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Oxygen isotopes in water extracted from carbonaceous chondrites

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Oxygen Isotopes in Water Extracted from Carbonaceous Chondrites. L. Baker, I.A. Franchi, I.P. Wright and C.T. Pillinger. Planetary and Space Sciences Research Institute, The Open University, Walton Hall, Milton Keynes, MK76AA, UK. (l.baker@open.ac.uk).

Introduction: Understanding the sources and isotopic evolution of oxygen and water reservoirs in the Solar System could be greatly enhanced with measurements of the oxygen isotopic composition of water from meteorites. Previous hypotheses regarding the origin and movement of water in the Solar System using D/H ratios [e.g. 1,2] have provided little insight into the interaction that has taken place between water reservoirs and primitive solids.

Modeling of parent body evolution using measured silicate and carbonate compositions [3-5] have allowed first order estimates of the isotopic composition of early Solar System water. However, the requirement for direct measurements is undiminished. Using a recently developed stepped pyrolysis/fluorination system [6] we have measured the oxygen isotopic composition of water extracted from a range of whole-rock samples of CI and CM chondrites. Results presented herein allow discrimination between indigenous water and that of terrestrial origin, and provide new insight into the sources and interaction of parent body water.

Analytical Technique: Water was released from crushed, bulk meteorite samples of 1-4 mg by stepped pyrolysis in a flow of helium. Oxygen, liberated from water by an in-line fluorinating agent (CoF_3) was analysed for its $\delta^{17}\text{O}$ and $\delta^{18}\text{O}$ composition using a continuous-flow, isotope ratio mass spectrometer (Delta C, Finnigan Mat). For details see [6]. Precision of the data (1σ) as determined by water and solid standards are: $\delta^{18}\text{O} = \pm 0.30 \text{ ‰}$, and $\Delta^{17}\text{O} = \pm 0.14 \text{ ‰}$, (where $\Delta^{17}\text{O} = \delta^{17}\text{O} - 0.52\delta^{18}\text{O}$).

Results: Yields of water from all samples were between 4 and 11 wt%. In all cases low temperature water had oxygen isotopic compositions characteristic of a terrestrial origin, with $\Delta^{17}\text{O}$ values close to 0‰. Above 300°C $\Delta^{17}\text{O}$ values indicated a largely extraterrestrial origin. $\delta^{18}\text{O}$ values from CM samples displayed a relatively simple release pattern whilst those from CI samples were more complex, indicative of multiple reservoirs. $\Delta^{17}\text{O}$ values from CI samples above 300°C were positive ($\sim +0.6\text{‰}$), close to isotopic values measured in bulk samples and matrix. $\Delta^{17}\text{O}$ values from CM samples were, like the CM matrix and silicate, negative (-0.6 to -1.3‰). Tagish Lake meteorite shows similarities to both groups but does not comfortably fit into either. It has a relatively low water content and displays a simple $\delta^{18}\text{O}$ pattern over a wide range of values. Its $\Delta^{17}\text{O}$ values are much more positive than whole rock and other solid components.

Discussion. Alteration phases in carbonaceous chondrites retain an isotopic record of the water within which they formed. Comparison of oxygen isotopic data from carbonates [7] with water from phyllosilicates suggests that for each of the CI and CM meteorites the two groups of minerals lie close to a single mass fractionation line (similar $\Delta^{17}\text{O}$). As water in phyllosilicates is likely to maintain isotopic equilibrium with the fluid and so reflect the final water composition, this suggests that either deposition of carbonate and formation of phyllosilicates occurred simultaneously or the isotopic composition of the water reservoir did not change appreciably during alteration.

Assuming that water evolved during alteration from an initial composition with positive $\Delta^{17}\text{O}$ values and silicates from negative $\Delta^{17}\text{O}$ [3], then closed system alteration should have produced greatly differing isotopic compositions for the two phases. That this is not observed suggests that a more open system may have predominated.

Tagish Lake which does show isotopic differences between the phases is an exception to this pattern.

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