Electron-ion recombination of the open-4f-shell ion W^{19+}

2015 J. Phys.: Conf. Ser. 635 052003

(http://iopscience.iop.org/1742-6596/635/5/052003)

Journal of Physics: Conference Series **635** (2015) 052003 doi:10.1088/1742-6596/635/5/052003

Electron-ion recombination of the open-4f-shell ion W^{19+}

N. R. Badnell[1], K. Spruck[2,3], C. Krantz[3], O. Novotný[3,4], A. Becker[3], D. Bernhardt[2], M. Grieser[3], M. Hahn[4], R. Repnow[3], D. W. Savin[4], A. Wolf[3], A. Müller[2], S. Schippers[2]

[1]Department of Physics, University of Strathclyde, Glasgow G4 0NG, United Kingdom
[2] Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen, 35392 Gießen, Germany
[3] Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany
[4] Columbia Astrophysics Laboratory, Columbia University, New York, NY 10027, USA

Synopsis Electron-ion recombination of W^{19+} forming W^{18+} has been studied both experimentally and theoretically. An exceptionally large recombination rate coefficient was observed by the storage-ring experiment at zero electron-ion collision energy. It exceeds the expectation for nonresonant radiative recombination (RR) by more than two orders of magnitude. This follows the pattern seen previously for the neighboring charge states of tungsten. The results of our present theoretical calculations, which were carried-out within the Breit-Wigner partitioned framework for resonant electron-ion recombination of complex ions, agree with this observation.

Tungsten is used for the coating of parts of the inner walls of fusion devices such as ITER. Therefore, atomic collision processes with tungsten ions are of immediate interest for understanding the role of tungsten impurities in the fusion plasma. For example, the ionization balance of tungsten is determined by the interplay of electron-impact ionization and electron-ion recombination. Most of the required cross sections come from theoretical calculations which often bear large uncertainties and, thus, require benchmarking by experiment. To this end, we have focussed on tungsten ions with a particularly complex atomic structure, i.e, ions with a nearly half open $4f$ shell. The present study extends our previous work on electron-ion recombination of $W^{20+}([\mathrm{Kr}]\,4d^{10}\,4f^{8})$ [1, 2] and $W^{18+}([\mathrm{Kr}]\,4d^{10}\,4f^{10})$ [3] to $W^{19+}([\mathrm{Kr}]\,4d^{10}\,4f^{9})$.

The experiment was carried out by employing the electron-ion merged-beams technique at the heavy-ion storage ring TSR of the Max-Planck-Institute for Nuclear Physics in Heidelberg, Germany. As in the previous cases of W^{18+} and W^{20+}, an extremely large W^{19+} recombination rate coefficient has been observed at low electron-ion collision energies (Fig. 1). According to our present understanding, this is caused by resonant recombination involving many-electron processes which cannot fully be treated by the standard theory for electron-ion recombination. Nevertheless, they can be accounted for in an approximate manner by appealing to statistical theory [4]. Different implementations have already been applied successfully to the electron-ion recombination of W^{20+} [2, 5] and W^{18+} [3]. Our present calculations for W^{19+} are in good agreement with the experimental findings (Fig. 1). This puts much confidence in theory being able to provide reliable electron-ion recombination rate coefficients for other complex ions.

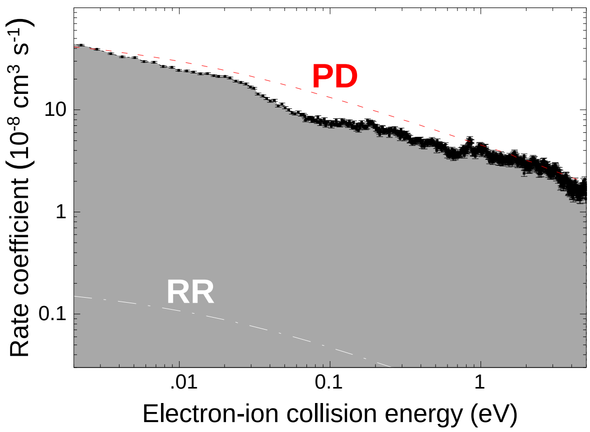

Figure 1. Measured rate coefficient (shaded curve) for the recombination of $W^{19+}([\mathrm{Kr}]\,4d^{10}\,4f^{9})$ ions with free electrons at low electron-ion collision energies. The dashed curve is the result of our "partitioned and damped" (PD) calculations. The dash-dotted curve is the theoretical rate coefficient for nonresonant radiative recombination (RR).

References

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

[2] N. R. Badnell *et al.* 2012 *Phys. Rev. A* **85** 052716

[3] K. Spruck *et al.* 2014 *Phys. Rev. A* **90** 032715

[4] V. Flambaum *et al.* 2002 *Phys. Rev. A* **66** 012713

[5] V. A. Dzuba *et al.* 2013 *Phys. Rev. A* **88** 062713

[1]E-mail: badnell@phys.strath.ac.uk