

EXPERIMENTAL RESULTS OF EVAPORITE DEPOSITS ON TITAN USING A SURFACE SIMULATION CHAMBER. E. Czaplinski¹, K. Farnsworth¹, D. Laxton¹, V. Chevrier¹, M. Heslar², S. Singh³. ¹University of Arkansas, Center for Space and Planetary Sciences, Fayetteville, AR 72701. ²Department of Astronomy, University of Florida, Gainesville, FL 32611. ³Bear Fight Institute, 22 Fiddlers Rd, Winthrop, WA 98862. (ecczapli@email.uark.edu).

Introduction: Ontario Lacus, the largest southern latitude lake on Titan, is thought to contain evaporite deposits that would form an annulus around the rim of the lake. Concentric, 5 μm -bright deposits were discovered from VIMS data, and are interpreted to have a composition that is poor in water ice and possibly of organic origins [1][2][3]. Although evaporites have also been found in the north polar region where most of the surface liquid is located, the largest deposits by surface area are located in the Tui and Hotei Regios, closer to midlatitude [4][5].

Good candidates for evaporite composition include: benzene (C_6H_6) [6][7], acetylene (C_2H_2) [3][8][9], ethylene (C_2H_4) [10], butane (C_4H_{10}) [3][8], acetonitrile (CH_3CN) [11], and cyanoacetylene (C_3HN) [9]. These evaporites would exist in mixtures with methane (CH_4) and ethane (C_2H_6) in the lacustrine regions of Titan, which we recreate in the lab with our Titan simulation chamber. Current data primarily focuses on theoretical data and lacks a complete understanding of Titan's evaporites, including their composition, how they alter the spectra of the lakes, their depth, order of precipitation (for solutions with multiple solutes), and whether or not new compounds form as a result of deposition.

We present preliminary evaporation data on C_2H_4 and C_2H_2 within mixtures of CH_4 or C_2H_6 . Determining the exact compositions of these evaporite deposits will ultimately help us better understand the cycling of solid organics on Titan and how the lakes evolve over time.

Methods: The University of Arkansas owns a specialized Titan simulation chamber that reproduces the same conditions present on Titan's surface (Fig. 1). A 1.5 bar "atmosphere" is maintained by constant flow of N_2 gas during the experiments. Temperatures of 90 K – 94 K are reached with the use of liquid N_2 . The chamber is made of stainless steel with a height of 2.08 m and internal diameter of 0.61 m [12]. Liquid N_2 flows through copper cooling coils and cryogenic lines that surround the chamber and temperature control box (TCB), allowing temperatures to decrease drastically.

A petri dish covered in Spectralon sits at the bottom of the TCB and is connected via nylon wires to a balance that rests on top of the TCB. Below the balance is the TCB, where the experiments are performed. The TCB includes a condenser, which condenses the gas samples to liquids at their specific boiling/freezing

points. A solenoid valve is connected to the bottom of the condenser, allowing the liquid samples to exit and remain on the petri dish where they are spectrally analyzed via Fourier transform infrared spectroscopy (FTIR) probes connected to a Nicolet 6700 FTIR (wavelength 0.4 – 2.5 μm).

Temperatures are constantly monitored via eight thermocouples placed throughout the chamber. Titan surface temperatures (90 K – 94 K) are sustained after the mixture is poured onto the petri dish, in order to determine which mixtures evaporate at Titan temperatures. New spectra is taken every few minutes with 250 scans via Omnic software.

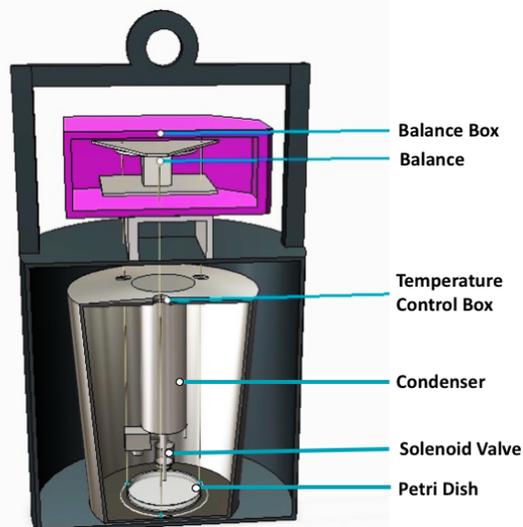


Figure 1: A 3D schematic of the Titan simulation chamber created in Autodesk 123D Design. Courtesy of D. Laxton.

