EXPERIMENTAL STUDIES OF ETHYLENE AND BENZENE EVAPORITES ON TITAN.
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Introduction: Titan’s dynamic lakes of liquid methane/ethane have intrigued scientists for over a decade. Using the Visual Infrared Mappig Spectrometer (VIMS) onboard Cassini, regions described as 5-µm-bright were first observed in the Xanadu (110°W, 15°S) and Tseghi (15°W, 40°S) Regios [1]. In-depth studies of these 5-µm-bright regions have concluded that they are non-water ice materials, similar to the 5-µm-bright signatures found in the Tui and Hoteli Regios (near 25°S) [2]. A 5-µm-bright ring was also found around Ontario Lacus [3,4]. Described as “bathtub rings” of low water ice condensates, they may have been deposited in the past when lake levels were higher. Further, VIMS observations identified additional 5-µm-bright annuli surrounding many empty north polar lakes [5,6]. Combined, these observations provide the foundation on which evaporites can be studied on Titan.

Current evaporite studies focus on models and theoretical work [7,8], but some experimental work is also being undertaken to constrain potential solvents and solutes that may be active in evaporite production [9,10]. This study expands the compounds studied by analyzing both ethylene and benzene evaporites.

Methods:
Simulation Chamber: The University of Arkansas owns a specialized Titan simulation chamber that reproduces the same conditions that are present on Titan’s surface [11]. This chamber is unique in that it provides real-time experimental data on the composition of Titan’s lakes. The chamber is made of stainless steel with a height of 2.08 m and internal diameter of 0.61 m. A 1.5 bar atmosphere is maintained with N₂. Temperatures of 90 K – 94 K are reached with the use of a liquid nitrogen refrigeration system. Liquid nitrogen flows through copper cooling coils and cryogenic lines that surround the chamber and temperature control box (TCB). The TCB is cooled using this method, while the rest of the chamber serves to maintain the atmospheric pressure of 1.5 bar.

Compounds in gaseous phase at room temperature (CH₄, C₂H₆, C₂H₄) are contained in gas cylinders, and introduced to the condenser via gas lines. C₆H₆, however, is a liquid at room temperature, so an Erlenmeyer flask was modified and connected to the condenser. N₂ is bubbled through the Erlenmeyer flask for ~10 min until the N₂ is saturated with respect to C₆H₆. Then, the line to the condenser is opened, which allows N₂ to carry gaseous C₆H₆ into the condenser where C₆H₆ condenses in the solid phase. After the compounds are added to the condenser and given time to condense and dissolve into a mixture, a solenoid valve is turned on, which allows the sample to be transferred from the condenser to the petri dish at the bottom of the chamber. The petri dish is covered with a layer of Spectalon® reflectance material, which serves as a background for two way transmission infrared spectral measurements. Here, the sample is analyzed via Fourier transform infrared (FTIR) spectroscopy probes connected to a Nicolet 6700 FTIR (wavelength 1–2.5 µm).

Spectral Unmixing Model: Various spectra of the pure compounds (CH₄, C₂H₆, C₂H₄, C₆H₆) were recorded before use in experiments. Any compound mixture should have a spectrum that is some combination of the spectra of its parts. A Python code was written to decompose a given spectrum into a best fit of pure spectra added together. This provides the weighted composition of the mixture through the evaporation process. For compound spectra (C) with i components, the Python code would break C down into pure spectra (P) as follows:

\[ C = A + \sum_{i} w_i P_i \]

The A term allows for a constant offset to be applied, as the spectra tends to increase in reflectance over the time of the evaporation process. The weight of a pure spectrum (w) is normalized so the sum adds to 100%. This unmixing process is similar to previous studies [9], but is an original process for these experiments.

Results and Discussion:
Ethylene: Three different experiments were analyzed for C₂H₄ evaporites: CH₄/C₂H₄ (Fig. 1, 2), C₂H₆/C₂H₄, and CH₄/C₂H₆/C₂H₄. Through band depth measurements, mass data, and spectral data, we determined that a solid C₂H₄ evaporite deposit only formed in the CH₄/C₂H₄ experiment (Fig. 1A). This is due to the fact that CH₄ evaporates at Titan surface conditions, thus CH₄ evaporated in the conditions of our chamber. Band depth measurements confirm this evaporation, as the CH₄ band depths decreased to zero throughout the experiment, while C₂H₄ band depths increased because of an increase in reflectance (Fig. 2). We also observe horizontal band shifts in the characteristic C₂H₄ absorptions (1.64 and 2.12 µm) (Fig. 1B, 1C). This band shift...
represents a phase change of the mixture from liquid phase to solid phase.

![Figure 1: Spectra from the CH4/C2H4 experiment. (A): Initial spectrum is shown in red, final spectrum is shown in blue. (B), (C): Zoom of the 1.64 μm and 2.12 μm C2H4 band to show horizontal shift to longer wavelengths.](image)

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![Figure 2: Band depth results for the CH4/C2H4 experiment. CH4 band depths (blue) decrease to 0, while C2H4 band depths (black) increase.](image)

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**Benzene:** The C6H6 data presented here represents one experiment of both C6H6/C2H6. Using spectral data acquired from this experiment, we were able to produce a model (described in methods section) of a best fit spectrum to compare the experimental spectrum to (Fig. 3). Similar to the C2H4 experiment, the initial and final spectra were compared with each other to determine if the mixture evaporated. Figure 3 shows that from (A) to (B), the percentage of C6H6 in the spectra decreased from 92.67% to 84.82%. This can be interpreted in one of two ways: 1) the C2H6 evaporated or 2) the C2H6 and C6H6 formed a co-crystalline structure [10]. We are still in the process of analyzing this data to more accurately constrain these answers.

**Conclusions:** Under Titan conditions, we have experimentally formed C2H6 evaporites in a solution of CH4. The formation of the C2H6 evaporite is confirmed by observations of spectral data and band depth measurements. We also observe a horizontal band shift to longer wavelengths in the characteristic C2H6 bands.

Although still preliminary, we have detected C6H6 in the C6H6/C2H6 experiments and have observed a decrease in the abundance of C2H6. This data is being analyzed to determine if the decrease in C2H6 is due to evaporation, or the formation of a co-crystal of C2H6/C6H6. Future work includes additional experiments of C6H6/C2H6 as well as CH4/C2H4 experiments.

![Figure 3: Spectra from one experiment of C2H6/C4H6. Experimental data (blue) is compared to our model data (orange) to determine specific percentages of each compound. Initial spectrum is shown by (A) and final spectrum is shown by (B).](image)

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**References:**