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Titan's bulk composition constrained by Cassini-Huygens: Implication for internal outgassing

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Abstract

The origin of Titan's thick nitrogen atmosphere and the source of its present-day methane has long been debated. Measurements performed since 2005 by the Cassini-Huygens mission provide key constraints to determine what is the most likely scenario for the origin of this massive atmosphere and the recycling process of methane. In particular, *in situ* measurements performed during the descent of the Huygens probe by the Gas Chromatograph Mass Spectrometer (GCMS) has provided the first detection of argon as well as first estimates of the isotopic ratios in the major species (N_2 and CH_4) [1]. The GCMS measurements have been recently recalibrated by [2], resulting in a substantial revision of the data previously published by [1]. The present work is based on the revised values.

By using the data gathered by the Cassini-Huygens mission and experimental constraints on gas stability in water-rich environments, we provide upper and lower limits for the bulk content of Titan's interior for various gas species (CH_4, CO_2, CO, NH_3, H_2S, Ar, Ne, Xe). We show that most of the gas compounds (except H_2S and Xe) initially incorporated within Titan are likely stored dissolved in the subsurface water ocean. Our calculations indicate that the most abundant gas species is CO_2 (up to 4 % of Titan's total mass) and that the ammonia mass fraction should not exceed 0.5% (much less that what is commonly considered in evolution models). We predict that only a moderate fraction of CH_4, CO_2 and CO should be incorporated in the crust in the form of clathrate hydrates. By contrast, most of the H_2S and Xe should be incorporated at the base of the subsurface ocean, in the form of heavy clathrate hydrates within the high-pressure ice layer. Moreover, we show that the rocky phase of Titan is a likely source for the noble gas isotopes (^{40}Ar, ^{36}Ar, ^{22}Ne) that have been detected in the atmosphere. Our calculations show that a moderate outgassing of methane containing traces of neon and argon would be sufficient to explain the abundance estimated by the GCMS. The extraction process may explain why the $^{22}Ne/^{36}Ar$ ratio in Titan's atmosphere appears higher than the ratio in carbonaceous chondrites.

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References

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