

Oxygen Isotope Exchange between Amorphous Silicates and Water Vapor: Implication for Survivability for Presolar Amorphous Silicates in the Solar Nebula

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Introduction: Presolar silicate grains exhibiting large oxygen isotope anomalies are the most abundant type of presolar material [e.g. 1]. Floss & Stadermann [2] proposed a possibility of nebular thermal destruction of presolar silicate/oxide grains in an ungrouped carbonaceous chondrite Adelaide. However, the susceptibility and/or survivability of presolar silicate in the Solar nebula have not yet been investigated in detail. We experimentally showed that water molecules diffuse into amorphous forsterite under nebula-like low water vapor pressure ($P_{\text{H}_2\text{O}}$) conditions to promote crystallization [3], implying that water molecule reacts with presolar amorphous silicates to change their oxygen isotopic compositions in the Solar nebula.

Experiments: Oxygen-isotope exchange reaction experiments between sub- μm -sized amorphous forsterite and H_2^{18}O vapor were conducted at 803–1073 K and $P_{\text{H}_2\text{O}} \sim 1$ Pa in a gold-image furnace equipped with a gas injection system.

Results & Discussion: Crystallization did not proceed in samples heated at 803–883 K and $P_{\text{H}_2^{18}\text{O}} \sim 1$ Pa, but the 10- μm infrared absorption peak shifted to higher wavelength with time. This indicates that the isotopic exchange between amorphous forsterite and ^{18}O -enriched water occurred without accompanying crystallization. At 953 K, amorphous forsterite crystallized and its infrared absorption peak positions shifted to higher wavelengths than those of isotopically normal crystalline forsterite. Moreover, these peaks were broader than crystalline forsterite heated at the same condition with normal H_2O vapor. These can be interpreted as simultaneous oxygen isotope exchange and crystallization. At 1073K, an infrared spectrum of a run product heated for 2 hr showed sharp features, consistent with isotopically normal crystalline forsterite, suggesting that crystallization proceeded without the aid of water molecules and no isotopic exchange occurred between crystalline forsterite and ^{18}O -enriched water vapor.

These results imply that there would be nebular conditions, where oxygen isotope signatures of presolar amorphous silicates were erased by isotopic exchange with nebular water vapor.

References: [1] Floss, C. & Haenecour, P. (2016) *Geochem. J.* 50, 3–25. [2] Floss, C. & Stadermann, F. J. (2012) *MAPS* 47, 992–1009. [3] Yamamoto, D. (2016) *Master thesis*.

NUCLEOSYNTHETIC ISOTOPE VARIATIONS IN REFRACTORY INCLUSIONS: RECORDS OF PROTOPLANETARY DISK EVOLUTION.

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Calcium-aluminum-rich inclusions (CAIs) are the oldest known solids that formed in our solar system. They condensed during the earliest evolution stages in a hot region of the cooling protoplanetary disk. Many CAIs were subsequently re-heated and melted before they were transported into cooler disk regions and accreted onto their respective chondrite parent body. CAIs preserved characteristic isotope fingerprints from the region of the disk where they formed and thereby provide vital clues about the conditions prevailing in the hot region of the disk where they formed and evolved.

Our previous results showed that common CAIs (non-FUN) can be divided into two groups based on their nucleosynthetic variations in Zr, Ti, Ni and Hf isotopes [1, 2]. For the majority of the analyzed CAIs (main group), ^{96}Zr excesses positively correlate with excesses in the neutron-rich ^{50}Ti , and surprisingly s-process excesses (= r-process deficits) in Hf isotopes. The other rarer group exhibits lower ^{96}Zr and ^{50}Ti excesses coupled with s-process depletions in Hf isotopes. Our preferred interpretation for these data is a decoupling of the nucleosynthetic sources that produced the heavy ($A > 130$) neutron-rich isotopes compared to the lighter isotopes. In the context of our model, the light isotopes (e.g., ^{96}Zr) were mainly produced in Type II supernovae by charged-particle reactions. These took place in a high entropy wind environment, in which Hf isotopes cannot be synthesized.

Here, we have extended our study to 15 new CAIs from the CV chondrites Allende and Mokoia. The CAIs were classified as type A, B or C. Rare earth element concentrations and high precision Zr, Sr and Ti isotope data were also determined. The new data are consistent with our previous results [1, 2], which showed a relatively limited spread in isotopic composition with e.g., $\epsilon^{96}\text{Zr}$ around 0.8 (rare group) or 2.0 (main group). This indicates that these CAIs (fine-grained and coarse-grained) formed from a relatively well-homogenized gas-rich reservoir, potentially close to the Sun in the protoplanetary disk.

However, in contrast to the previous work [1, 2], we also analyzed fine-grained, spinel-rich inclusions with group II rare earth element patterns. These patterns suggest that these inclusions formed by condensation [3]. The nucleosynthetic isotope data of these CAIs display a much larger and more variable isotopic spread in particular for Zr isotopes ($\epsilon^{96}\text{Zr}$ from -0.3 to + 5.0). This indicates that these inclusions formed from a less well-homogenized reservoir that was separated from the reservoir of the other CAIs either in time and/or space.

Therefore, common CAIs can be divided into different groups that likely sampled an evolving reservoir in the protoplanetary disk close to the Sun. They reflect condensates and re-melting on one hand, but potentially also record the survival of extremely refractory minerals in a hot environment.

References: [1] Akram et al. (2013) *ApJ* 777, 169. [2] Leya et al. (2009) *ApJ* 702, 1118. [3] Aléon et al. (2005) *MAPS* 40, 1043.