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On the reactivity of anions in Titan's atmosphere: Synthesis of their precursors and low-temperature experiments

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Abstract

The presence of numerous negative ions in the upper atmosphere of Saturn's biggest satellite Titan has been revealed by the Electron Spectrometer, one of the sensors making up the Cassini Plasma Spectrometer. The presence of anions was not expected, and their formation mechanisms remain mostly unknown. Anions may play some important role in the production of the aerosols which in turn contribute to the formation of a dense haze which blackens Titan's surface.[1] The investigation of their reactivity appears indispensable.

The first objective of our work is to synthesize precursors of anions of astrophysical interest, mainly C_xH^- (where x = 2, 4, 6) and C_xN^- (x = 1, 3, 5) selected for their probable presence. [2] The second objective is to investigate the reactivity of these molecular anions down to low temperatures in gaseous phase with the help of the CRESU apparatus (French acronym for Kinetics of Reactions in Supersonic Uniform Flows). Reactions between anions and abundant heavy molecular species are likely to contribute to the growth of molecular anions in Titan's upper atmosphere.

For choosing the appropriate precursors of the anions, there are certain criteria that should be satisfied. First of all, the synthesized and purified precursor should be stable. That is, it shouldn't polymerize, decompose, or become self-reactive due to pressure or temperature. Also, the vapor pressure of the precursor should be rather high. Another important criterion is related to the dissociative electron attachment of the precursor ($AB + e^- \rightarrow A^- + B$). The electron attachment on the precursor should be efficient at low electron energy (close to 0 eV) and upon dissociation, the dominating exit channel should be the one that leads to the desired anion.

The reactivity of the molecular anions is then investigated with the CRESU which is designed to operate in the gas phase and down to low temperatures (from 300 down to 50 K). It consists of a Laval nozzle in which the gas expands to generate a supersonic beam. Its temperature is set according to the design of the nozzle and the pressure in the chamber and reservoir. An electron beam which crosses the flow generates a plasma which initiates ion chemistry. The anions of interest are produced by dissociative electron attachment onto the synthesized precursors. A moveable quadrupole mass spectrometer coupled to a Langmuir probe measure the ion population and the electron density respectively. The molecular co-reactant is introduced in large excess in the flow through the reservoir to perform pseudo first order kinetic experiments. [3]

This study aims to determine the rate coefficients and branching ratio of selected anion-molecule reactions down to low temperatures. Our work should contribute to the understanding of complex chemistry taking place in Titan's atmosphere. Farther from us, this is also of interest for the cold chemistry of molecular clouds and circumstellar envelopes in which anions have been recently detected.

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