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Recombination of open-4f-shell W^{18+} ions with free electrons

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Synopsis Electron-ion recombination of W^{18+} forming W^{17+} has been studied both experimentally and theoretically. The W^{18+} recombination rate coefficient is dominated by strong recombination resonances even at the lowest experimental energies. According to our calculations these resonances are mainly associated with $4f \to 5\ell$ excitations of the $W^{18+}(4f^{10})$ core. For the purpose of fusion plasma modeling, the total W^{18+} recombination rate coefficient in a plasma is derived from our results.

Atomic spectroscopy and collision processes involving tungsten ions currently receive much attention, since tungsten is used as a wall material in nuclear fusion reactors. Consequently, tungsten ions are expected to be prominent impurities in fusion plasmas. Radiation from excited tungsten ions leads to substantial plasma cooling which has to be well controlled in order to maintain the required conditions for nuclear fusion. Thus, a comprehensive knowledge of atomic energy levels and collision cross sections is required for a thorough understanding of the spatial and temporal evolution of the tungsten charge states and emission spectra in fusion plasmas.

The recombination rate coefficients of tungsten ions that are currently used for plasma modeling stem from semi-empirical calculations based on the Burgess formula. They bear rather large uncertainties as has become evident from a first storage-ring electron-ion recombination experiment with W^{20+} ions [1]. New theoretical calculations for this ion [2] which used intermediate coupling (IC) for the description of the multiply excited recombination resonance states showed that the largest part of the observed discrepancy can be attributed to low-lying recombination resonances associated with $4d \to 4f$ excitations of the $W^{20+}(4d^{10}\,4f^{8})$ core. These cannot be treated in the semi-empirical calculations.

Here, we present experimental and theoretical recombination rate coefficients of W^{18+} from a storage-ring experiment and from IC calculations, respectively. Figure 1 compares the measured and calculated W^{18+} merged-beams recombination rate coefficient at electron-ion collision energies below 10 eV. At these energies the measured rate coefficient is about a factor of 200 above the rate coefficient for nonresonant radiative recombination (RR) estimated from a hydrogenic calculation. According to our IC calculations this large rate coefficient is caused by unresolved and surprisingly strong recombination resonances at very low electron-ion collision energies. In contrast to the previous findings for W^{20+}, the $4f \to 5\ell$ excitations of the $W^{18+}(4f^{10})$ core provide the largest contribution.

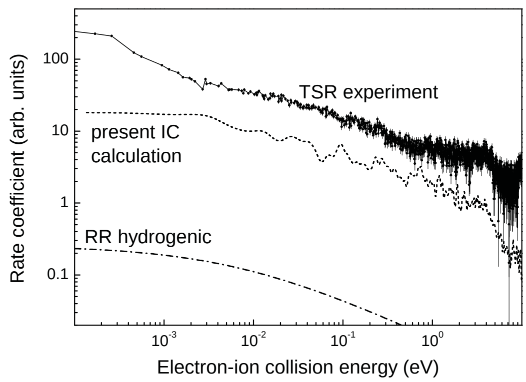

Figure 1. Merged-beams rate coefficient for electron-ion recombination of W^{18+} ions as function of electron-ion collision energy. Symbols: Experimental result from the heavy-ion storage ring TSR of the Heidelberg Max-Planck-Institute for Nuclear Physics. Dashed line: Present IC calculations. Dash-dotted line: Calculated RR rate coefficient using a hydrogenic approximation.

References

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