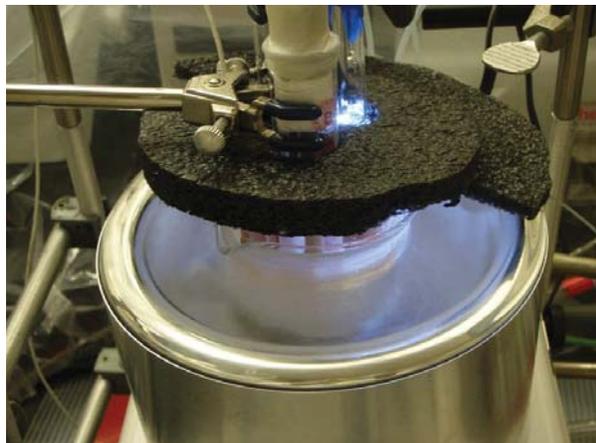


**LABORATORY INVESTIGATION OF BENZENE DISSOLVING IN A TITAN ETHANE LAKE.** M. Malaska and R. Hodyss, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA. ([Michael.J.Malaska@jpl.nasa.gov](mailto:Michael.J.Malaska@jpl.nasa.gov))

**Introduction:** The Cassini mission instruments have revealed that the geology of Titan is dominated by organic materials with erosive processes using hydrocarbon fluids [1-3]. Previous studies have identified possible karstic lakes [4], karst-like terrains and poljes [5], and evaporite deposits in dry lake beds [6]. These features may have resulted from the dissolution, transport, and evaporitic precipitation of Titan surface materials.

Theoretical estimates of the equilibrium solubilities of many proposed Titan materials in hydrocarbon liquids at 94 K are comparable to common terrestrial karst-forming materials in water at 298 K [7, 8]. However, the kinetics of dissolution in hydrocarbon liquids at 94 K – the time it takes to get to equilibrium, has not been measured. Our goal was to construct a laboratory apparatus that would enable the measurement of the kinetics of dissolution and the saturation concentration of organic materials under Titan conditions.

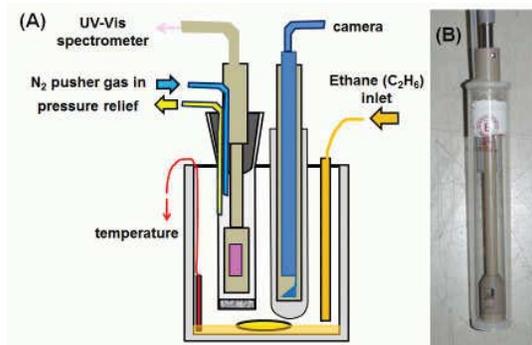
Our initial experiments focused on the determination of the solubility of benzene ( $C_6H_6$ ) in ethane. Benzene has been estimated to account for up to 5% of the surface materials on Titan [2]. The ability or inability of benzene to dissolve in hydrocarbon solution would help constrain the surface processes and lake compositions [9]. Benzene will also serve as a benchmark for other organic compounds of interest with either higher or lower theoretical solubilities.



**Figure 1.** Apparatus for measuring solubilities under Titan conditions. Fritted tube clamped at top center. Beaker containing solution at center, surrounded by a liquid nitrogen filled Dewar. Bluish glow emanating from the interior is from the endoscope LED illumination.

**Apparatus:** At the core of our experimental set up is a heavily parameterized 150 mL beaker that we have

affectionately called "FrankenBeaker" (Figure 1). This beaker sits inside a larger 250 mL beaker that is half-filled with sand. The 250 mL beaker is placed in an 850 mL wide-mouth Dewar that is filled with liquid nitrogen. The sides and bottom of the 150 mL beaker are wrapped with heating wire held in place with Kapton tape. The temperature of the fluid in the central beaker is measured with a platinum resistance thermoelectric detector coupled with a proportional-integrative-device controller that allows a constant temperature to be maintained by balancing the buffered cooling from the surrounding liquid nitrogen bath. Held inside the 150 mL beaker is a 20 mm diameter glass tube with a glass frit of 70-100 micron porosity (Figure 2). The fritted tube contains an Ocean Optics UV-Vis fiber-optic probe for in situ analysis [10]. The fritted tube assembly is sealed using a combination of foam, Teflon tape, and parafilm. Passing through the seal are two lines, one serving as a nitrogen gas inlet, the other tube as a vent to a gas bubbler. Nitrogen pressure is used to purge the fritted tube and the vent allows the test solution to refill the tube through the glass frit. The 150 mL beaker also contains a stir bar and an Oasis Scientific endoscope camera protected by a test tube. The endoscope permits viewing of the solution level in the fritted tube (Figure 3). The entire apparatus is enclosed in a large glove bag continually purged by nitrogen gas.



