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How fast do hydrocarbons condense in Titan's atmosphere? Insights from the laboratory

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Abstract

Titan's dense atmosphere shows a complex photo-chemistry initiated by the dissociation of its two most abundant components, nitrogen N_2 and methane CH_4. This cold chemistry generates a plethora of hydrocarbons and nitriles and takes part in the production of a thick haze. According to a recent scenario constructed from Cassini-Huygens measurements, the chemical reactions and physical processes occurring at high altitudes near 1000 km could be the haze source [1]. This haze material could act as a nucleus for the condensation of organic vapors in Titan's stratosphere and troposphere. However, the pathways leading to the formation and growth of haze aerosols remain far to be well understood.

Hydrocarbons, which are formed in Titan's cold atmosphere, starting with ethane C_2H_6, ethylene C_2H_4, acetylene C_2H_2, propane C_3H_8… up to benzene C_6H_6, play also some active role in aerosol production, cloud processes, rain generation and Titan's lakes formation.

Our goal is to study in the laboratory the kinetics of the first steps of condensation of these hydrocarbon molecules. Several studies have investigated the phase of e.g. ethane and propane and their spectral signatures. At the exception of our recent studies on the dimerization of pyrene $C_{16}H_{10}$ [2] and anthracene $C_{14}H_{10}$ [3] performed over the 50-300 K temperature range, there is however no other work on the first elementary steps of the kinetics of nucleation for hydrocarbons.

Here we present the first experimental kinetics study of the dimerization of a small hydrocarbon: propane C_3H_8. We have performed experiments to identify the temperature range over which small propane clusters form in saturated uniform supersonic flows. Using our unique reactor based on a Laval nozzle [4], the kinetics of the formation has also been investigated over the 15-300 K temperature range. The chemical species present in the reactor are probed by a time of flight mass spectrometer equipped with an electron gun for soft ionization of the neutral reagents and products. The experimental data is combined with state-of-the-art theoretical calculations that employ careful consideration of the intermolecular interaction energies and intermolecular dynamics to estimate the binding energy, equilibrium constant, and rate coefficients.

This work aims at putting some constraints on the role of small hydrocarbon condensation in the formation of haze particles in the dense atmosphere of Titan.

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