SOLUBILITY OF ETHYLENE AND ACETYLENE IN LIQUID METHANE AND ETHANE. S. Singh[1], Z. McMahon[1], V. F. Chevrier[1], J. P. Combe[2], [1]Arkansas Center for Space and Planetary Science, University of Arkansas, Fayetteville, AR, 72701 (sxs099@uark.edu), [2]Bear Fight Institute, Winthrop, WA

Introduction:

Since the arrival of the Cassini-Huygens mission into the Saturn system in 2004, strong indicators of the presence of liquid bodies have been found on Titan's surface near the poles [1][2][3]. Titan possesses a thick atmosphere that is mainly composed of N_2 and CH_4. It also experiences an active methane cycle, in many ways similar to the water cycle on Earth [3][4]. Large reservoirs of liquid have been identified, and the observed lake morphologies in Cassini's data, by comparison with similar terrestrial landforms encountered in semi-arid regions suggesting that the lakes lie in a depression formed by dissolution of a surface soluble porous layer [5].

The photochemical model of [6] argues that lake composition is dominated by ethane (C_2H_6)(more than 70%), propane (C_3H_8)(7-10%), and methane (CH_4)(5-10%) in which some solid compounds can be dissolved if thermodynamic equilibrium between the lake and the atmosphere is assumed. Some of these main solutes are acetylene (C_2H_2) and ethylene (C_2H_4). Photochemical and thermodynamic models [6][7], as well as the potential detection of hydrocarbon compounds on Titan's surface [8], provide evidence about the potential solutes existing in Titan's lakes.

Using these studies, we aim at realizing experiments to constrain and to determine the solubility of solid C_2H_2 and C_2H_4 by simulating Titan's surface with a liquid enriched with a soluble organic compound in CH_4 and C_2H_6. We also determined if the soluble compounds can be detected by conventional FTIR reflectance spectroscopy methods (Cassini VIMS).

Methods:

The facility used for the experiments is specifically designed for simulating Titan surface conditions [9]. Pressure of 1.5 bar is maintained with N_2 gas and temperature of 90 to 94 K is maintained with liquid nitrogen. Organics compounds are condensed from gas phase in the condenser, and then washed with liquid hydrocarbons (CH_4 or C_2H_6) for approximately 5-10 minutes before being collected in a Petri dish. The Titan chamber is also connected to a Nicolet 6700 FTIR that acquires in situ IR spectra of the sample (range of 1 to 2.5 µm) via fiber optic. The sample mass is also continuously recorded to measure potential liquid mixture and evaporation processes [9]

Results:

First of all, we determined whether if C_2H_2 and C_2H_4 have any spectral difference in different phases. To identify these compounds in Cassini VIMS data it is important to know the spectral properties in both the liquid and solid phase. These compounds could be present under their liquid phase as dissolved solids in Titan lakes and in solid phase on the surface of Titan. We determined that one factor that changes in both C_2H_2 and C_2H_4 is reflectivity (Fig. 1). A reflectivity ratio (R_{solid}/R_{liquid}) of 1.13 for C_2H_2 and 1.50 for C_2H_4 was calculated. The ratio could potentially explain why Titan's lakes, supposed to bear dissolved materials such as C_2H_2 and C_2H_4 remain dark at all wavelengths while the evaporite-like deposits appear bright at all wavelengths.

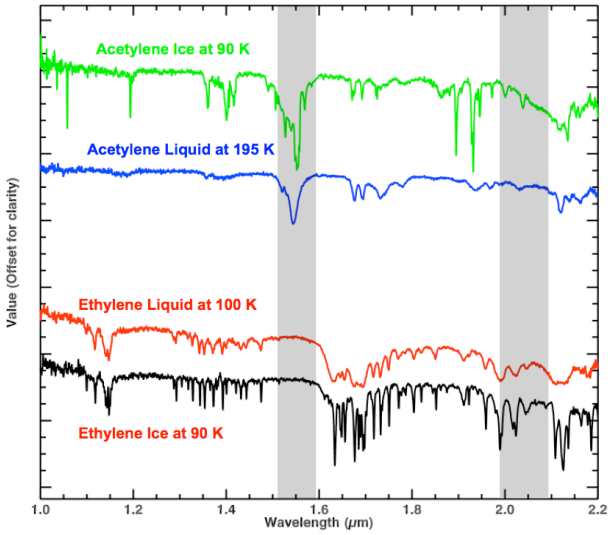

Figure 1: NIR spectra of $C_2H_2$and C_2H_4 in liquid and solid phase under Titan simulated surface conditions.

For the solubility of C_2H_2, our results show that NIR signature of dissolved C_2H_2 has partially disappeared except for the absorption band at 1.55 µm and a negative slope at 2.0 µm (Fig. 2A). The C_2H_2 bands are barely visible in the CH_4 mixture; which can be related to the amount of C_2H_2 present in liquid CH_4. The spectral features of C_2H_2 lie within the two largest VIMS atmospheric windows centered at 1.59 and 2.0 µm and can be potentially detected by VIMS (Fig. 2A). The solubility calculations show that the amount molar ratio of C_2H_2 dissolved in CH_4 is 4.9 x 10^{-2}.