**Figure 2.** A) Diagram showing parameterization of internal 150 mL beaker. B) Photo of fiber optic UV-Vis probe in a 20 mm diameter fritted tube. Lines for the nitrogen inlet and exit port are visible.

**Experimental:** In a typical experiment run, 120 mL of ethane is condensed into the central beaker using a plastic tube. The condensation takes place in a pure nitrogen atmosphere at approximately 160 - 180 K. The liquid is cooled to the set point at 94 K. In a chemical fume hood, a small amount of benzene is

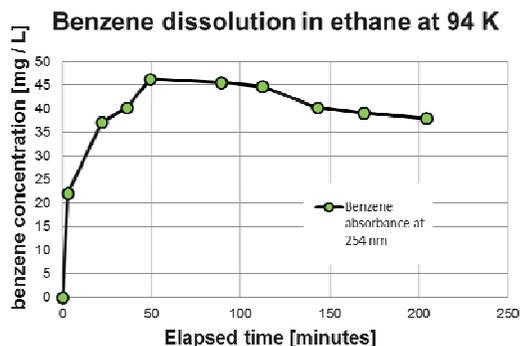
solidified using a liquid nitrogen bath. The waxy solid is scraped with a metal spatula to form a free-flowing white powder. Approximately 100 mg of powdered benzene is then transferred into the beaker containing the ethane.



**Figure 3.** Endoscope view showing the optical path length of the fiber-optic UV-Vis probe immersed in ethane at 94 K. The white cable cutting across the view is for the temperature probe. Volume markings on the 150 mL beaker are visible.

At key timepoints, the fritted tube containing the UV-Vis probe is purged with nitrogen gas and allowed to refill. As the tube refills, the solution passes through the frit and particulates are filtered out. Thus only dissolved materials are analyzed by the UV-Vis probe.

In a separate experiment, we determined the molar extinction coefficient of benzene in pentane over a concentration range from 730 mg/L to 7.3 mg/L at 298 K. If we assume that the extinction coefficient of benzene in pentane at 298 K is an approximation of the extinction coefficient in ethane at 94 K, we can use Beer's law to derive the absolute concentrations of benzene in our experiment.



**Figure 4:** Increasing concentration of benzene over time derived from the 254 nm UV absorbance signal.

**Results and Discussion.** The plot of derived benzene concentration over time shows a rapid increase in concentration followed by a leveling off after 50 minutes as equilibrium saturation is reached (Figure 4).

(A slow drop in signal after the initial plateau is due to a signal artifact from the UV-Vis fiber-optic probe at cryogenic temperatures.)

This demonstrates that solid powdered benzene dissolves in ethane solution at 94 K. Saturation is reached within 1 hour of exposure and attains a level of 45 mg/L in ethane. These values provide an upper limit to the amount of benzene that can be contained in solution in an ethane-composed Titan lake. That saturation occurs on a reasonable timescale suggests that the lakes can quickly achieve equilibrium when benzene deposits are rewetted.

This equilibrium value is roughly 3 times the 15.6 mg/L value predicted by theoretical calculations [8]. A value of 45 mg/L of dissolved benzene in ethane under Titan conditions can be compared to the 120 mg/L equilibrium solubility of amorphous silica in water. Since amorphous silica can form karst-like structures on Earth, it is reasonable to predict that benzene could also form karst-like structures on Titan, if ethane is the working fluid and given a suitable contact period and fluid flux.

**Conclusions:** An apparatus has been developed to measure the equilibrium solubilities and the kinetics of dissolution of Titan materials under Titan conditions.

We have used this apparatus to determine that benzene will achieve saturation equilibrium in roughly 1 h and with a value slightly higher than predicted by theoretical models. This measured value implies that benzene, and many of the other more-soluble surface materials may be capable of being dissolved and transported by Titan's surface fluids. These laboratory results suggest that karst-like processes could occur on Titan.

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