EVAPORATION OF HYRDOCARBONS UNDER SIMULATED TITAN LAKE CONDITIONS.

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Introduction: Recent observations from NASA's Cassini-Huygens mission in 2006 show dark, lake-like features within Titan's polar regions and confirm the presence of liquid on Titan [1]. These lakes are predominately located in the polar regions, but there are currently indications for possible bodies of equatorial liquids as well [2, 3].

The composition of Titan's lakes is not exactly known. At Titan temperatures and pressure (90-95 K, 1.5 bar), both methane and ethane are near the triple points and the presumed compositions are chemical cocktails primarily of ethane and methane, with minor contribution from other, heavier hydrocarbons [4, 5]. The lakes play an important role in Titan's hydrological cycle, similar to the water cycle on Earth. It is thought to be dominated by methane, and is relevant when it comes to determining the stability and evolution of these liquids [6]. Liquid evaporation is a critical component in these processes and thus, need to be studied. Quantitative experimental data is scarce and much needed to confirm thermal models addressing the hydrocarbon stability and evolution.

In this project, ethane and methane were condensed and evaporation rates were measured quantitatively in a chamber, simulating Titan's surface temperature and pressure.

Experimental: An experimental simulation chamber (Fig. 1) has been designed for simulating Titan's surface temperature and pressure [7, 8]. Titan-relevant temperatures are reached through cooling with liquid nitrogen throughout the chamber and Titan pressure is achieved through filling the chamber with nitrogen gas. Ethane is first condensed through a condenser and then introduced into a Petri dish exposed to the simulated atmosphere. Methane is then condensed and poured onto the ethane already in the dish. The mass is continuously recorded as well as the temperature. Evaporation rates are then calculated through the observed mass change over time throughout the linear portion of the curves. The same experimental setup within previous experiments reported elsewhere [6] was used for the experiments presented here involving ethane-methane mixtures. A detailed description of the simulation chamber and the experimental methods can be found in [6, 7, 9].

Figure 1. Photograph of the outside of the Titan chamber, with the top of the chamber suspended in the air.

Results: Figure 2A shows a typical run depicting the relationship of the mass of an ethane-methane mixture and time. The temperatures at various locations in the chamber as a function of time can be seen in Figure 2B. A total of five experiments with varying ratios of ethane-methane mixtures are reported here.
The calculated evaporation rates from linear fits (Fig. 2A, over section III) were 0.15 g/min, 0.21 g/min, 0.132 g/min, 0.132 g/min, and 0.096 g/min, respectively. The average evaporation rate for the ethane-methane mixture is therefore 0.144 g/min.

Discussion: Figure 2A can be divided to three distinctive sections. The first dashed line (Fig. 2A) indicates the instant when ethane was first condensed and then poured, as seen from the sudden mass increase.at the end of section I. Due to the temperatures apparent on Titan, as well as simulated temperatures within the experimental chamber and the low saturation pressure, ethane appears to not evaporate under these conditions. This is indicated by the roughly horizontal section in Fig. 2A, II. The second dashed line shows the pouring of methane, followed by the mixture evaporation over section III. Since ethane does not start evaporating until warmer temperatures are present, the average rate of 0.144 g/min is representative of the evaporation of methane within the mixture. This is also supported by

the fact that the end of the linear slope in section III approaches the starting mass after ethane was poured, indicating that by that point methane has completely evaporated.

Previous experiments show the average pure methane evaporation rate to be $(5.4 \pm 1.1) \times 10^{-3}$ g/s or approximately 0.324 g/min at an average temperature of 94.1 ± 0.6 K [6, 9]. While the results presented here are preliminary, the methane evaporation rate in an ethane-methane mixture appears to be slower than that of pure methane. At the same time, they appear to be within the same order of magnitude as previous results. A possible reason for this slight discrepancy is the assumed dampening effect of ethane on the overall evaporation of methane. When present in a mixture, the individual components are thought to evaporate with a different rate due to the presence of other components. Therefore, the evaporation rate of a mixture would not be expected to be the same as that of a pure substance, even if that substance is the only component evaporating within the mixture. We note that this process under Titan conditions is not well understood or quantified for the above mixtures, and requires further study. Furthermore, surface tension and heat transfer between ethane and methane in the mixture could have a role in the observed slower evaporation rate of methane within the mixture.
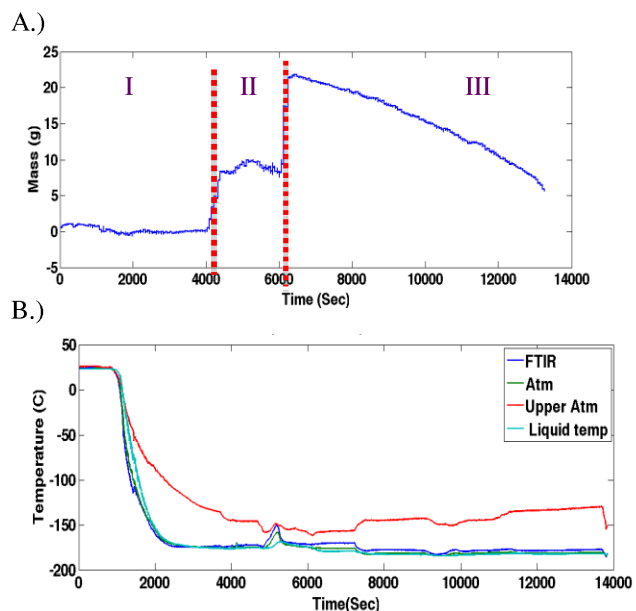
A.)

B.)

Figure 2. Relationship between hydrocarbon mass and time (A), and various temperatures within the simulation chamber and time (B). The dashed lines and the numbered sections indicate distinctive parts of the run.

Conclusion: A key point of understanding the hydrocarbon cycle on Titan is determining the evaporation rates of liquids on the surface of Titan, involving the three phases of gas, liquid, and solid. The evaporation rates of ethane-methane mixtures, which are thought to be the main components of the lakes of Titan, were determined under simulated Titan conditions through continuous mass monitoring of the sample mixture.

While we present the first preliminary results on the evaporation of these mixtures, more work is needed for understanding their behavior under the extreme conditions of Titan. Future work will involve further evaporation experiments for ethane-methane mixtures as well as various hydrocarbon solubility experiments within the Titan simulation chamber to help understand the chemistry of compounds present on Titan. In addition, experiments will be run with a gas chromatograph equipped with a flame ionization detector, as well as Fourier transform infrared spectroscopy (FTIR) to help monitor the hydrocarbon concentration in the chamber's atmosphere and the liquid itself. These experiments will significantly help with the understanding of the behavior of these compounds on the surface Titan.

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