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How do anions grow in the cold upper atmosphere of Titan? Insights from the laboratory

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Abstract

The Cassini-Huygens probe has revealed the existence of a profusion of negatively charged molecular species in the cold upper atmosphere of Titan (∼950 km). The presence of large amounts of negative ions was unexpected and the chemical pathways leading to their formation mostly unknown. The investigation of the negative ion chemistry appears therefore to be a key factor for modeling Titan's upper atmosphere. According to a recent study, the formation of aerosols in Titan's upper atmosphere could also be directly related to ion processes [1].

Here, we present the first low temperature experimental kinetic studies involving CN^- and C_3N^-. These negative ions were proposed by Vuitton *et al.* [2] to be responsible for the low mass peaks emerging from the mass spectrum measured by the CAPS-ELS instrument onboard the Cassini spacecraft. The temperature dependence of the rate coefficient of the CN^- + HC_3N reaction was explored over the 49–294 K temperature range in uniform supersonic flows using the CRESU technique. Cyanoacetylene, HC_3N, represents one of the most abundant nitrogen containing constituents of the atmosphere of Titan, with a strong acidity that could promote the charge transfer. Our measurements show that the kinetics of this reaction is fast ($k \sim 5 \times 10^{-9}$ cm^3 molec^{-1} s^{-1}) and presents a slightly negative temperature dependence well reproduced by long-range based capture theory. C_3N^- + HCN represents the dominant exit channel demonstrating that this reaction could participate efficiently to the growth of negative ions in the atmosphere of Titan.

In order to understand how the ions grow further, the study has been then extended to C_3N^- + HC_3N using an isotopically labeled nitrogen ^{15}N precursor for the negative ion. Preliminary results have allowed to identify proton exchange as the major channel. The temperature dependence of the reaction will be examined.

Our research illustrates that the accurate determination of reaction rate coefficients over relevant cold temperatures and of the branching into different exit channels is essential to get a clear picture of the macroscopic evolution of Titan's atmosphere.

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