INFRARED STUDY OF HYDROCARBON MIXTURES UNDER TITAN SIMULATED CONDITIONS.

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Introduction

Titan is the only body other than Earth in our Solar System with thick atmosphere and surface liquid. It has been suggested that Titan has an active hydrological cycle expressed at the surface by the presence of lakes and seas [1]. The average surface temperature is 94K which allows methane and ethane to be liquid on Titan. Photodissociation of the methane in the upper atmosphere produces several other hydrocarbons such as propane, hydrogen cyanide, butane, acetylene, etc… [2]. The Cassini Visual and Infrared Mapping Spectrometer (VIMS) have obtained spectral data over Ontario Lacus displaying a possible absorption feature at 2 μm interpreted as liquid ethane inside the lake [3]. Other possible absorption feature at 5 μm, attributed to various hydrocarbons or nitriles along the margin of Ontario Lacus [4]. The detection of the other compounds in lakes remains challenging, due to the presence of methane in the atmosphere, which absorbs all the solar radiation except at few wavelengths known as atmospheric windows. Several hydrocarbons exist as solids and can be dissolved in liquids and/or cover Titan's surface [2], but Infrared reflectance spectra acquired in Titan's surface conditions would allow their potential detection using VIMS data, are often lacking.

We investigated several hydrocarbons to characterize the infrared properties of Titan's liquids and ices. Spectra are then quantitatively analyzed and used to show the presence/absence of these compounds during evaporation/sublimation processes

Methods

We use a Titan simulation chamber, a detailed explanation is given by [5]. Titan module is purged with N2 gas to get rid of any contamination and also to simulate Titan atmospheric pressure of 1.5 bar. Using liquid N2 with coils around the Titan module, we bring down the temperature to Titan surface temperature range (90-94K). The samples are condensed and poured on a sample pan and are monitored continuously via *In situ* FTIR and weighed to record the loss of mass over time.

A version of Nicolet 6700 Smart Diffuse spectrometer with N2 purge gas is used to collect infrared spectra. *In situ* data are acquired via a fiber optics operating from 1.0 to 2.5 μm with a spectral resolution of 4cm^{-1}. This wavelength range allows to cover 4 of the 7 atmospheric windows, centered at 1.08, 1.27, 1.59, 2.01 μm, resolved by VIMS instrument [6]. Unfortunately some of them are not included in our data centered at 2.7-2.8 and 5 μm, where tentative composition mapping have been realized [7,8,9,10].

Spectral Analysis

Using our operating chamber, we are able to synthesize liquid and solid hydrocarbons, and to monitor their infrared spectral properties under Titan simulated conditions. We already measured infrared spectra of liquid methane, liquid ethane, liquid methane-ethane mixture and acetylene ice [11]. These spectra acquired along with new spectra of liquid propane, liquid propane-methane and butane-ethane are represented on fig. 1

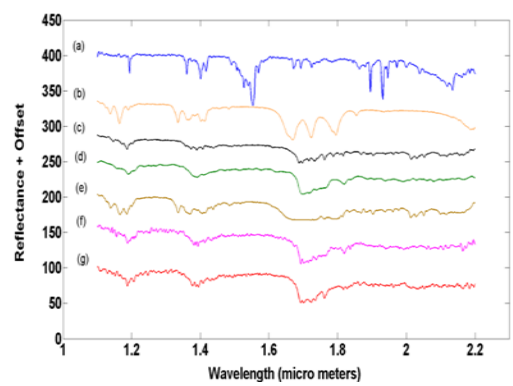

Figure 1: Infrared spectra of different hydrocarbons under simulated Titan chamber. (a) Acetylene (C_2H_2), (b) methane (CH_4), (c) ethane (C_2H_6), (d) propane (C_3H_8), (e) mixture of methane and ethane (CH_4 & C_2H_6), (f) mixture of propane and methane (C_3H_8 & CH_4), (g) mixture of butane and ethane (C_4H_{10} & C_2H_6).

