Bulk Hydrogen Isotopes in Ordinary Chondrites

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Introduction: Hydrogen isotope characterization of bulk samples from a wide range of bodies is a necessary step to better our understanding of the origins and proliferation of water in our solar system. Rough determinations of hydrogen isotope ratios in planetary atmospheres have been conducted through remote sensing (e.g. [1]), but high-quality measurements of hydrogen held within the rocks of a body requires physical samples to be measured on instruments we have on the Earth. Historically, there has been a particular focus on hydrated chondrites and meteorites from known bodies (e.g. [2], [3]). The extensive measurements of these specific meteorite groups can be attributed to the relative ease of measuring hydrogen in hydrated chondrites, CM chondrites' isotopic similarity to the Earth [4], and the inherent scientific benefit of fully characterizing a suite of meteorites attributed to a specific body. One class which has been largely ignored due to its nominally anhydrous nature is the ordinary chondrites.

Notably, there has been increased interest in hydrogen isotopes within ordinary chondrites over the past decade. However, the vast majority of studies have focused extensively on low petrologic types [5] and specific components of the sample, using techniques like Secondary Ion Mass Spectrometery (e.g. [6], [7]). Focused measurements within a sample are inherently flawed when considering the source of water to a body, as any water deposited will consist of the entire volume of the meteorite, not only that within specific minerals. Since the early 1980s [8], bulk hydrogen isotope measurements within ordinary chondrites have almost exclusively been conducted on Semarkona [5], one of the least thermally altered of the class with an anomalously high hydrogen isotope value compared to any other meteorite. Due to the recent measurements being the most significant studies of hydrogen isotopes in ordinary chondrites to date, the Semarkona hydrogen isotope value is often used as the average value for the class [9]. In this study, we are measuring a range of ordinary chondrite subclasses and petrologic types to create a more representative average hydrogen isotope value of ordinary chondrites.

Samples and Methods: Herein we intend to perform hydrogen isotope measurements from 25 ordinary chondrite falls from the collection of the Institute of Meteoritics at the University of New Mexico. Samples include at least one meteorite of each petrologic type, subgroups excluded, of H, L, and LL meteorites. Each sample, stored in a desiccator, is ground and placed into silver foil to be measured using continuous-flow gas-phase mass spectrometery. With our micro-extraction line, we step heat each sample at 150, 300, 500, 700, and 900°C followed by complete melting with an oxy-gas torch in a quartz glass tube. Each step is cryo-concentrated for at least an hour, allowing us to measure quantities of H_2 down to 0.13 micromols. Step-heating allows us to remove low-temperature terrestrial contamination that is inherent to meteorites and better understand how the hydrogen is incorporated into the material.

Initial Results & Discussion: Preliminary measurements were conducted on Chelyabinsk, Kheneg Ljouâd, Nuevo Mercurio and Dhajala. A consistently large release of hydrogen in all steps up to 500°C with a δD of -58 ± 25‰ across all meteorites has been observed. A significant drop in hydrogen release occurs past the 500°C step of up to an order of magnitude corresponding to higher measured δD values ranging from 19 ± 6‰ for Chelyabinsk to 202 ± 6‰ for Dhajala. More measurements still must be made to better understand trends within and between groups, but there appears to be a weak correlation between lower petrologic types and higher δD values.

Preliminary data shows that even for falls which are quickly collected, terrestrial contamination appears to be rampant in low temperature steps with hydrogen concentrations high enough to completely dominate the bulk hydrogen isotope value of the sample. Even for our Chelyabinsk sample, its tenure in the Russian snow and later rain appears to have been enough to contaminate even the higher temperature phases with both an increased concentration of hydrogen compared to any other meteorite measured so far and a lower δD value. The rampant contamination leads us to question earlier bulk ordinary chondrite data as it was previously impossible to step-heat the samples in order to remove the vast majority of terrestrial contamination while the low hydrogen isotope values compared to Semarkona highlight the necessity of more high-quality bulk measurements of this class.

References: [1] Trauger J. T. et al. 1973. *The Astrophysical Journal* 184:L137-L141. [2] Kerridge J. F. 1985. *Geochemica et Cosmochemicia Acta* 49:1707-1714. [3] Saal A. E. et al. 2013. *Science* 340:1317-1320. [4] Marty B. 2012. *Earth and Planetary Science Letters* 313-314:55-56 [5] Alexander C. M. O'D. 2012. *Science* 337:721-723. [6] Shimizu K. et al. 2019. *LPS L*, Abstract #6840. [7] Sanborn M. E. et al. 2019. *LPS L*, Abstract #6279. [8] McNaughton N. J. et al. 1981. *Nature* 294:639-641. [9] Lin, Y. and van Westrenen W. 2019. *National Science Review*.