

EVAPORATION OF ETHANE-METHANE LIQUID MIXTURES UNDER SIMULATED TITAN CONDITIONS. A. Wagner^{1,2}, V.F. Chevrier¹, S.S. Magar¹, A. Luspay-Kuti¹, L.A. Roe¹. ¹W. M. Keck Laboratory for Space Simulation, Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, Arkansas, 72701. ²Department of Chemistry, Biochemistry, and Physics, University of Tampa, Tampa, Florida 33606, awagner@spartans.ut.edu

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 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].

Results: Figure 1A 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 1B. A total of eleven experiments with varying ratios of ethane-methane mixtures are reported here.

The calculated evaporation rates from linear fits (Fig. 1A, over section III) ranged from $3.62 \times 10^{-5} \text{ kg s}^{-1} \text{ m}^{-2}$ to $1.24 \times 10^{-4} \text{ kg s}^{-1} \text{ m}^{-2}$. The average evaporation rate for the ethane-methane mixture was $9.0 \times 10^{-5} \text{ kg s}^{-1} \text{ m}^{-2}$. The methane concentrations, in mole ratio, for the following experiments ranged from 0.470 to 0.934.

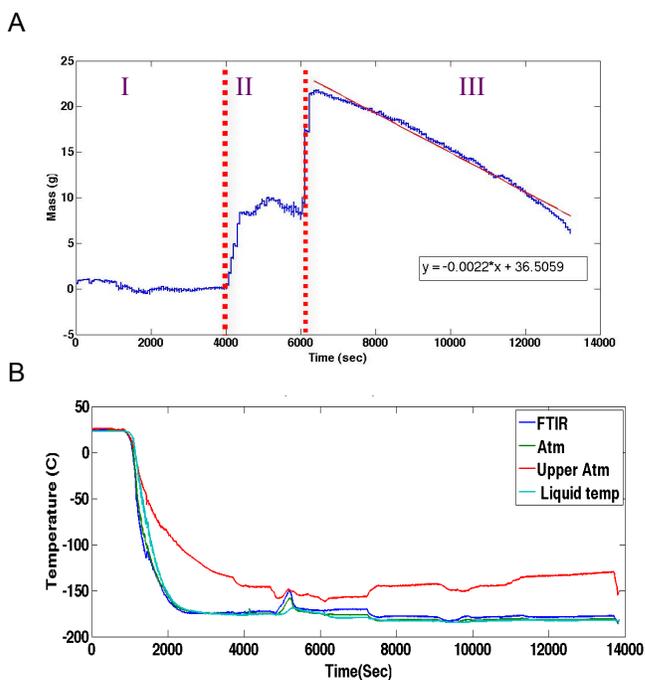


Figure 1. Relationship between hydrocarbon mass and time (A), and various temperatures within the simulation chamber and time (B). The dashed lines and the numbered sections indicate distinctive parts of the run. The methane mole ratio in this specific run was 0.696.

Discussion: Figure 1A can be divided to three distinctive sections. The first dashed line (Fig. 1A) 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. 1A, II. It is also confirmed through an experimental run of pure ethane in Figure 2. 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 $9.0 \times 10^{-5} \text{ kg s}^{-1} \text{ m}^{-2}$ 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.