Results and Discussion: Preliminary data for these experiments focuses on FTIR spectra of different mixtures of solutes ($\text{C}_2\text{H}_4/\text{C}_2\text{H}_2$) in solvents ($\text{CH}_4/\text{C}_2\text{H}_6$). Comparisons will be made between individual spectra and mixtures of the same compounds, as well as identifying any differences among spectra when different solutes are present. Here, we present data on the evaporation of $\text{C}_2\text{H}_4/\text{C}_2\text{H}_6/\text{CH}_4$. One important aspect to keep in mind are the VIMS atmospheric windows through which the atmosphere is partially transparent and these evaporites can be detected (0.93, 1.08, 1.27, 1.59, 2.01, 2.7-2.8, and 5.0 μm) [13]. Since our FTIR spectrum only extends to 2.5 μm , we are not able

to detect any features that would be seen at the 2.7-2.8 μm and 5.0 μm windows.

Evaporite detection requires that the solvent (CH_4 or C_2H_6) evaporates gradually, leaving behind some residual solute (in this case C_2H_4 or C_2H_2). It is undesirable for the entire mixture to evaporate at the same time (Fig. 2A), because no residual solute remains, preventing us from obtaining any further information on the evaporite species of that experiment. Figure 2B represents the ideal situation, where we observe the solvent ($\text{CH}_4/\text{C}_2\text{H}_6$) evaporating, while the C_2H_4 signatures (1.64 μm and 2.12 μm) retain their band depths.

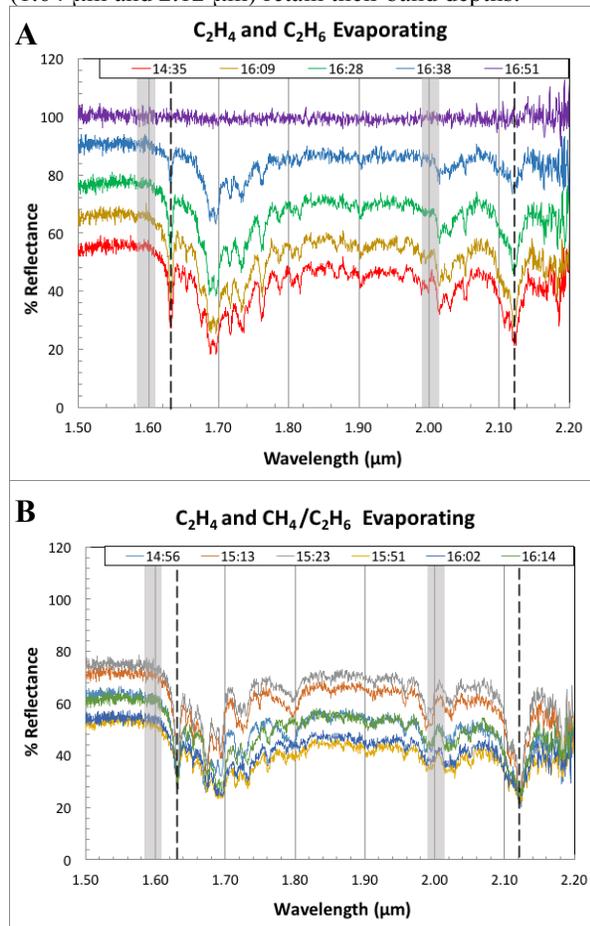


Figure 2: A) Spectra of C_2H_4 and C_2H_6 evaporating at the same rate. C_2H_4 is indicated by absorbances at 1.64 μm and 2.12 μm (dashed lines). VIMS atmospheric windows are shown with gray rectangles centered at 1.59 μm and 2.01 μm . B) Spectra of $\text{CH}_4/\text{C}_2\text{H}_6$ evaporating while leaving behind C_2H_4 (dashed lines). C_2H_4 band depths do not evaporate with the $\text{CH}_4/\text{C}_2\text{H}_6$ evaporation.

