EPSC Abstracts
Vol. 6, EPSC-DPS2011-121, 2011
EPSC-DPS Joint Meeting 2011

Production of neutral species in Titan's ionosphere through dissociative recombination of ions as measured by INMS

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Abstract

This work aims to quantify the neutrals fluxes produced by ion dissociative recombination processes (DR) in Titan's ionosphere. The calculation is based on the ion densities measured by the INMS instrument on Cassini orbiter during flyby T19 at 1200 km of altitude. The dissociative recombination exhaustive chemical model is taken from Plessis *et al.* [1]. Neutral fluxes are compared with those predicted by the photochemical model of Hébrard *et al.* [2]. The comparison shows that the neutral production rates are at least of the same order of magnitude, with neutral fluxes from DR reactions which are often even larger. This first study confirms the necessity to build coupled models for the ionosphere taking into account the respective impacts of ions on the neutrals and of neutrals on the ions budget. Moreover we show that the highly dissociative contribution of the ion-electron recombinations leads to cascade effects on the neutral budget, with significant contribution to neutral species smaller than their parent ion. This important global chemical lysis effect of the DR is missed if implementing a simplified H-loss scheme.

1. Introduction

1.1 Densities measured by INMS

Titan's upper atmosphere is a place for active ion chemistry as revealed by the Cassini space mission. The Ion Neutral Mass Spectrometer instrument (INMS) onboard Cassini detects positive ion species with masses up to 100 u and a resolution of 1 u. Ion densities are varying notably with altitude: the maximum density of the total ion profile is found at about 1100 km of altitude, the optimum altitude between a decrease of the neutral densities and an increase of the ionizing fluxes.

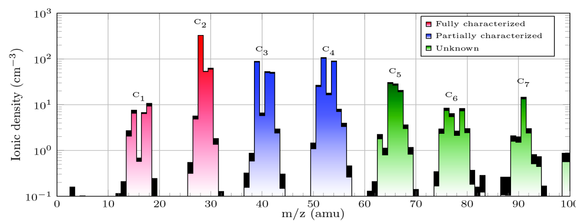

Figure 1: INMS ion mass spectrum measured during the T19 day-time flyby of Cassini. The color of the blocks is the signature of the state of knowledge of the DR branching ratios corresponding to the identified ions.

An example of a monitored INMS ion mass spectrum is given on Fig.1 (T19 flyby).

1.2 Recombination of ions with electrons

It is now admitted that ion chemistry may be involved into the production of a few specific neutrals (e.g. NH_3, benzene), through ion-electron dissociative recombination. DR reactions are highly exothermic, leading to numerous possible fragments. As discussed in detail in [1], the knowledge on the resulting neutrals is scarce and becomes non-existent for ions larger than 4 carbon atoms. Fig. 1 illustrates on the INMS T19 spectrum at 1100 km of altitude this state of knowledge. The red part of the mass spectrum (m/z < 35) corresponds to ions with well-known fragmentation patterns through DR, whereas the blue part (35 < m/z < 60) corresponds to ions with partially known neutral products; and the green part, for m/z> 60, corresponds to ions with unstudied dissociative recombination reactions. The total effect of the ions DR is as a consequence an important issue for predicting the impact of the ion chemistry on the neutral budget in Titan ionosphere.

The aim of this study is precisely to calculate the impact of the DR reactions on the neutral production rate, by comparing these fluxes with the production rate of a photochemical model [2].

2. Results

DR production rates are given on Fig. 2 for the hydrocarbon families.

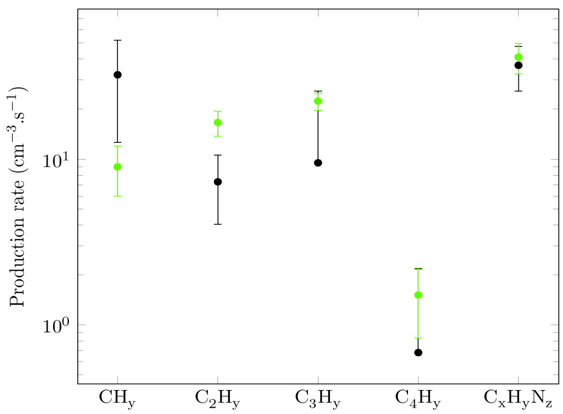

Figure 1: Comparison of some neutrals production rates at 1100 km. Black: photochemical model, green: RD production rates at T19 INMS ionic conditions.

The comparison with the photochemical model production rates shows that the fluxes are of the same order of magnitude in the T19 ionic conditions, and even predominates over the photochemical models. This analysis in global fluxes shows that the neutrals production rates are largely underestimated if using only a photochemical model to describe the chemistry in the ionosphere. The ion chemistry plays a major role on the neutrals at these altitudes, confirming the necessity to develop fully coupled ion-neutral models for such altitude ranges.

3. Summary and Conclusions

In a previous study [3], we calculated the impact of the neutral uncertainties on the ion density profiles, showing in a first step the importance of a semi-coupling between neutral and ion chemistry in Titan ionospheric models. Here, we provide the complementary evaluation of the impact of the ion chemistry on the neutral budget. We show that ionic chemistry has a significant influence on neutral densities. In the T19 ionic conditions, the neutral production rates of the ionic model are comparable to the neutral production rates of photochemical models. DR is the process between an ion and an electron leading to several neutral after dissociation of the resulting species. This process is very efficient and highly multipathway in a diluted plasma as Titan's ionosphere. Therefore the DR reactions have mainly a global lysis effect, producing neutrals smaller than their parent ions. This important global effect is in disagreement with the current view carried by a simplistic H-loss description.

Acknowledgements

We thank the CNRS (PNP, ANR-09- JCJC-0038 contract) for financial support.

References

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