Experimental Determination of the Solubilities of Organics and Rare Gases in Simulated Titan Lake Solutions. Robert Hodyss[1], Paul V. Johnson[1] and Isik Kanik[1]. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: The Cassini/Huygens mission has dramatically altered our understanding of the surface of Titan. Radar images of the surface reveal a wide variety of landforms, including lakes of methane or ethane near the poles, and other features clearly indicative of liquid erosion. The presence of liquid hydrocarbons on the surface of Titan naturally motivates questions about the solubility of surface materials in the liquid. Two classes of materials are relevant: the putative bedrock material of Titan (water, ammonia) and photochemically produced organics that precipitate from the atmosphere (acetylene, benzene, HCN). In addition, the solubilities of the rare gases Ar , Kr, and Xe are of interest on Titan as well. The solubilities of many of these materials in liquid methane/ethane solutions have been estimated theoretically, but have not been measured experimentally. We are performing initial measurements of the solubilities of these materials in liquid hydrocarbons in order to constrain the composition of the hydrocarbon lakes, and provide an understanding into the nature of erosion on Titan. This data is also necessary for the planning and execution of future in situ missions to Titan.

Widespread lakes were discovered on Titan by the Cassini mission in 2006. Radar images of the north pole of Titan show a number of sharp-edged, dark features, presumed to lakes of liquid hydrocarbons [1]. At Titan surface pressures and temperatures a mixture of liquid methane and photochemically produced ethane is the most likely liquid [2]. This mixture will serve as a solvent for the complex mixture of photochemical products formed in the upper atmosphere of Titan, which eventually fall to the surface. We report the solubilities of toluene and benzene in liquid methane and ethane. Benzene has been observed on Titan by the Cassini INMS [3] and by the Huygens probe [4]. We will also report on the solubilities of rare gases in liquid hydrocarbon mixtures.

Experimental Approach: We have used two different experimental approaches for the determination of solubilities in liquid hydrocarbons. Our first approach was to determine solubilities via ultraviolet (UV) absorption spectroscopy of solutions of liquid methane and appropriate solutes. UV was chosen over infrared (IR) as absorption band strengths for aromatic hydrocarbons (e.g. toluene, benzene) are stronger in the UV spectral region than in the IR, enabling more sensitive detection. Experiments were performed with a liquid nitrogen (LN2) cooled, fiber optic absorption cell, constructed for this purpose. In conjunction with an Ocean Optics fiber optic spectrometer equipped with a fiber coupled deuterium lamp, the system is capable of operating at wavelengths down to 200nm. Methane is condensed in the liquid cell, and the organic of interest added as a frozen powder until a saturated solution resulted, as indicated by a plateau in the absorbance of the solute. The concentration (c) of organic in the saturated solution was determined from the strength of a selected absorption band (A).

We measured the absorptivity (ε) of the organic solute as a function of temperature in hexane, a hydrocarbon with properties similar to that of methane. By determining the temperature dependence of the organic spectrum in hexane at temperatures from 283 K to 178 K (the freezing point of hexane), the band strength in methane at the surface temperature of Titan (~105 K) can be extrapolated. An example of this extrapolation is given in Figure 1 for toluene. Since the experiments were performed in the same liquid cell as the methane measurements, the absorption pathlengths (l) were identical. Assuming that absorptivity (ε) of the organic in hexane is the same as in liquid methane, Beer's law ($A = \varepsilon\ l\ c$) was used to determine the concentration of organic in solution.

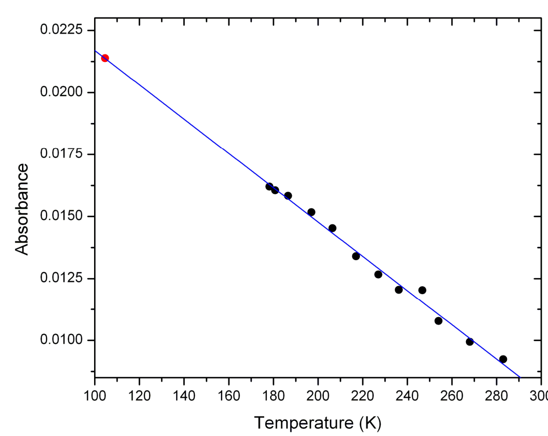

Figure 1. Absorbance at 269 nm of toluene in hexane at various temperatures. A linear extrapolation to 105 K, the approximate surface temperature of Titan, gives an absorbance of 0.214.

Since the rare gases do not exhibit an ultraviolet absorption spectrum, we developed a mass spectrometric method for determine the solubility of these species. A quadrupole mass spectrometer system fitted with a capillary inlet is used to "sip" hydrocarbon solutions that have been saturated with Ar, Kr, or Xe. The saturated solutions are made by first condensing the hydrocarbon, then bubbling the rare gas of interest through the solution until saturation is reached.

Results: Figure 2 gives the ultraviolet absorption spectrum of liquid methane saturated with toluene at an average temperature of 105 K. The absorbance of the 269 nm band was then used to determine the concentration of toluene in the solution. We arrive at a concentration of 0.018 mg/mL, or 6.8 6.8×10^{-6} mole fraction.

We will report on the solubilities of the rare gases and additional organic compounds at the meeting.

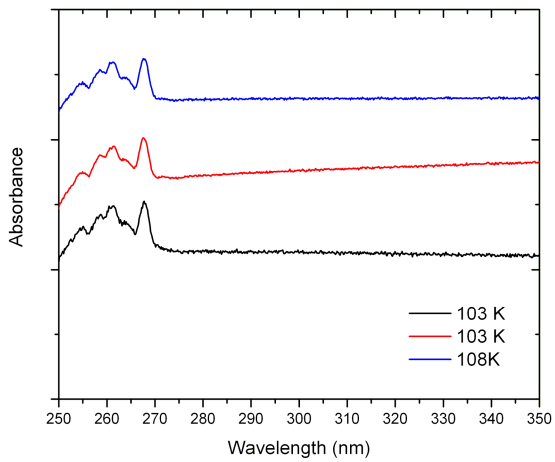

Figure 2. UV spectra of a saturated solution of toluene in methane (105 K average temperature).

References:
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[4] H. B. Niemann et al. (2005) *Nature*. *438* 779-784.