§16. Symmetric Resonant Charge Transfer between He and He^+ in High Rydberg States at Very Low Collision Energies

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Divertor plasma parameters of magnetic confinement fusion devices have principal roles on heat and particle loads of the divertor plates. Passive spectroscopy is used for measurements of electron temperature and density of the divertor plasmas. For the spectroscopic measurement based on line intensity ratios of He I series, collisional-radiative (CR) models for He I was first developed by Fujimoto [1)], and updated by Goto [2)]. Due to high neutral density (10^{11}-10^{15} cm^{-3}) in the divertor region, influence of radiation trapping on atomic population kinetics must be taken into account [3)]. Neutral gas temperature is required to evaluate the optical escape factor [4)].

Doppler widths of He I resonance line series have recently been measured carefully in the linear divertor plasma simulator, MAP-II [5)]. It was found that Doppler widths of lines from higher Rydberg levels were significantly larger than those of lower excited levels at an elevated electron density [6)]. It has been puzzling that neutral temperatures of the high Rydberg He atoms were distinctively high. A possible mechanism was proposed by Kado that the "hot" Rydberg states could be populated via the symmetric resonant charge transfer between "cold" He neutrals and "hot" He^+ ions in the Rydberg states, provided the Rydberg levels lie above so-called Griem's limit. The present collaboration studies have been undertaken to evaluate accurate frequencies of the symmetric resonant charge transfer for the Rydberg states at very low collision energies.

Demkov model [7)] for quasi-resonance charge exchange is extended to calculate symmetric resonance charge transfer cross sections for high Rydberg states. In the present calculations, electronic Schrödinger equations of He_2^+ are solved in the spheroidal coordinates. The principal quantum number of the spherical coordinates is written by spheroidal quantum numbers (n_η, n_ξ, m),

$$n = n_\xi + \frac{n_\eta}{2} + m + 1.$$

There are many levels involved in a high Rydberg state $(n >> 1)$. We assume strong couplings only between two states (*garade* and *ungerade*) in one manifold with the same pair of spheroidal quantum numbers (n_ξ, m), but coupling among other states are neglected. This assumption has been validated at low collision energies by comparing results with other theoretical cross sections of the symmetric resonant charge transfer between H(n=2) and H^+ [8)].

Fig. 1 shows the cross sections obtained in the present work for,

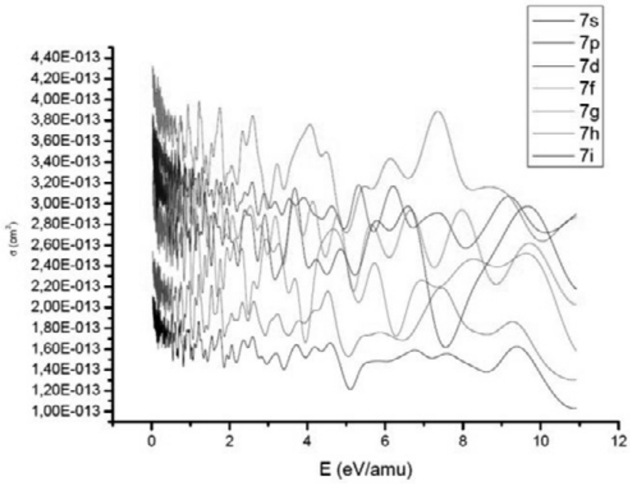
$$\mathrm{He}\,(1s7l, m=0) + \mathrm{He}^+(1s) \rightarrow \mathrm{He}^+(1s) + \mathrm{He}\,(1s7l, m=0).$$

Oscillatory structures in the cross sections may be ascribed to dephased action integrals along the *gerade* and *ungerade* levels, as inferred from the Firsov formula [9)] of the cross sections,

$$\sigma = 2\pi \int_0^\infty \sin^2\left(\int_b^\infty \frac{E_g(R) - E_u(R)}{2v\sqrt{R^2 - b^2}} R dR \right) b db,$$

where R is inter-nuclear distance, b is impact parameter, v is collision velocity, and $E_{g,u}(R)$ are electronic terms (energies) of the *gerade* and *ungerade* states.

This work is supported by the NIFS/NINS project of Formation of International Network for Scientific Collaborations.



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