§5. Recommended Atomic Data for Collisional-Radiative Model of Li-like Ions and Gain Calculation for Li-like Al Plasmas

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Many experiments of x-ray laser using recombining plasma is performed[1-2]. Theoretically, relatively high gain (~10) is expected, however, almost all experiments were not able to get it. To study the reason of its discrepancy, we also begun to make an computational code to analyze the electronic population of recombining lithium-like ions for example.

To remove the ambiguity of the rate coefficients, evaluation of accurate atomic data as good as possible is required for many process (energy eigen value of electronic state, oscillator strength, cross section of electron collisional ionization, electron collisional excitation, radiative recombination and dielectronic recombination). First of all, we have evaluated atomic data of lithium-like ions for different z (atomic number) values to check the validity of published data in many articles. The evaluated data were fitted to fitting formula for convenience. Detail of the fitting formula and the fitting constants will be published in NIFS report before long. Here, we show the summary of the recommendation of the atomic data.

Energy eigen value and oscillator strength between two electronic states of lithium-like ions were summarized by Lingered and Nielsen[3] and Zhang et al.[4]. Our fitting formula is able to reproduce the recommended values within 1 % differences.

Electron collisional excitation cross section were summarized by Zhang et al.[4] and Clark et al.[5]. The cross section calculated by Clark is for hydrogen-like ions. The scaled cross section of dipole forbidden transition by hydrogen-like ion for lithium-like ion is good, but dipole allowed is not. For dipole allowed transition, we multiplied the factor, which is the values of dipole oscillator strength of lithium-like ions divided by the oscillator strength of hydrogen. The cross section is quite improved to multiply the factor.

Electron collisional ionization cross section were summarized by Sampson and co-authors[6-8]. Radiative recombination rate coefficient for hydrogenic ions is given by Burgess[9]. Dielectronic recombination is an important processes in the high temperature plasma.

To solve the collisional radiative model[9] of lithium-like aluminum plasma, we have evaluated the atomic data restricted to lithium-like aluminum ions. We also made fitting formulas for all atomic data for this case.

Population can be calculated for the steady state by neglecting the ionizing plasma component in collisional-radiative model. We have calculated typical cases of Te = 20 eV, 30 eV and 50 eV, which is correspond to the experiments[1], [2]. Resultant gain in the recombining plasma is also calculated.

As the result, the gain of the transition to 3p state is always negative though relatively high gain is observed in experiments. But the result is very sensitive to the rate coefficients of l-changing collision among the subshells of same principal quantum number.

The gain of the transition of 3d-5f is much smaller than that of 3d-4f. But experimental results show that the gains of 3d-5f, 3p-5d, 3d-4f and 3p-4d are comparable. In the case of recombining plasma of such low temperature like 20 ~ 30 eV, the electronic population of 5d and 5f are determined by collisional process and resultant population is the maximum value of local thermodynamic equilibrium. Therefore, the estimation of the population of n = 5 states cannot be affected by the small change of the rate coefficients. Moreover, the oscillator strength of 3d-5f transition is about 6.5 times smaller than that of 3d-4f. Therefore, we cannot believe that that the gain of 3d-5f transition is comparable to the gain of 3d-4f within the framework of collisional-radiative model of recombining plasma.

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