Although the spectra in Fig. 2B shows evaporation of only $\text{CH}_4/\text{C}_2\text{H}_6$, and we indeed retain most of the C_2H_4 signatures, this experiment was still non ideal due to the fact that a decent amount of $\text{CH}_4/\text{C}_2\text{H}_6$ remains in the mixture after evaporation. These conditions were

caused by adding C_2H_6 between the series labeled “15:23” and “15:51.” Prior to the C_2H_6 addition, this experiment consisted of solely CH_4 and C_2H_4 . As we continue to fine-tune our techniques, experiments will be performed more accurately, yielding higher quality results.

Conclusion: By using a Titan surface simulation chamber at the University Arkansas, we have been able to obtain preliminary results simulating the lake compositions and further, residual evaporite deposits that could potentially be detected through VIMS atmospheric windows. Our results show that C_2H_4 is a good primary candidate for evaporite deposits, because it can be dissolved and evaporated in C_2H_6 (Fig. 2A) or a mixture of CH_4 and C_2H_6 (Fig. 2B). Future experiments will focus on analyzing additional solutes including: acetylene (C_2H_2), benzene (C_6H_6), butane (C_4H_{10}), acetonitrile (CH_3CN), and cyanoacetylene (C_3HN). Further, we plan to condense mixtures with multiple solutes (e.g. C_2H_2 and C_2H_4) combined with $\text{CH}_4/\text{C}_2\text{H}_6$ (Fig. 3). These mixed solute experiments will better represent the extant lacustrine environments on Titan.

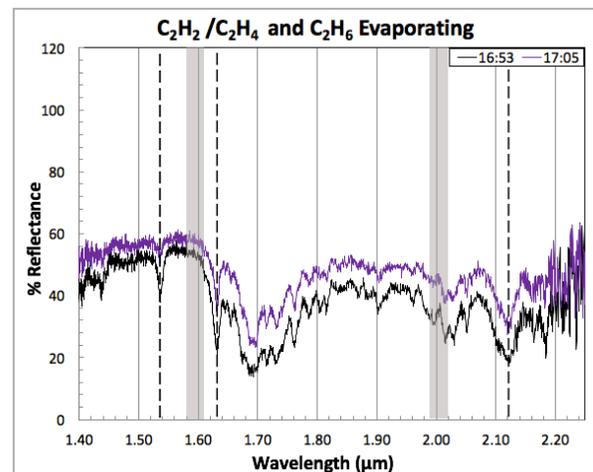


Figure 3: Mixture of C_2H_2 , C_2H_4 , and C_2H_6 . C_2H_2 is detected at 1.54 μm , C_2H_4 at 1.64 μm and 2.12 μm .

References: [1] Barnes, J.W. et al. (2009a) *Icarus*, 201, 217-225. [2] Barnes, J.W. et al. (2011) *Icarus*, 216, 136-140. [3] Cordier, D. et al. (2013) *Icarus*, 226, 1431-1437. [4] Moore, J.M. and Howard, A.D. (2010). *GRL*, 37, L22205. [5] MacKenzie, S.M. and Barnes, J.W. (2016) *Astrophysical Journal*, 821, 1-13. [6] Vu, T. et al. (2014) *J. Phys. Chem*, 118, 4087-4094. [7] Cable, M.L. et al. (2014) *GRL*, 41, 1-6. [8] Cordier, D. et al. (2016) *Icarus*, 270, 41-56. [9] Singh, S. et al. (2016) *Astrophysical Journal*, 828, 1-8. [10] Singh, S. et al. (2015) *LPSC MMXV*, Abstract #1626. [11] Leitner, M. et al. (2014) *LPSC MMXIV*, Abstract #2658. [12] Wasiak, F.C. et al. (2012) *Adv. Space Res.* [13] Sotin, C. et al. (2005) *Nature*, 435, 786-789.