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THE RATE COEFFICIENTS OF THE SLOW ATOM-RYDBERG ATOM COLLISIONS IN GEOCOSMICAL PLASMAS

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Abstract. The processes in slow-atom-Rydberg-atom collisions are investigated in this contribution. The calculation of rate coefficients is done for Li and Na for the principal quantum numbers n≥4 and temperatures T≥500K. The chemi-ionization processes in slow collisions of excited alkali atoms with atoms in ground and excited states were considered, with a particular accent to the applications to geocosmical plasmas. We intend to present the results of calculation of the rate coefficients of the corresponding chemi-ionization processes in the tabulated form easy for further use.

1. INTRODUCTION

Finding new calculation possibilities and experimental techniques, has been continually inciting interest in the chemi-ionization processes in atom–Rydberg atom collisions, which resulted in numerous experimental/theoretical papers dedicated to this thematic (see e.g. Ignjatović et al. (2005)). The main aim of this work is to extend the investigation of Li and Na collisional ionization presented in Ignjatović et al. (2008) for the wider region of principal quantum numbers and temperature with a particular accent to the applications for low temperature laboratory Yubero et al. (2007) and astrophysical plasma research Klyucharev et al (2007) and Gnedin et al. (2009). We studied the non-symmetric chemi-ionization processes

$$X^*(n) + Y \Rightarrow e + XY^+ \qquad (1)$$

$$X^*(n) + Y \Rightarrow e + X^+ + Y \qquad (2)$$

where Rydberg atom X =Li and Y =Na, LiNa+ is the molecular ion in the electronic ground state ($X^2\sum^+$). The resonant mechanism method is used for the calculations of the rate coefficients of the processes (1) and (2). The description and basic theory is presented in the papers Ignjatović et al. (2005), Mihajlov et al. (2012). Here, the calculations of these rate coefficients are performed for the principal quantum number $4 \leq n \leq 25$ and temperatures 500 K $\leq T \leq$ 1500 K. The partial and the total rate coefficients which characterize the processes (1) and (2) separately and together can be presented by $K_{ci}^{(a)}(n; T)$, $K_{ci}^{(b)}(n; T)$ and $K_{ci}^{(ab)}(n; T)$, where

$$K_{ci}^{(ab)}(n,T) = K_{ci}^{(a)}(n,T) + K_{ci}^{(b)}(n,T). \qquad (3)$$

By definition, rate coefficients K(ab)ci (n; T) and K(a)ci (n; T) and the cross-sections $\sigma_{ci}^{(a,ab)}(n; T)$ are calculated as in Ignjatović et al. (2005) or Mihajlov et al. (2012,2017).

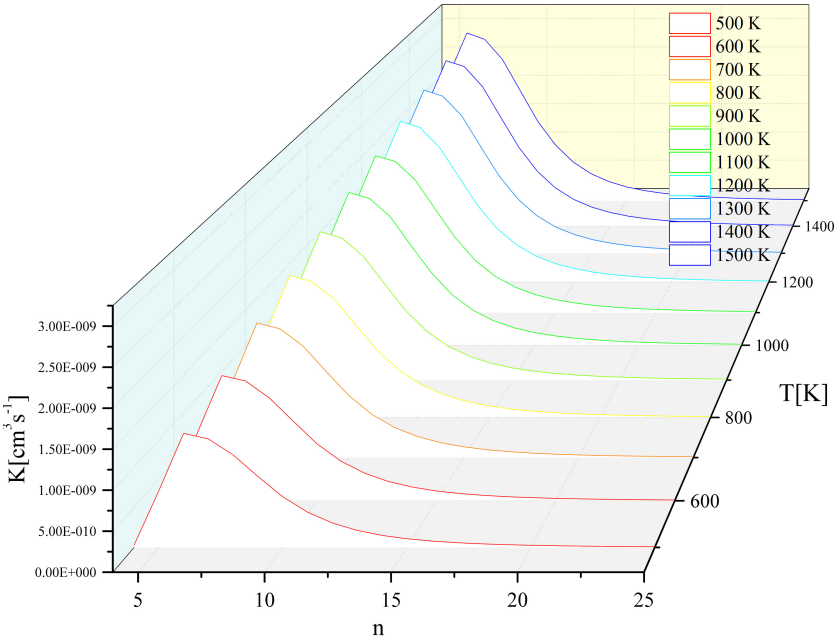

Figure 1: The total rate coefficient $K_{ci}^{(ab)}(n; T)$, Eq. (4) for chemi-ionization processes (1) and (2) in Li*(n) + Na collisions.

