Electron-impact excitation and recombination of molecular cations of astrophysical interest

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The modeling of the media characterizing the early Universe, the interstellar molecular clouds and the planetary atmospheres requires rate coefficients for the major elementary reactions. In diffuse environments, electrons are expected to be the dominant exciting species for molecular ions, as the cross sections for electron impact excitation are several orders of magnitude larger than those corresponding to excitation by neutral atomic or molecular species. Electron impact rotational excitation of the molecular cations is competed by electronic dissociative recombination, a major process for the charged particle kinetics and an important link in the various reaction networks involving most of the major species [1].

![Figure 1: Maxwell rate coefficients for rotational excitation (left) and dissociative recombination (right) of vibrationally relaxed HD$^+$ on its lowest rotational levels N$_i$\textsuperscript{+} [3].](image)

Using the Multichannel Quantum Defect Theory (MQDT) [2, 3] and the Adiabatic-Nuclei Rotation (ANR) approximation [3], cross sections and rate coefficients have been obtained for rotational transitions induced in H$_2^+$ and HD$^+$ molecular ions – Figure 1. New
data on vibrational transitions in CO$^+$ [4] – Figure 2 - have also been produced and, following a careful study of the role of the core-excited Rydberg states in the dynamics, dissociative recombination rate coefficients have been obtained for N$_2^+$ [5]. For all these species, comparison with measurements in CRYRING and TSR heavy-ion-storage-rings resulted in very good agreement.

**Figure 2:** Maxwell rate coefficients for dissociative recombination (DR), vibrational excitation (VE) and vibrational de-excitation (VdE) of CO$^+$ in its vibrational state $v_i^+$ [4]. The colored numbers stand for the final vibrational level of the transition.

Besides analyzing these recent results, we will discuss the huge role of the resonant electron capture into Rydberg states in the dissociative recombination of H$_3^+$, and we will present a very effective reduced analytical model [6], which can be applied for the estimation of rate coefficients for a large number of polyatomic species.

Finally, we will display preliminary promising data on CH$^+$, SH$^+$ and AlO$^+$ ions.


