...