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THOLINS AS COLORING AGENTS ON PLUTO AND OTHER ICY SOLAR SYSTEM BODIES

Dale Cruikshank, dale.p.cruikshank@nasa.gov
NASA Ames Research Center, Moffett Field, California, United States

Tholins are refractory organic solids of complex structure and high molecular weight, with a wide range of color ranging from yellow and orange to dark red, and through tan to black. They are made in the laboratory by energy deposition (photons or charged particles) in gases and ices containing the simple molecules (e.g., N_2, CH_4, CO) found in planetary atmospheres or condensed on planetary surfaces. They are widely implicated in providing the colors and albedos, particularly in the region 0.3-1.0 μm, of several outer Solar System bodies, including Pluto (1), as well as aerosols in planetary atmospheres such as Titan (e.g., 2). Recent color images of Pluto with the *New Horizons* spacecraft show concentrations of coloring agent(s) in some regions of the surface, and apparent near-absence in other regions (3). Tholins that may to some degree represent surface chemistry on Pluto have been synthesized in the laboratory by energetic processing of mixtures of the ices (N_2, CH_4, CO) known on Pluto's surface, or the same molecules in the gas phase (4,5,6). Details of the composition and yield vary with experimental conditions. Chemical analysis of Pluto ice tholins shows evidence of amides, carboxylic acids, urea, carbodiimides, and nitriles. Aromatic/olefinic, amide, and other functional groups are identified in XANES analysis (5,6). The ice tholins produced by e^- irradiation have a higher concentration of N than UV ice tholins, with N/C $\sim$ 0.9 (versus $\sim$ 0.5 for UV tholins) and O/C$\sim$ 0.2. Raman spectra of the electron tholin show a high degree of structural disorder, while strong UV fluorescence indicates a large aromatic content. EUV photolysis of a Pluto gaseous atmosphere analog yields pale yellow solids relatively transparent in the visual, and with aliphatic CH bonds prominent in IR spectra (4). This or similar material may be responsible for Pluto's hazes. References: 1. Cruikshank, D. P. et al. 2005 Adv. Space Res. 36, 178 ; 2. Quirico, E. et al. 2008 Icarus 198, 218; 3. Stern, S. A. et al. 2015 Science 350 (6258) pp. 1815-1-8; 4. Imanaka, H. et al. 2014 DPS abstract 419.10; 5. Materese, C. K. et al. 2014 Ap.J. 788:111, June 20; 6. Materese, C. K. et al. 2015 Ap.J. 812:150, Oct. 20.