The positions of methane and ethane absorption bands in our spectra are consistent with those measured by [12]. Methane absorptions bands are centered at 1.16, 1.33, 1.41, 1.66, 1.72, 1.79 and 1.85 μm. Hydrocarbons possessing a higher number of carbon atoms are more complex to characterize due to the high abundance of spectral absorption feature. Liquid ethane possesses a large number of absorption bands, some of which are centered at 1.14, 1.18, 1.36,

1.44, 1.68, 1.76, 1.80, and 2.0 μm. The absorption bands of ethane in 2.0 μm region have been used to potentially identify liquid ethane in Ontario Lacus spectra [3].

In propane the absorption bands are centered at 1.15, 1.19, 1.39, 1.69, 1.81 μm. In Fig. 1(e), we were able to see combined methane and ethane absorptions bands. At 1.6 μm the mixture spectra is saturated with methane. Two different compounds were separately identified using non-overlapping absorption bands, such as 2.0 μm absorption bands for ethane and the most of the shorter wavelengths bands for methane. In Propane and methane mixture (Fig. 1f), we were also able to detect several combined unsaturated absorption bands centered at 1.19, 1.38, 1.70, 1.80 μm. In butane and ethane (Figure 1g), the absorption bands are centered at 1.18, 1.2, 1.37, 1.69, 1.76, 2.0 μm.

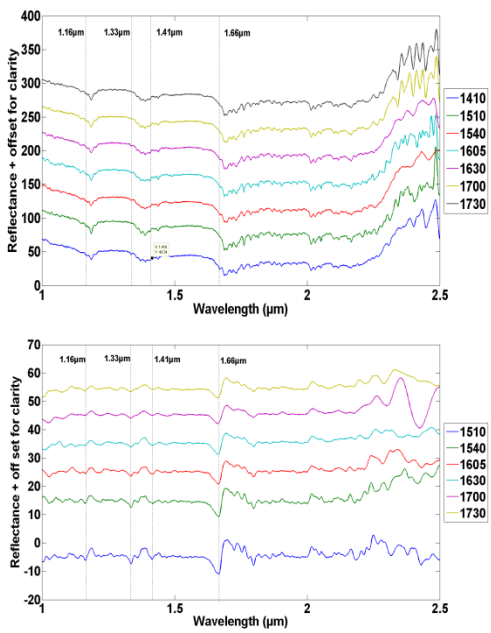

Figure 2: Top: FTIR spectra of liquid methane-ethane spectra over time span of 3 hrs. (Time shown is legend). Bottom: same spectra after removing ethane, methane absorption bands tend to decrease in band depths.

Results

Abundance of a given compound is directly linked to the depth of an absorption band. In a mixture of methane and ethane, we computed the absorption band depths of each compound along the time with the formula given in Massé et al [13] Fig. 2. Band depth with time is used to constrain the presence/absence of the liquids or ices in the module. In fig.2 top methane absorption bands were overlapped with ethane absorption band. After subtracting ethane spectra from mixture we were able to identify the methane absorption bands (fig. 2 bottom). Over the time span of three hours we were able to evaporate methane out of the liquid mixture. As seen in fig. 2 bottom we can see band depths of the methane absorption bands decreasing and are centered at 1.16, 1.33, 1.41, 1.66 μm. In fig. 2 top, the band depth at 1410 increases during the pour of methane into sample pan. The band depths at 1540 and all the others are decreasing, which proves the methane is evaporating. Adrienn et al. [14] have discussed the evaporation rates of methane and possible methane mixtures by monitoring mass and temperature data of the simulated chamber.

Discussion

Infrared data acquired using the FTIR implemented in the Titan module can be used as a second checking of the evaporation of these compounds, owing to the direct identification of the presence/absence of their absorption bands in the infrared spectra. Future work will include the determination of the evaporation rates using Infrared data. Further experiments on liquid and solid hydrocarbons and the interactions containing dissolved compounds will be useful to understand the dissolution process that model the surface of Titan. FTIR measurements of these experiments will help us follow the evaporation/sublimation of some hydrocarbons on Titan's surface. Such laboratory data will also be helpful to interpret the data acquired by VIMS imaging spectrometer on Cassini spacecraft.

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