VOLATILES ENRICHMENTS IN SATURN – PREDICTIONS FOR CASSINI. O. Mousis[1,2], Y. Alibert[2] and W. Benz[2], [1]Observatoire de Besançon, CNRS-UMR 6091, 41 bis, avenue de l'Observatoire, BP 1615 Besançon, France (Olivier.Mousis@obs-besancon.fr); [2]Physikalisches Institut, Universitaet Bern Sidlerstrasse 5, CH-3012 Bern, Switzerland (Yann.Alibert@phim.unibe.ch, Willy.Benz@phim.unibe.ch).

Introduction: We use the giant planets extended core-accretion model [1] and the clathrate hydrate trapping theory [2] to calculate the enrichments in O, C, N, S, Xe, Ar and Kr with respect to their solar abundances in Saturn's atmosphere. In the past years, abundances of C and N have been determined from ground-based observations [3] [4]. Thus, C and N were estimated to be enhanced by factors of ~ 2.85±0.95 and 2±0.5 in Saturn's atmosphere compared to their solar value, respectively. However, recent *Cassini* spacecraft measurements have led to a revision of C abundance in Saturn's atmosphere, which is now estimated to be 7±2 times the solar value [5]. As a result, this unexpected high C enhancement may lead to important changes in the calculations of the volatiles enrichments in Saturn's atmosphere, if we compare them with those calculated with the former value.

In the present work, we discuss the implications of both ground-based and *Cassini* measurements on the amount of ices accreted by proto-Saturn during its formation. In addition, from the calibration on the two existing measurements of C enhancement in Saturn, we derive the corresponding enrichments values of other volatile species with respect to their solar abundances. Some of these predictions may be tested by the *Cassini* spacecraft mission in a near future.

Formation of Saturn: The model of Saturn's formation considered here is based on the extended core-accretion formation approach described by [6] [7]. In this model, Saturn forms from an embryo with an initial mass of 0.6 $M_\oplus$ which is originally located at ~ 12 AU. The giant planet migrates inwards and stops at the current position of Saturn at the epoch when the disk has disappeared. The resulting planet exhibits an internal structure comparable to that of the actual Saturn [7].

Composition of planetesimals produced in Saturn's feeding zone: In this work, we assume that abundances of all elements are solar [8] and that O, C, and N exist only under the form of H_2O, CO_2, CO, CH_4, N_2, and NH_3 in the solar nebula gas-phase. We also adopt CO_2:CO:CH_4 = 30:10:1 and N_2:NH_3 = 1 in the solar nebula gas-phase, a range of values compatible with ISM measurements [9] [10] and with catalytic effects on the kinetics of the $N_2 \rightarrow NH_3$ chemical conversion, due to the presence of Fe grains in the gas-phase [11]. We also assume that volatiles have been trapped during the cooling of the nebula in planetesimals either in form of pure condensates or in form of hydrates or clathrate hydrates. Note that the amount of available water ice is assumed to be sufficient to trapp all volatiles, except CO_2. Once condensed, ices are assumed to decouple from the gas and to be incorporated into growing planetesimals which may subsequently be accreted by the forming Saturn. Figure 1 represents the cooling curves of the nebula at 9.8 and 12 AU derived from the extended core-accretion model [7], as well as the condensation curves for the various ices considered in this work. The stability curves of clathrate hydrates are derived from [2] whereas we used a fit to the experimental data for the pure CO_2 condensate [12]. Figure 1 provides the condensation sequence of the different volatiles initially existing in vapor phase inside Saturn's feeding zone. The intersection between the cooling curve and the stability curve of the different condensates also gives the thermodynamical conditions at which the different ices are formed. These assumptions allow us to calculate the composition of ices incorporated in planetesimals that were accreted by proto-Saturn. Since the composition of planetesimals does not vary significantly along the migration path of Saturn, we assume that all the ices of accreted planetesimals have an identical composition.

Enrichments in volatiles: From our Saturn formation model and in order to reproduce the ground-based C and N measurements, we show that C, N, S, Ar, Kr, and Xe are at least enriched respectively by a factor of about 1.9, 1.7, 1.4, 1.3, 1.4, and 1.7 compared to their solar values. This corresponds to an enhancement for O of at least 3 times the solar value in Saturn. Moreover, these enrichments result from the accretion of at least 4.7 $M_\oplus$ of ices in the giant planet.

On the other hand, 12.5 $M_\oplus$ of ices at least must have been accreted in Saturn in order to fit the revised value of C enhancement in its atmosphere. In that case, we obtain abundances of Ar, Kr, Xe, N, and S of respectively 3.5, 3.6, 4.4, 4.4, and 3.7 times their solar values. The resulting O enhancement would be then greater or equal to 8 times the solar value. The *Cassini* spacecraft mission may have the capacity to test some predictions.

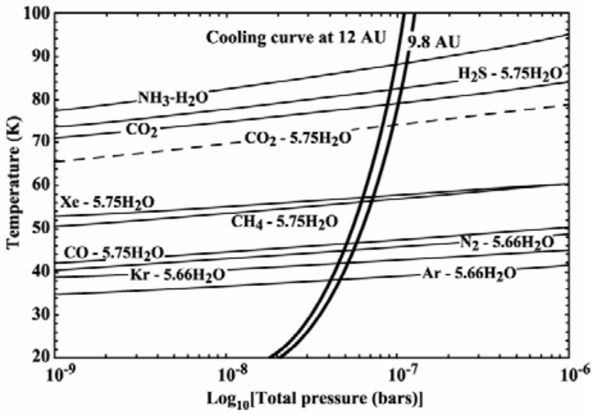

Figure 1: Stability curves of the condensates considered in the present work, and evolutionary tracks of the nebula at 12 and 9.8 AU. Abundances of various elements are solar, with CO_2:CO:CH_4 = 30:10:1 and N_2:NH_3 = 1 in vapor phase. The condensation curve of CO_2 pure condensate (solid line) is shown together with that of the corresponding clathrate hydrate (dashed line). Species remain in the vapor phase as long as they stay in domains located above the curves of stability.

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