THE ORGANIC CLOUDS OF TITAN

CARL SAGAN and B. N. KHARE
Laboratory for Planetary Studies, Cornell University, Ithaca, U.S.A.

In the light of Voyager 1 Titan results, a mixture of 9 % CH_4 and 91 % N_2 was exposed for 10^7 s at a total pressure of 73 mb to high frequency electrical discharge. The gas phase products include NH_3, HCN, $(CN)_2$ and other molecules. Solid phase products, here called tholins, appear as a thin red film which, under scanning electron microscopy, is found to be comprised of irregular micron and sub-micron sized particles, with a preponderance of particles exhibiting a radius $\simeq 0.3\ \mu$m. The wavelength-dependent real part of their refractive indices $n \simeq 1.6 \pm 0.1$. These properties seem to be consistent with those deduced for the Titan aerosols from Earth-based observations (Rages and Pollack, *Icarus* **41**, 119, 1980). Values of $n(\lambda)$ and $k(\lambda)$, and the UV, visible and IR reflectivities of these tholins have been measured, and compared with the CH_4/NH_3 and $CH_4/NH_3/H_2S$ tholins described earlier (Khare *et al.*, *Science* **199**, 1199, 1978; Sagan and Khare, *Nature* **277**, 102; **292**, 536, 1979). The spectral reflectivity of this tholin has been measured between 0.38 and 1.1 μm. The tholin absorbs strongly between 0.38 and 0.60 μm, and in this wavelength range follows, within the probable errors, the measured reflectance of Titan. At longer wavelengths, where the CH_4 Kuiper bands become prominent, the tholin, not masked by CH_4 absorption, continues to increase in reflectivity. We find that the infrared absorption spectra or tholins we have previously reported on can be explained by a weighted linear superposition of the absorptions by the most abundant organic functional groups appearing as GC/MS pyrolyzates. The infrared spectrum of the Titan tholin is similar, and suggests that this material is a complex heteropolymer which contains, among others, nitrile and hydrocarbon functional groups. The infrared reflection spectra of the Titan tholin longward of 6 μm and in the near ultraviolet are flat and approximately featureless, consistent with Titan observational results from the International Ultraviolet Explorer and from the Voyager IRIS experiments, respectively. The Titan tholin may include polynitriles with hydrocarbon functional groups. It seems likely that the Titan clouds are composed, at least in part, of organic molecules, as proposed some years ago (Sagan, *Space Sci. Revs.* **11**, 73, 1971; *Icarus* **18**, 649, 1973; Khare and Sagan, *Icarus* **20**, 311, 1973). From the direct photolysis of methane alone by ultraviolet light at wavelengths shortward of 1440 Å, the accumulation of organic tholins on the surface of Titan over geological time amounts to a surface layer tens of meters thick. Other energy sources serve to increase this number. At the 95 K surface temperature of Titan these organic heteropolymers will tend to be preserved for very long periods of time. It is therefore possible that the surface of Tian is a planet-scale repository of some of the early steps which led on Earth – more than 4×10^9 yrs ago and in the presence of liquid water – to the origin of life. It is also conceivable that the abundant water ice in the interior of Tian (deduced from the satellite's bulk density) is intermittently released in liquid form to the surface, and that subsequent aqueous tholin chemistry occurs, even if episodically and on local scales.

Origins of Life **12** (1982) 280.