§30. Dielectronic Recombination Processes in Li Isoelectronic Sequence

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Dielectronic Recombination (DR) can be regarded as a resonant radiative recombination process. Its importance to influence the ionic balance in high temperature plasmas, such as solar corona, has been known for many years. Many theoretical methods have been developed to calculate the DR process, but it is still a tedious work to obtain the accurate DR rate coefficients since they involve many resonant doubly excited high Rydberg states. In the frame of quantum defect theory (QDT), we have developed a Simplified Relativistic Configuration Interaction (SRCI) method to study the dielectronic recombination processes. In this method, the infinite resonant doubly excited states involving high Rydberg state can be treated conveniently in a unified mannar by interpolation[1]. In this paper, we studied the DR processes for the Li isoelectronic sequence.

DR from a state in the ground configuration of a Li like ion to a state in a Be like ion can be accomplished through L-shell or K-shell excitation can be represented by

$$\begin{aligned} 1s^2 2s &\rightarrow 1s^2 n_a l_a n_b l_b \rightarrow 1s^2 2l' n'' l'' + h\nu, \quad (1) \\ 1s^2 2s &\rightarrow 1s2l n_a l_a n_b l_b \rightarrow 1s^2 n' l' n'' l'' + h\nu. (2) \end{aligned}$$

There are two distinct classes in the L-shell excitation [Eq. (1)] that have quite different convergence characteristics along the doubly excited Rydberg series. The first $1s^2 2pnl$, with no change in principal quantum number in the excited electron ($\Delta n = 0$), can only occur when the principal quantum number n of the Rydberg electron is greater than a critical value n_0 due to the energy conservation. With the increasing nuclear number, the relativistic effects increase and the core energy splitting between $1s^2 2p_{1/2}$ and $1s^2 2p_{3/2}$ become large, which will induce a very large n_0 for $1s^2 2p_{1/2}$ (for example, $n_0 = 25$ in Au^{75+} ion). It is very diffcult to calculate the wave function of the states with the high n, and the high Rydberg states will also involve many radiative transition processes. Using the SRCI method, we can treat all the Auger and radiative processes in a unified mannar, that is, we only calculate the Auger and Radiative rates for the states with $n \leq 15, l \leq 13$ and one according continuum state in a channel, and then we can obtain all the rates in the channel by interpolation in the frame of QDT. For the high Z ions, $n_0 > 15$, the energy of continuum electron in Auger matrix elements can be calculated by the states $n = n_0$ instead of the state $n = 15$. In this paper, we also check the validity of this interpolation. The second $1s^2 3lnl$, involving change in the principal quantum number ($\Delta n = 1$), we take into account the contributions from all the states with $l \leq 10$, because the contributions from the states with higher l are not important. For K-shell excitation [Eq. (2)], explicit calculations were carried out for the $1s2l2l'nl''$ with $n \leq 5, l'' \leq 4$.

All relativistic single-electron wavefunctions (bound and continuum) are calculated based on the atomic self-consistent potential. The configuration wavefunctions are obtained by diagonalizing the relevant Hamiltonian matrices. When the energy-normalized matrix elements of a few states (including one continuum state) in a channel have been calculated, the matrix elements of infinite discrete states of that channel can be calculated by interpolation, and all the Auger and radiative rates in the channel can be obtained. Then, we can calculate the DR cross sections or rate coefficients. In past decade, many detailed experiments have been performed to measure the DR cross sections or rate coefficients. In this paper, we calculate the DR processes for 5 ions with $z = 6, 10, 18, 28, 79$, and all the results are compared with the experimental measurements. In order to use the rate coefficients conveniently, we also provide the partial DR rate coefficients to the excited states, and then fit them into a formula with two fitting parameters [2].

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[1]. J.G. Wang, T. Kato, and I. Murakami, Phys. Rev. **A60**, 2104 (1999).
[2]. J.G. Wang, T. Kato, and I. Murakami, Phys. Rev. **A60**, 3750 (1999).