§12. Validity of n^{-3} Scaling Law in Dielectronic Re-combination Processes

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Dielectronic Recombination (DR) can be regarded as a resonant radiative recombination process. 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. most calculations simply use the n^{-3} scaling law to treat them. But it should be checked for high Rydberg states. In the frame of quantum defect theory, 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. This gives an overall description of all high Rydberg states in a channel, and avoid the inaccuracies of extrapolation through one point. By analyzing the energy-normalized matrix elements in a small energy domain, we can check the validity of n^{-3} scaling law.

In this paper, as an example, we studied the DR processes of $\Delta N = 0$ transition for Li-like argon. 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. We check the validity of n^{-3} scaling for Auger and radiative rates respectively, and find that the accuracy of n^{-3} scaling decreases with increasing l in $Ar^{14+}(1s^2 2pnl)^{**}$ resonances. These extrapolation can give a rather good results for DR cross sections and rate coefficients (within 10%), although the difference between extrapolation and SRCI method increases with increasing l. However, when we extrapolate cross sections or rate coefficients explicitly by n^{-3} scaling law, we found the errors are very large for high Rydberg states. So different extrapolations of n^{-3} scaling have their own valid condition. The theoretical rate coefficients are plotted in Fig.1(a), which is obtained from integrated cross sections folded with the electron beam temperatures (20 meV $/k_B$ transverse temperature and 0.13 meV $/k_B$ longitudinal temperature). The experimental measurements at the ion storage ring CRYRING [1] are plotted in Fig.1(b), where a background of $5 \times 10^{-9} cm^3 s^{-1}$ has been subtracted. The theoretical and experimental line positions compare rather well. In the spectral one can identify Rydberg states up to $n = 18$ for the $1s^2 2p_{1/2}$ core excitation and $n = 25$ for the $1s^2 2p_{3/2}$ core excitation, we only give labels for a few resonances for simplicity. In general, the theoretical rate coefficients are a little smaller than experimental measurements for high Rydberg states. It may come from the background or an extenal field effect.

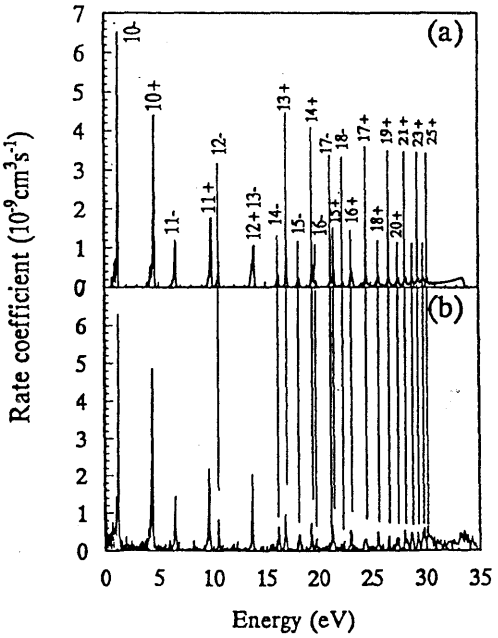

Fig.1 DR rate coefficients as a function of relative energy. "-": $1s^2 2p_{1/2}$ core excitation; "+": $1s^2 2p_{3/2}$ core excitation. (a). Theoretical results; (b). Experimental measurements[1]

References

[1]. W. Zong et al., Phys. Rev. A **56**, 5730(1997).