Prominent role of indirect processes in electron-impact ionization of Xe^{24+} ions

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Synopsis The cross section for electron-impact single ionization of Xe^{24+} has been studied both experimentally and theoretically. The cross section exhibits significant features from resonant ionization processes such as resonant-excitation double autoionization. These are well described by the theoretical calculations if the latter take into account excitations to atomic shells with principal quantum numbers of up to $n = 39$.

Electron-impact ionization of ions is the fundamental atomic collision process. Accurate data on ionization cross sections for atoms and ions are of crucial importance for the correct description and understanding of the processes occurring in ionized gases. With their many-electron nature and rather low binding energies, xenon ions are well suited for studying atomic processes in complex many-electron atomic systems, where electron-impact ionization results from a complicated pattern of ionization mechanisms. Depending on impact energy, the ionization vent might involve the simultaneous rearrangement of several atomic subshells. Previous studies on ionization of xenon ions revealed, that mainly mechanisms of direct ionization (DI) and non-resonant excitation-autoionization (EA) contribute to the single-ionization cross section. For intermediate charge states, resonant processes such as resonant-excitation double autoionization (REDA) yield sizeable contributions, in addition [1, 2].

Here, we report on case where resonant processes are as significant as direct ionization, i.e., single ionization of Xe^{24+} ions [3]. Experimental measurements were performed at the Giessen crossed-beams setup at electron energies ranging from the lowest ionization threshold up to 1000 eV. In addition, fine-structure resolved distorted-wave calculations of the ionization cross section employing the Flexible Atomic Code (FAC) [4] were performed including all relevant partial cross-section contributions. Therefore, DI, EA, as well as REDA processes were considered. Figure 1 shows the comparison of the experimental and the theoretical results. The experimental data exhibit distinct resonant structures which, at certain energies, reach up to 50% of the total measured cross section. According to our calculations, these originate from REDA processes involving, e.g., $3d \to 4f$ excitations and simultaneous capture of the impacting electron into high-n levels with principal quantum numbers of up to at least $n = 39$. A similarly slow convergence was found for the EA contributions to the total cross section. This strongly suggests, that calculations of accurate cross sections for collision processes involving many-electron ions are, in general, very demanding, and that, conversely, simple scaling formula as often applied in plasmaphysical and astrophysical applications are bound to fail.

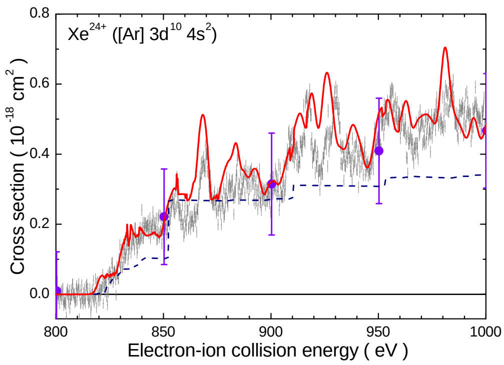

Figure 1. Cross section for electron-impact ionization of Xe^{24+} ions [3]. Symbols represent the experimental data. The solid (red) curve is the result of the theoretical calculation including DI, EA and REDA processes, while the dashed (navy) curve represents the summed contributions of the non-resonant processes DI and EA, only.

References

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