Comment on "Role of the Ground State in Electron-Atom Double Ionization"

In a recent Letter Jones and Madison (JM) [1] reported calculations on the double ionization of ground state of helium upon the impact of 5.6 keV electron impact. They conclude in their abstract that (i) the first Born approximation (FBA) is valid and (ii) that the discrepancy between previous calculations in the first Born approximation and the overall magnitude of the measurements is due to a poor description of the ground state. Both conclusions made by JM are not persuasive: JM did not attempt to evaluate (neither quantitatively nor qualitatively) any higher order terms in the Born series. This point is vital for conclusion (i) in so far as the convergence of the Born series is questionable for Coulomb potentials. In fact, it is known that in this case the Born series contains divergent terms (cf. the discussion as well as the motivation for the theory developed in [2] and references therein). Their conclusion (i) is based on the numerical results of an approximate model, the so-called 6C model in which the free motion of the final state particles is distorted by a factor consisting of a product of six two-body Coulomb continuum wave distortions [3]. Small differences are observed between cross sections for positron and electron impact double ionization (these cross sections are identical within FBA). For the FBA calculations, JM employed the well-known three Coulomb wave approximation (3C) that describes the final state of the ejected electrons in the field of He^{2+} as a product of three two-body Coulomb waves. It should be stressed however that, as shown in Ref. [4], even at an impact energy as low as 500 eV, the FBA-3C and the 6C approximation yield cross sections which are similar in shape and both at variance with experiments [5]. That is, the 6C approximation is not necessarily a substantial improvement on the 3C. In contrast, it has been demonstrated experimentally [6] that double ionization by electron e^- and proton p^+ impact is qualitatively different even at an impact velocity of $\sim$12 a.u. [6] (2 keV electron impact energy). In addition, for a fixed impact velocity and a fixed momentum transfer, the deviations between e^- and p^+ impact double-ionization cross sections depend on the geometrical configuration of the two ejected electrons (cf. Fig. 2 of Ref. [6]), a phenomena whose description is beyond the FBA capability [2]. Thus, there is experimental evidence of the shortcoming of the FBA in this energy regime.

The conclusion (ii) of JM is not substantiated by either the formal mathematical analysis [3] of the employed wave functions or by previously established knowledge of the 3C and the 6C cross sections: Using a certain initial ground state when calculating particular cross sections does not remedy the known deficiencies of the final state wave functions. It is well established that the 3C and the 6C approximations [3] are not valid at low energies, and it is not clear at which (high) energy these approximations become reliable. Nevertheless, even in some low-energy scattering geometries the 3C model can *accidentally* yield results in accord with absolute experiments, as demonstrated in Ref. [7] for photo double ionization of He. Conclusion (ii) of JM is based on the agreement of a particular set of experiments. There are a number of various other examples demonstrating the limitations of the 3C model for describing atomic double and single ionization processes [8] (where the ground state for atomic hydrogen is exactly known). Generally, the 3C and the 6C approaches have been very instrumental in unravelling the underlying global physical mechanisms of single- and double-ionization processes [9,10]. However, when it comes to precise quantitative agreement with experiments, serious improvements are due. These may be done systematically, e.g., by inspecting the parts of the Hamiltonian that have been neglected to derive the 3C and the 6C wave functions [3]. On the other hand, from a formal point of view, there are still a number of open questions concerning the proper formulation of a few-body Coulomb scattering theory, such as the convergence properties of the few-body T matrix.

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