Dielectronic recombination of rubidium-like tungsten ions

Z. W. Wu[1,2], *Y. Z. Zhang*[2], *Y. B. Fu*[2], *A. Surzhykov*[1], *S. Fritzsche*[1,3], *and C. Z. Dong*[2]

[1]Helmholtz Institute Jena, Germany; [2]Northwest Normal University, Lanzhou, China; [3]University of Jena, Germany

Owing to its high melting point, low sputtering rate and low absorption of tritium, tungsten has been utilized as a plasma-facing material in magnetically confined fusion facilities. Most recently, it was considered as a leading candidate for the divertor and main chamber regions of the International Thermonuclear Experimental Reactor (ITER) tokamak. Inevitably, tungsten ions are expected to be prominent impurities in fusion plasmas. The emitted radiation from excited tungsten leads to substantial plasma cooling that has to be well controlled in order to maintain conditions for nuclear fusion. In addition, dielectronic recombination (DR) is an important atomic process in such plasmas in which an initially free electron is captured by a target ion under simultaneous excitation of one of its bound electrons. This leads to a doubly excited state of the ion that may subsequently stabilize by photon emission. Accurate DR cross sections and rate coefficients are essential for simulating ionization balance of highly charged ions in high-temperature plasmas. Therefore, studies on the DR of tungsten ions have attracted much attention.

In the isolated-resonance approximation, if we assume that the electron velocity obeys the Maxwellian distribution in plasmas, DR rate coefficients can be given by

$$\alpha^{DR}(kT_e) = \left(\frac{2\pi\hbar^2}{m_e kT_e}\right)^{3/2} \frac{g_j}{2g_i} A^a_{ji} B^r_{j,f} \exp\left(-\frac{E_{ij}}{kT_e}\right). \quad (1)$$

Here, kT_e is the electron temperature, E_{ij} the resonance energy, g_i and g_j the statistical weights of initial and intermediate states, respectively. Moreover, $B^r_{j,f}$ denotes the radiative branching ratio and is defined in terms of the Auger decay rate A^a_{ji} and the radiative decay rate A^r_{jf}.

In order to learn importance of different subshell excitations, we perform *ab initio* calculations for DR of Rb-like W^{37+} through the intermediate doubly excited configurations [Ne]$(3s^2 3p^6 3d^{10})^{-1} 4s^2 4p^6 4d\, nl\, n'l'$ with $n' \leq 16$ and $l' \leq 9$, and [Ne]$3s^2 3p^6 3d^{10} (4s^2 4p^6 4d)^{-1}\, nl\, n'l'$ with $n' \leq 18$ and $l' \leq 12$, while the contribution from other configurations with larger $n'l'$ is estimated by using the extrapolation procedures [1]. In Figure 1, we display total DR rate coefficients of initially W^{37+} ions together with partial contributions as associated with excitations of the $3s$, $3p$, $3d$, $4s$, $4p$, and $4d$ subshells as functions of the electron temperature. These coefficients are calculated for electron temperatures from 1 eV to 5×10^4 eV. Each partial contribution to total DR rate coefficients is given here by the sum of rate coefficients for the doubly excited configurations [Ne]$(3s^2 3p^6 3d^{10} 4s^2 4p^6 4d)^{-1} nln'l'$ with all permitted nl and $n'l'$ combinations. As seen clearly in Figure 1, the excitation of $4p$ subshell dominates total DR rate coefficients in the whole region of electron temperature.

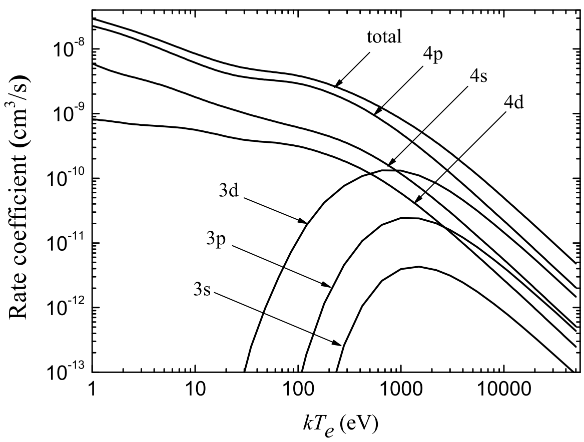

Figure 1: Total DR rate coefficients of initially Rb-like W^{37+} ion and the partial contributions associated with the excitations of $3s$, $3p$, $3d$, $4s$, $4p$ and $4d$ subshells as functions of the electron temperature kT_e. Each partial contribution gives the sum of rate coefficients for all DR channels corresponding to the excitations from nl subshells.

With respect to the excitation of $3l$ subshells, it is found that the DR rate coefficients for the excitation from $3d$ subshell are the largest and that the corresponding DR rate coefficients decrease with the quantum number l. For electron temperatures lower than 100 eV, the excitations of $3l$ subshells are much less significant than the ones of $4l$, and so its contributions to total DR rate coefficients can be neglected. However, as the electron temperature increases, the DR rate coefficients for the excitations of $3l$ subshells start to compete with their counterparts for the $4l$. This behavior arises mainly because of the influence of near-threshold states, since their resonance energies are quite small and since the DR rate coefficients have an $\exp(-E_{ij}/kT_e)$ dependence. Regarding the excitation of $4l$ subshells, the rate coefficients for the $4p$ excitation are the largest, while the contribution from $4s$ and $4d$ subshells cannot be neglected. The largest contributions to the total DR rate coefficients can reach 8% and 21% for the excitations from $4d$ and $4s$ subshells, respectively, even for electron temperatures below 100 eV.

References

[1] Z. W. Wu *et al.*, Eur. Phys. J. D, submitted (2014).

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