Experimental and theoretical investigations into ion-neutral reaction relevant to Titan's atmosphere

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Ion processes play a pivotal role in the interstellar medium (ISM) and planetary atmospheres as intermediate steps in the build-up of larger complex molecules. Since the first detection of molecular anions in a circumstellar envelope, several negative ions (HC$_4^-$, HC$_5^-$, and HC$_6^-$, C$_3$N and, tentatively, C$_3$N') have been identified in the ISM [1]. In addition, a multitude of large anions (up to a mass of 10000 Da) and a large number of nitrogen-containing cations have been observed by the Cassini Plasma Spectrometer (CAPS) and the Ion and Neutral Mass Spectrometer (INMS) [2] in the atmosphere of the Kronian satellite Titan. Also, several protonated nitriles were detected in this environment by the same device. In addition, the anions CN', C$_3$N and, possibly, C$_3$N' have been identified in Titan’s ionosphere by CAPS [2]. It is therefore necessary to investigate possible formation and destruction pathways of these species in order to explain their presence and abundances in the interstellar medium, star-forming regions and atmospheres. Whereas ion-neutral and ion-electron reactions (dissociative recombinations) are the most important degradation processes for cations in these environments, feasible destruction pathways of anions include photodetachment, ion-neutral reactions (e.g. associative detachment) as well as mutual neutralisations.

During the last years, ion traps and guided beam devices have been successfully employed to investigate ion-neutral processes. We have performed laboratory measurements of the reactions of different isomers of the cyanomethyl cation (c-C$_2$H$_2$N$^+$ and CH$_2$CN$^+$) with several saturated and unsaturated hydrocarbons (e.g. CH$_4$, C$_2$H$_2$, C$_3$H$_4$ and C$_2$H$_6$) using tandem mass spectrometric techniques and appropriate neutral precursors to ensure the production of specific isomers of the C$_2$H$_2$N$^+$ ion [3,4,5]. The principal aim was to identify possible growth mechanisms large carbon-and nitrogen-containing molecules in Titan’s atmosphere via ion-molecule reactions. Such heavy entities can act as intermediates for the formation of tholines which are regarded as being responsible for the orange haze Titan is enveloped in. Furthermore, ion traps have been employed to determine absolute cross sections of photodetachment of HC$_{2n}^-$ ions C$_{2n+1}$N$^+$ ions which have been detected in the interstellar medium and Titan’s ionosphere. The obtained findings were included in state-of-the art model calculations of dark clouds and circumstellar envelopes [6,7]. Another series of experiments concentrated on reactions of cyano ions with unsaturated hydrocarbons present in Titan’s atmosphere, since these species have been identified as possible pathways to larger entities there [8,9]. The guided beam devices at Trento and Prague were employed to carry out these studies.

References