HYDROGEN ISOTOPIC COMPOSITION OF WATER IN HYDRATED CHONDRITES

L. Piani[1], Y. Marrocchi[1], L.G. Vacher[1], M. Piralla[1], M. Bizzarro[2], C.M.O'D. Alexander[3] and, K.T. Howard[4]. [1]CRPG - UMR7358, Université de Lorraine, 15 rue Notre Dame des Pauvres, Vandoeuvre-les-Nancy, France. (laurette.piani@univ-lorraine.fr). [2]Centre for Star and Planet Formation and Natural History Museum of Denmark, University of Copenhagen, DK-1350 Copenhagen, Denmark. [3]Department of Terrestrial Magnetism, Carnegie Institution for Science, Washington, DC 20015, USA. [4]Physical Sciences Department, Kingsborough Community College, City University of New York, 2001 Oriental Blvd., Brooklyn, New York, NY 11235, USA.

Introduction: Hydrogen is the most abundant element in the solar system. The hydrogen isotopic composition of water (expressed as the D/H ratio) in planetary objects [1] is generally thought to increase from very low values close to the Sun (D/H ≈ 20 × 10^{-6}), to intermediate D/H ratios in inner solar system objects (e.g., Earth's ocean D/H ≈ 156 × 10^{-6}), to high D-enrichments in outer solar system objects such as comets (up to 530 × 10^{-6} in comet 67P/Churyumov-Gerasimenko; [2]).

Chondrites are rocky fragments of asteroids that could have formed at heliocentric distances from ~ 2 to more than 15 AU in the early solar system (e.g., [3]). Most of chondrite groups contain water-bearing minerals attesting that efficient water-rock interactions occurred on asteroids. Nonetheless, the hydrogen isotopic composition of water in the different chondrite groups remains poorly constrained (e.g., [4]). This is because hydrated minerals cannot be easily separated from organic matter, the other main H-bearing phase in chondrites, intertwinned at the submicrometer scale with minerals in the matrix [5]. Bulk chondrite hydrogen isotopic compositions are thus complex mixtures of these two H-bearing phases. Direct estimates of the chondritic water D/H ratios cannot be obtained easily due to the difficultly in estimating the organic matter contribution to the whole H budget.

Method and previous results: We developed a method based on in-situ measurements of the C/H and D/H ratios of hydrated chondrite matrices by Secondary Ion Mass Spectrometer (SIMS) IMS 1280-HR [6]. This protocol allows the D/H ratios of hydrous chondritic minerals to be determined without hindrance from hydrogen in adjacent organic materials. Depending on the position of the SIMS primary beam on the matrix, the D/H and C/H ratios vary as a function of the relative amount of hydrated minerals to organics. Since the D/H ratio is higher for organics than for hydrated minerals in carbonaceous chondrites, correlations between the D/H and C/H ratios can be obtained and used to estimate the D/H ratio of water [6]. Using this method, we determined the D/H ratios of hydrated minerals in carbonaceous chondrites from different groups and petrological types. Results on six CM-type and three CV-type carbonaceous chondrites have been reported in [6] and [7], respectively. We recently obtained data for four new CM-type carbonaceous chondrites (Mukundpura, Jbilet Winselwan, Lonewolf Nunataks 94101 and Maribo), one CR chondrite (Renazzo), one CI chondrite (Orgueil) and two anomalous carbonaceous chondrites (Essebi and Bells).

Results: The isotope signature of the water component of most of the CM-type carbonaceous chondrites is D-poor (D/H = [101 ± 6] × 10^{-6}) [6]. This D-poor value indicates that water in CM chondrites is not inherited from the outer solar system contrary to water in comets [1], but has been equilibrated with H_2 in the inner disk before CM parent body accretion. On the least altered CM chondrites (Paris and to a lesser extent Maribo and LON 94101), the D/H ratio of water is less depleted in D. The D/H signtaure of hydrated phases present in the CM protolith before parent body alteration might have been partially preserved in these meteorites.

Water in CV-type carbonaceous chondrites (CV_{oxB}) shows less depletion in deuterium (D/H ≈ 144× 10^{-6}) than CM chondrite water. CV chondrites might have partially accreted D-rich water ice grains from the outer solar system or the water D/H ratio in CV chondrite could have been modified by exchange with D-rich organics [7].

For Orgueil, Renazzo and in the ungrouped carbonaceous chondrites Bells and Essebi, the water D/H ratio is significantly higher than that of CM-type chondrite water (D/H ≈ 130 to 350 × 10^{-6}).

The hydrogen isotopic compositions of the different groups and types of chondrites will be compared to previous estimation of water in carbonaceous and ordinary chondrites and in other solar system objects [1, 8-10], and used to discuss the isotopic distribution of water in the proto-planetary disk at the time and place of the carbonaceous asteroid formation.

Acknowledgments: This work was supported by the grant-in-aid for Scientific Research on Innovative Areas "Evolution of molecules in space" (16H00929, PI. L. Piani) and by the ERC grant Photonis (PI. B. Marty).

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