Variational-Iteration Calculations of the Ionization Processes in the Simple Quantum Mechanics Systems

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In recent years, progress in experimental techniques, particularly the development of cold-target recoil-ion momentum spectroscopy (COLTRIMS), has made it possible to perform precise, kinematically complete studies of complex atomic collisions. The double processes of He in electron-impact ionization, single ionization with simultaneous excitation and double ionization, have been studied at large momentum transfer using an energy- and momentum-dispersive binary $(e, 2e)$ spectrometer. The experiment has been performed at an impact energy of 2080 eV in the symmetric noncoplanar geometry. In this way we have achieved a large momentum transfer of 9 a.u., a value that has never been realized so far for the study on double ionization. The measured $(e, 2e)$ and $(e, 3\text{–}1e)$ cross sections for transitions to the $n = 2$ excited state of He^+ and to doubly ionized He^{2+} are presented as normalized intensities relative to that to the $n = 1$ ground state of He^+. The results are compared with first-order plane-wave impulse approximation PWIA calculations using various He ground-state wave functions. It is shown that shapes of the momentum-dependent $(e, 2e)$ and $(e,\ 3\text{–}1e)$ cross sections are well reproduced by the PWIA calculations only when highly correlated wave functions are employed. However, noticeable discrepancies between experiment and theory remain in magnitude for both the double processes, suggesting the importance of higher-order effects under the experimental conditions examined as well as of acquiring more complete knowledge of electron correlation in the target [1, 2, 3].

Three-particle models with zero-range potentials have found wide applications in atomic physics. In particular, this model was used to describe weakly bound states and elastic scattering in the system of three helium atoms considered as point particles. In this context it is of great importance to develop approximate methods providing given accuracy, like the conventional variational iteration approaches, as well as to test them using appropriate exactly solvable models. In the papers [4, 5, 6] we consider new stable variational-iteration schemes and apply them to the simplified model of three identical particles with the attractive pair delta-function interactions on a straight line. For this model exact solutions to the three-body S-matrix and bound state energy are well known. We demonstrate explicitly that this low-dimensional model preserves the most important characteristic features of the three-body problem to be an interesting benchmark for approximate calculations in the framework of multichannel methods.

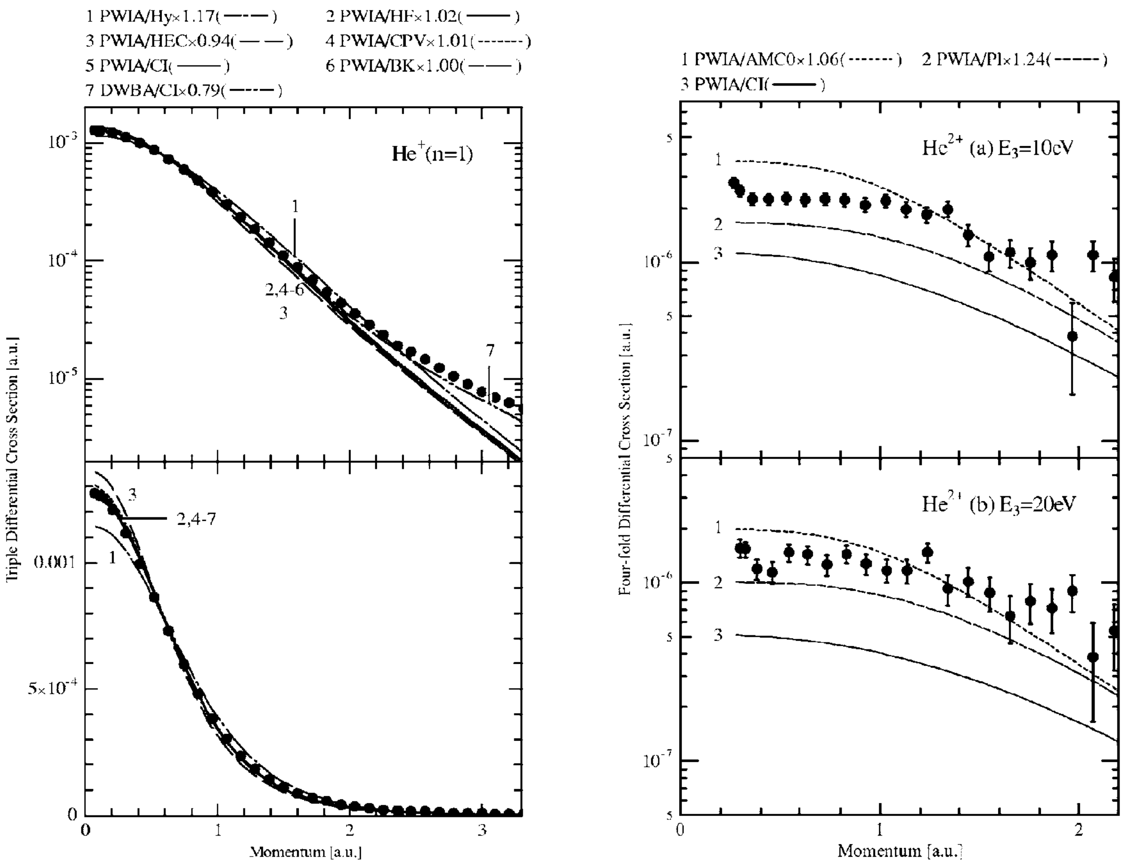

Fig. 1: **l.h.s.** Comparison of experimental $(e, 2e)$ momentum profile of He for the transition to the $n = 1$ ground ion state with associated theoretical calculations using various variational wave functions. **r.h.s.** Comparison of experimental (e, 3–1e) momentum profiles of He for the doubly ionized He^{2+} with E_3 = (a) 10 and (b) 20 eV with associated PWIA calculations using the AMC0, Pluvinage, and BK wave functions. The theoretical momentum profiles are folded with the experimental momentum resolution. All the experimental and theoretical momentum profiles are shown as normalized intensities relative to the PWIA/CI cross section for the $n = 1$ ground state of He^+

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