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The effect of electron correlation on trielectronic recombination rate coefficients for Be-like argon

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Abstract

The merged-beam rate coefficients of dielectronic and trielectronic recombinations (DR and TR) within $\Delta N = 0$ channels for Be-like Ar^{14+} were measured by Huang $et\ al.$ [Astrophy. J. Supp. Ser. 235, 2 (2018)] with the cooler storage ring at Lanzhou, China. Meanwhile, theoretical data are calculated with Autostructure code for comparison with the measured resonance spectrum. However, TR resonance strengths are significantly underestimated by Autostructure calculations in most cases. In the present work, we find that the electron correlation between DR and TR resonance states with different captured electron principal quantum numbers n can lead to a obvious increase in TR resonance strengths for $n = 6, 7$. Previous theoretical calculations for this system did not include this form of electron correlation. Considering additionally it could account for most of the discrepancy between existed theoretical calculations and experimental results. Understanding electron correlation and their consequences is of great importance for obtaining the accurate total rate coefficients that are extremely useful for plasma modeling and diagnostics.

Resonance energies

The low resonance energies are calculated with the relativistic second-order many-body perturbation theory (RMBPT) implemented in the FAC. In RMBPT calculations, the Hilbert space of the system is divided into two subspaces, including a model space M and an orthogonal space N. By means of solving the eigenvalue problem of a non–Hermitian effective Hamiltonian in the space M, we can get the true eigenvalues of the Dirac–Coulomb–Breit Hamiltonian. The configuration interaction effects in the M space is exactly considered, and the interaction of the spaces M and N is accounted for with the many-body perturbation theory up to the second order. Through the single and double virtual excitations of the states spanning the M space, all states are contained in the space N.

The high-n resonance positions can be estimated by the hydrogenic formula

$$E_{nl} = E_{\mathrm{exc}} - R\left(\frac{z}{n-\mu_l}\right)^2, \tag{1}$$

where E_{nl} is resonance energy for a given nl state, E_{exc} is core-excitation energy of recombining ion, z is the charge state of recombining ion, and R is the Rydberg energy.

Resonance strengths

The resonance capture strength are related to autoionization rates by the detailed balance. It can be written as

$$S_{ij}^{\mathrm{cap}} = \frac{g_j}{2g_i}\frac{\pi^2\hbar^3}{m_e E_{ij}}A_{ji}^a, \tag{2}$$

where m_e denotes the electron mass, g_j and g_i represent respectively the statistical weights of j and i, E_{ij} is the resonance energy.
The DR (TR) resonance strength is given by

$$S_{ij} = S_{ij}^{\mathrm{cap}} B_j^r, \tag{3}$$

where B^r indicates radiative branching ratio. It can be defined iteratively as

$$B_j^r = \frac{\sum_f A_{jf}^r + \sum_{j'} A_{jj'}^r B_{j'}^r}{\sum_k A_{jk}^a + \sum_f A_{jf}^r + \sum_{j'} A_{jj'}^r}, \tag{4}$$

here A_{jf}^r is radiative decay rate from j to f, the final states f lie below the ionization limit, j' is the low-lying autoionizing levels. $B_{j'}^r$ is the radiative branching ratio for radiative stabilization of j'.

Results

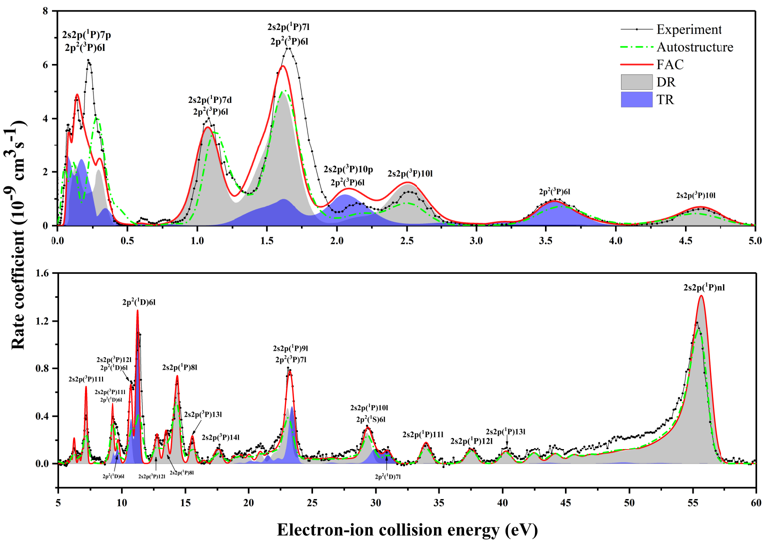

Fig.1 Comparison of the present merged-beam rate coefficients (red solid line) with the measured recombination spectrum (black data points). The present DR and TR parts are shown by the gray shaded areas and the blue shaded areas, respectively. The Autostructure calculations are presented by the green dash dot line.

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