In a similar type of experiment with the same amount of C_2H_2 in 10g of C_2H_6, different results are shown. Figure 2B shows the dissolution of C_2H_2 in liquid C_2H_6. Comparing C_2H_2 dissolution in CH_4, the solubility of C_2H_2 in C_2H_6 is significantly larger. The calculated solubility for C_2H_2 molar ratio in C_2H_6 is 20.2 x 10^{-2}. The mixture spectra of C_2H_2 and C_2H_6

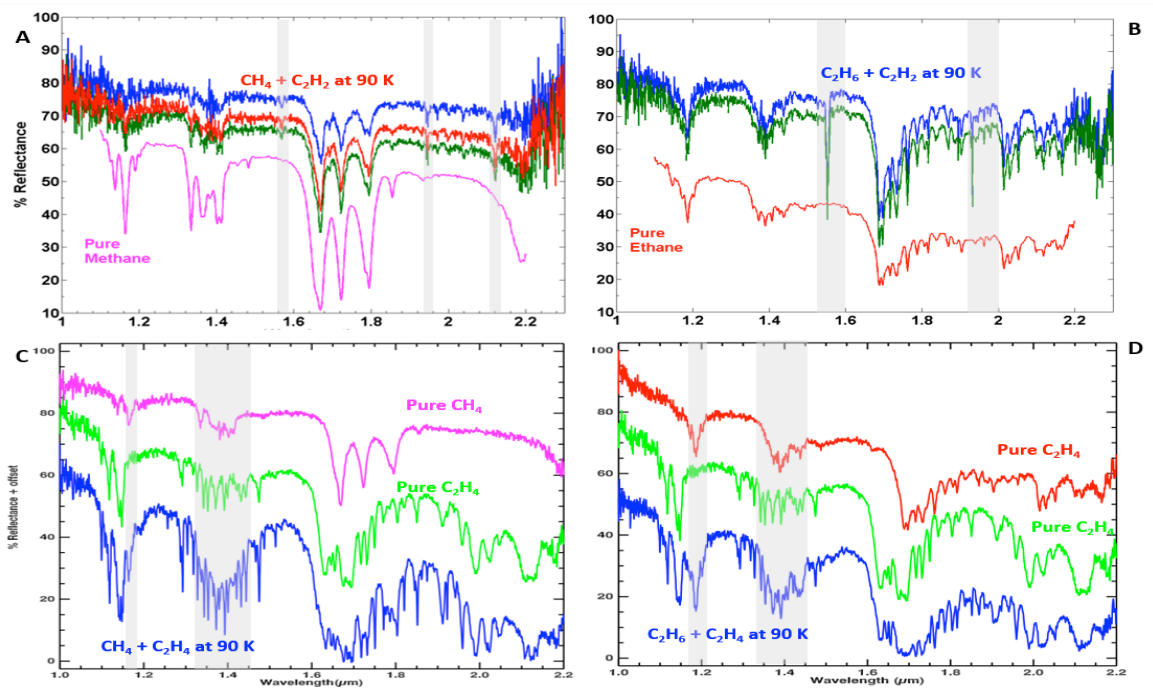

Figure 2: A) The NIR spectra of solid hydrocarbons dissolved in liquid CH_4 and C_2H_6 at 1.5 bar and 90 K. The shaded regions indicate the absorption feature of solid compound visible in mixtures. A) A mixture of $C_2H_2$and CH_4. B) A mixture of C_2H_2 and C_2H_6. C) A mixture of C_2H_4 and CH_4 with C_2H_4 and CH_4 spectra for comparison. D) A mixture of C_2H_4 and C_2H_6.

show several different absorption bands with higher band depth values than C_2H_2 and CH_4 mixture spectra. The NIR signature of C_2H_2 in C_2H_6 is easily differentiable and can be identified in 1.55 μm Cassini VIMS atmospheric window.

For C_2H_4 we performed similar dissolution experiments. Figure 2 C&D shows the NIR spectra of a mixture of C_2H_4 dissolved in CH_4 and C_2H_6. From the band depth calculations, it appears that C_2H_4 is equally soluble in both CH_4 and C_2H_6. We were able to resolve all the absorption bands of C_2H_4 in the mixture. C_2H_4 produces numerous absorption bands over the same region as CH_4 and C_2H_6. The C_2H_4 absorption bands covered a number of CH_4 and C_2H_6 absorption features. Provided the same time for C_2H_4 to dissolve in CH_4 and C_2H_6, the mixture seems to have an equal quantity of C_2H_4 present, indicating the similar solubility or within the same order of magnitude. The exact number for the solubility of C_2H_4 in CH_4 and C_2H_6 are being calculated using the spectral un-mixing model.

Conclusions:

We have successfully conducted several different experiments of C_2H_2 and C_2H_4 in liquid hydrocarbons under simulated Titan surface conditions. Our solubility spectra show that C_2H_2 is far more soluble in liquid C_2H_6 than in liquid CH_4. However, C_2H_4 seems to be equally soluble in both liquid CH_4 and C_2H_6. The exact number for C_2H_4 is being calculated using the spectral un-mixing model. This un-mixing model will provide the exact molar ratio of solute and solvent present in the mixture. The spectral features seen at 1.59 μm and 2.0 μm region lie within two of the VIMS atmospheric windows. Therefore, the absorption features seen in laboratory spectra are large enough to be potentially detected in VIMS data. The FTIR measurements used during these experiments will allow us to observe potential evaporite deposits of C_2H_2 and C_2H_4.

Acknowledgements:

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