HYDROGEN ABUNDANCES AND ISOTOPE COMPOSITIONS OF CHONDRULES IN CARBONACEOUS AND ORDIANARY CHONDRITES.

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Introduction: It may be possible to constrain the partial pressure of H_2/H_2O and its isotopic composition during chondrule formation using the H abundances and isotopic compositions in chondrules. If H_2 from nebula gas dominated during chondrule formation, it should have imparted low H contents and δD in chondrules. In contrast, if chondrules formed by planetesimal collisions [e.g., 1], one migh expect high H contents and δD values similar to those of the bulk chondrites, particularly the water-rich carbonaceous chondrites (CCs). For ordinary chondrite (OC) chondrules, this could help constrain the timing of migration of outer Solar System objects into the inner Solar System [e.g., 2, 3].

Due to the expected low H concentrations generated during chondrule formation, as well as the potential parent body overprinting, the measurement of primary H isotopic compositions in chondrules is challenging. Highly variable concentrations and isotopic compositions have been reported in previous in situ measurements of H in chondrites [e.g. 2, 4, 5, 6]. In situ studies of nominally anhydrous minerals (NAMS) in chondrules have reported high H contents [4, 6], which, if taken at face value, may require unreasonably high pressure environments during chondrule formation. Therefore, the high H contents reported in chondrule NAMS could instead imply parent body alterations at lower temperatures. We have undertaken an initial study to measure H abundances and isotopic compositions in chondrules of the least altered/metamorphosed primitive meteorites that are available.

Samples and Methods: The meteorites selected for this study are: QUE 97008, (L3.05), Semarkona (LL3.0), ALH 77307 (CO3.0), and Kaba (CV3.1). The majority of our analyses so far have been carried out on a section of QUE 97008 and most recently on a section of Semarkona for which the measurements are still ongoing. We have also analyzed chondrule NAM (olivine and orthopyroxene) grains that were picked from powdered meteorite samples that were then mounted in indium. The major element compositions of the mesostases and olivines were measured by EPMA. The volatile (H, C, P, S, F, Cl) concentrations H isotopic compositions were measured with the Cameca NanoSIMS 50L following the technique of [7, 8].

Results and Discussions: After background correction, the H_2O concentrations in the chondrule mesostases and NAMs in QUE 97008, ALH 77307, and Kaba range from 10 to 118 ppm and 9 to 17 ppm, respectively. These are significantly lower than previously reported values for mesostases (1000 to several wt.%) and NAMs (76–2100 ppm, [4, 6]). The measured H_2O concentrations are, however, significantly higher compared to the concurrently determined background of H_2O concentration using Suprasil glass (2–4 ppm).

The H isotopic compositions of the chondrule mesostases glass in QUE 97008, ALH 77307, and Kaba range from ~800 ‰ to 15,000 ‰. In particular, the mesostases glass in the QUE 97008 section have high average D/H ratios of 12,000±2,800 ‰. While these D-enrichments in mesostases glass may have been inherited from water ice that formed in the presolar molecular cloud [2, 4], this would require that the inner Solar System OCs accreted proportionately more interstellar water than the outer Solar System CCs and even all comets (maximum cometary D/H ≈ 3,000±1,000 ‰ observed on C/2012 F6 Lemmon). Alternatively, the mesostases may have approached isotopic equilibrium with D-rich water generated through an isotopic Rayleigh distillation process during oxidation of Fe by water and loss of D-poor H_2 [9, 10]. Diffusion lengthscales for H_2O in chondrule glass estimated from diffusion coefficients in relevant glass compositions [11] and relevant conditions (300ºC [12]) are at least ~350 μm in 1 Ma, suggesting the possibility of isotopic equilibration between D-rich fluids and chondrule through diffusion of D-rich H_2O into the mesostases. In contrast to the homogeneously D-rich chondrule mesostases of the QUE 97008 section, the recently conducted measurements of chondrule mesostases in the Semarkona section have found variable D/H ratios of ~200 ‰ to 11,000 ‰ (H_2O concentration = ~10 to 4,000 ppm) that do not seem to be associated with variable contamination via surface features (e.g., correlate with Cl and C associated with epoxy). The measurements on the Semarkona section are still ongoing, and the implications of these observations will be discussed at the meeting.

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