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Origin and Evolution of Titan's Nitrogen and Methane Atmosphere

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Titan acquired its nitrogen originally in the form of nitrogen compounds, most likely ammonia, as did the Earth. The extremely low upper limit of the heavy noble gases, especially xenon, found by the Huygens GCMS [1] supports this assertion. The conversion of ammonia to nitrogen must have taken place by photolysis by the solar UV early in Titan's accretionary heating phase [2], again as on primordial Earth. Production of N2 by shock induced dissociation of NH3 triggered by an impact [3] appears less likely, as the path to N2 may be short circuited by the hydrocarbon radicals and hydroxyl that are also produced inevitably in the shock chemistry. The present day nitrogen atmosphere of Titan is a relic of a much thicker atmosphere in the past, as indicated by the 14N/15N ratio [1, 4]. Methane, the second most abundant gas on Titan, comprises 5% by volume of the atmosphere. The source and production of methane is most likely in the interior of Titan. The proposed mechanism involves generation of H2 via serpentinization at low temperature followed by Fischer-Tropsch reaction between H2 and C, CO2 or CO in the crustal pores [5-8; 1]. Such a process could have taken place during Titan's accretionary heating phase, with methane stored as a stable clathrate-hydrate. The stored methane is subsequently released to the atmosphere either gradually over geologic time, or episodically during impacts, thus replenishing the methane lost to photolysis. Direct capture of methane (as methane clathrate) from Saturn's subnebula [6], instead of production on the satellite, seems less appealing in view of available data on the noble gases [1] and the CO/CH4 ratio [10]. References: [1] H. B. Niemann, et al., Nature 438, 779, 2005. [2] S. K. Atreya, et al., Science 201, 611, 1978. [3] C. P. McKay et al., Nature 332, 520, 1988. [4] H. W. Waite, et al., Science 308, 982, 2005. [5] S. K. Atreya, in Scientific American on-line article by G. Musser, http://www. sciam. com/ article. cfm?articleID=000CD50D-DA4A-1194-9A4A83414B7F0000&sc=I100322, 2004. [6] S. K. Atreya et al., Titan's methane cycle Abst. EGU, April 2005. [7] S. K. Atreya et al., Photochemical-Meteorological-Hydrogeochemical Cycle of Methane on Titan, Bull. Amer. Astron. Soc.37, 735. [8] S. K. Atreya et al., Titan's methane cycle, submitted to PSS 2005. [9] F. Hersant, et al., 52, 623, 2004). [10] K. H. Baines et al., CO on Titan, PSS, 2006.