Dielectronic recombination of xenonlike tungsten ions

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Synopsis

Dielectronic recombination (DR) of xenonlike W20+ forming W19+ has been studied in the collision energy range 0–140 eV. The measured rate coefficient is dominated by strong DR resonances even at the lowest experimental energies. At temperatures relevant for fusion plasmas, the experimentally derived plasma recombination rate coefficient is over a factor of 4 larger than the theoretically-calculated rate coefficient which is currently used in fusion plasma modeling. The largest part of this discrepancy stems most probably from the neglect in the theoretical calculations of DR associated with fine-structure excitations of the W20+ ([Kr]4d8 4f8) ion core.

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 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. To date, only a small fraction of the needed atomic data has been derived from experimental measurements and most comes from theory.

Here, we present the result of the first storage-ring electron-ion recombination experiment using tungsten ions, i.e., the absolute experimental rate coefficient of Xe-like W20+ recombining to form Cs-like W19+ [1]. Figure 1 shows the measured W20+ merged-beams recombination rate coefficient as a function of electron-ion collision energy. Most dramatically, the rate coefficient at energies of at least up to 30 eV is about three orders of magnitude above the RR rate coefficient estimated from a hydrogenic calculation.

This large rate coefficient is caused by individually unresolved, huge DR resonances at very low electron-ion collision energies. These strongly influence the plasma rate coefficient even at temperatures above 100 eV, where the fractional abundance of W20+ is expected to peak in a fusion plasma. Because of the extraordinary complexity of the W20+ atomic structure, no definitive assignment of the measured DR resonance features could be made. Atomic structure calculations suggest that DR associated with fine structure excitations of the W20+ ([Kr]4d8 4f8) ion core makes major contributions to the observed low-energy DR resonance strength [1]. This fact seems to have been disregarded in the theoretical calculation of the W20+ plasma DR rate coefficient which is used for plasma modeling by the nuclear fusion community. Their resulting rate coefficient is at least a factor of 4 lower than the present experimentally-derived result.

Figure 1. Measured merged-beams rate coefficient for electron-ion recombination of W20+ ions as function of relative collision energy. The short-dashed curve is the calculated RR rate coefficient using a hydrogenic approximation. The inset shows the same data in a log-log representation and a finer energy binning emphasizing the rate coefficient at very low energies.

References

[1] S. Schippers et al 2011 Phys. Rev. A 83 012711