2. RESULTS AND DISCUSSION

We calculate the partial $K_{ci}^{(a)}(n; T)$, $K_{ci}^{(b)}(n; T)$ and total chemi-ionization rate coefficients $K_{ci}^{(ab)}(n; T)$, for the extended regions of principal quantum numbers n≥4 and temperatures 500 K $\leq T \leq$ 1500 K. Fig.1 present the plot of total chemi-

ionization rate coefficient $K_{ci}^{(ab)}(n;\ T)$ for all mentioned conditions. One can see that the rate coefficient $K_{ci}^{(ab)}(n;\ T)$ has the maximum at n=6. For lower quantum numbers n the rate coefficients strongly depend on the temperature.

The relative contribution of the associative channel (1), is presented by Fig 2. It can be noticed that in the considered regions of n and T the associative chemi-ionization (1) dominates in comparison with the non-associative chemi-ionization channel (2).

Unlike the symmetric case, in the non-symmetric one associative channel changes non-monotonically with a maximum displaced to the region of small values of n.

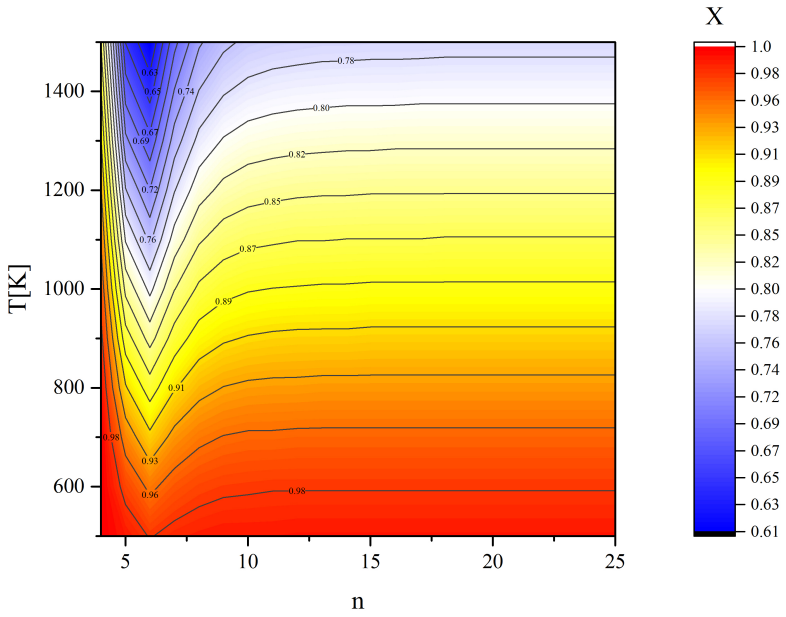

Figure 2: The ratio $O^{(ab)}$ of the partial rate coefficient $K_{ci}^{(a)}(n;\ T)$ and total ones $K_{ci}^{(ab)}(n;\ T)$ for chemi-ionization processes (1) and (2).

3. CONCLUSIONS AND PERSPECTIVES

The rate coefficients for the chemi-ionization processes in $Li^*(n)$ + Na collisions were calculated. The results of this work confirm the possibility of application of the resonant mechanism O'Keeffe et al. (2012) for the description of chemi-ionization collision processes, not only in the case, when the particles of the same type collide (symmetric case), but for the case of different type (non-symmetric) too. In the near future we aim to further investigate the chemi-ionization processes and develop completely quantum-mechanical methods of their description which could be applied in the cases of extremely low

temperatures. Results of this work provide part of kinetics for the modelling of sodium formations in Io atmosphere, not investigated before. The other needed processes are well known and could be easily included in the model.

Acknowledgments

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