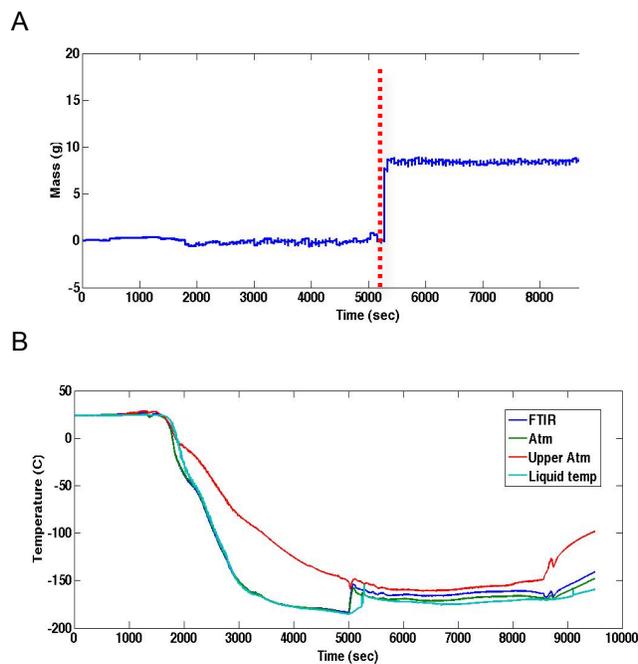


Figure 2. Relationship between ethane mass and time (A), and various temperatures within the simulation chamber and time (B). The dashed line indicates when approximately 8.0g of ethane was poured.

Previous experiments show the average pure methane evaporation rate to be $(3.1 \pm 0.6) \times 10^{-4} \text{ kg s}^{-1} \text{ m}^{-2}$ at an average temperature of $94.1 \pm 0.6 \text{ K}$ [6, 9]. As demonstrated in Figure 2, ethane appears to have no evaporation rate at Titan temperature and pressure. Through the binary mixture, an evolution of a methane evaporation rate occurs. The results presented here show that the evaporation of methane in an ethane-methane mixture is slower than that of pure methane.

The relationship between the evaporation rates and corresponding methane concentrations is depicted in Figure 3. There is a general trend of decreasing evaporation rate with increasing methane concentration, and thus decreasing ethane concentration. This anti-correlation still remains to be explained. A possible

explanation for this anti-correlation could be that the concentration of the liquid phase and the pressure and concentration of the gas phase are not linearly correlated. Other possible explanations could involve the enthalpy of mixing effects of a binary mixture or nitrogen dissolving into the binary mixture, which could affect the activity coefficients of each compound and therefore affect the evaporation rate [9].

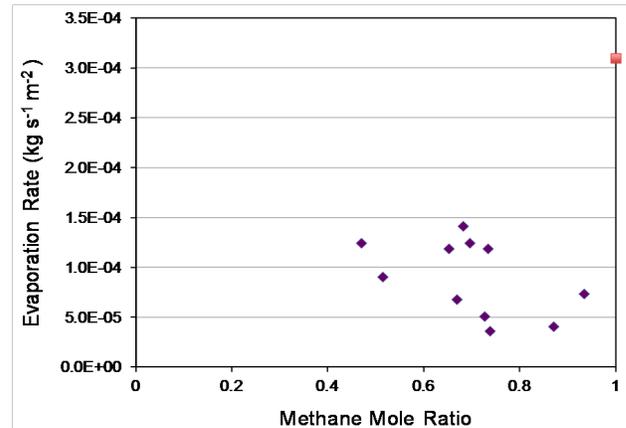


Figure 3. Relationship between evaporation rates and methane concentrations. The upper red dot in the right corner is the evaporation rate of pure methane.

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 with methane mole ratio concentrations less than 0.5.

Acknowledgements: This work was funded by NASA Grant project # NNX10AE10G.

References: [1] E.R.Stofan, et al. (2007) *Nature*, 445: 61. [2] C.A. Griffith, et al. (2012) *Nature*, 486: 237-239. [3] Turtle, et al. (2011) *Science*, 331, 1414-141. [4] D. Cordier, et al. (2011) *PSS*, 3101. [5] G. Mitri, et al. (2007) *Icarus* 186, 385-394. [6] A. Luspay-Kuti, et al. (2012) *43rd LPSC*, 2408. [7] A. Luspay-Kuti, et al. (2011) *42nd LPSC*, 1736. [8] F. C. Wasiak, et al. (2011) *42nd LPSC*, 1322. [9] A. Luspay-Kuti, et al. (2012) *Geophys. Res. Lett.*, 39.