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Chemical Composition of Titan's lakes: estimates and uncertainties

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Abstract

Between 2004 and 2007 [**?**] the instruments of the CASSINI spacecraft, orbiting within the Saturn system, discovered dark patches in the polar regions of Titan. These features are interpreted as hydrocarbon lakes and seas with ethane and methane identified as the main compounds. In this context, we have developed a lake-atmosphere equilibrium model allowing the determination of the chemical composition of these liquid areas present on Titan (see Table 1 for the nominal composition). Elaborated in the frame of the theory of regular solutions, this model is based on uncertain thermodynamic data and precipitation rates of organic species predicted to be present in the lakes and seas that are subject to spatial and temporal variations. Here we explore and discuss the influence of these uncertainties and variations. The errors and uncertainties relevant to thermodynamic data are simulated via Monte-Carlo simulations. Global Circulation Models (GCM) are also employed in order to investigate the possibility of chemical asymmetry between the south and the north poles, due to differences in precipitation rates. We find that mole fractions of compounds in the liquid phase have a high sensitivity to thermodynamic data used as inputs, in particular molar volumes and enthalpies of vaporization. When we combine all considered uncertainties, the ranges of obtained mole fractions are rather large (up to $\sim 8500\%$) but the distributions of values are narrow. The relative standard deviations remain between 10% and $\sim 300\%$ depending on the compound considered. Compared to other sources of uncertainties and variability, deviation caused by surface pressure variations are clearly negligible, remaining of the order of a few percent up to $\sim 20\%$. Moreover no significant difference is found between the composition of lakes located in north and south poles. Because the theory of regular solutions employed here is sensitive to thermodynamic data and is not suitable for polar molecules such as HCN and CH_3CN, our work strongly underlines the need for experimental simulations and the improvement of Titan's atmospheric models.

Table 1: Chemical composition of lakes at the poles and the equator.

	Equator (93.65 K)	Poles (90 K)
Main composition (lake mole fraction)		
N_2	2.95×10^{-3}	4.90×10^{-3}
CH_4	5.55×10^{-2}	9.69×10^{-2}
Ar	2.88×10^{-6}	5.01×10^{-6}
CO	2.05×10^{-7}	4.21×10^{-7}
C_2H_6	7.95×10^{-1}	7.64×10^{-1}
C_3H_8	7.71×10^{-2}	7.42×10^{-2}
C_4H_8	1.45×10^{-2}	1.39×10^{-2}
H_2	5.09×10^{-11}	3.99×10^{-11}
Solutes (lake mole fraction)		
HCN	2.89×10^{-2} (s)	2.09×10^{-2} (s)
C_4H_{10}	1.26×10^{-2} (ns)	1.21×10^{-2} (ns)
C_2H_2	1.19×10^{-2} (ns)	1.15×10^{-2} (ns)
C_6H_6	2.34×10^{-4} **(ns)**	2.25×10^{-4} **(ns)**
CH_3CN	1.03×10^{-3} (ns)	9.89×10^{-4} (ns)
CO_2	3.04×10^{-4} (ns)	2.92×10^{-4} (ns)

(s): saturated; (ns) non saturated.