WATER IN CALCIUM-ALUMINIUM INCLUSIONS: NEBULAR, ASTEROIDAL OR TERRESTRIAL?

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Introduction: Calcium-Aluminium rich Inclusions (CAIs) are the oldest preserved solids from the early solar system. The observed $\delta^{17,18}$O heterogeneity of >5% in CV chondrite CAIs has been studied and debated for over four decades [1]. Gas-solid or gas-melt reactions in the solar nebula and/or fluid-assisted thermal metamorphism on the CV chondrite parent body are the possible mechanisms proposed for the isotopic exchange between the initially ^{16}O-rich CAIs and ^{16}O-poor external reservoir. Water could be an important tracer to constrain the origin and nature of the ^{16}O-poor reservoir [2]. To understand the nature of the O-isotope exchange in CV CAIs and the role of water in it, we measured water content and δ^{18}O ratios (normalised to SMOW) in a suite of CAIs from CV3 chondrites.

Methodology: Multiple CAIs from CV3 chondrites Allende, Efremovka and NWA 4502 were mounted in Bi-Sn alloy, a mounting method developed for analysing trace amounts of water. Following anhydrous polishing and cleaning, the CAIs were analysed using the Sensitive High Resolution Ion Micro Probe Stable Isotope (SHRIMP SI) at RSES, Australian National University. A Cs^+ primary ion source and an electron gun were used to sputter ~25 µm spots in single phases or 'bulk' CAIs and simultaneously acquire $^{16}O^-$, $^{16}O^1H^-$ and $^{18}O^-$ secondary ions.

Raw $^{16}O^1H^-/^{16}O^-$ ratios were converted to water concentration in ppm using five standards: Suprasil Glass (SiO_2; ≤ 1 ppm water), San Carlos Olivine (SCO; 15±2 ppm), Russian Cr-diopside (100±10 ppm), 36.4 (8610±861 ppm) and ND70 (11300±1130 ppm) basaltic glasses [3]. All the standards were mounted along with the CAIs on the same sections to ensure similar treatment for the standards and the unknowns. A linear regression fit was used to calibrate the unknown water concentrations (R^2=0.97). SCO was used as the reference for δ^{18}O measurements.

Results: In situ water concentrations and δ^{18}O ratios from CAIs SJ101, AJEF355 and 3529 from $CV3_{OxA}$ Allende, CAIs E49 and E60 from $CV3_R$ Efremovka and CAIs 8, 11 and 13 from $CV3_{OxA}$ NWA 4502 are presented in Figure 1. All CAIs are either Type A or B. δ^{18}O values (uncorrected for matrix bias) span a similar range previously reported from these CAIs [4-6].

Water concentrations are highly variable in the CAIs with Allende CAIs showing typically lower water than Efremovka and NWA 4502 CAIs. Median water in Allende CAIs SJ101 (n=10), AJEF355 (n=9) and 3529 (n=5) is 58, 6 and 15 ppm respectively. On the other hand, Efremovka CAIs E49 (n=11) and E60 (n=11) show 1400 and 380 ppm; NWA 4502 CAIs 8 (n=10), 11 (n=10) and 13 (n=12) show 3100, 400 and 1800 ppm water respectively. Multi-phase bulk analyses generally show a slight overestimation of water contents due to the presence of grain boundaries/cracks which contribute to the intrinsic water from the target phases.

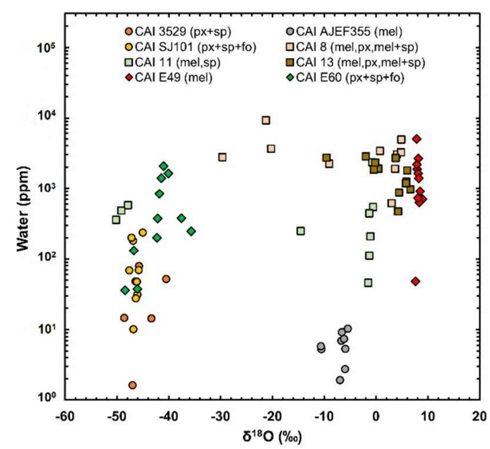

Figure 1: Water content in ppm and δ^{18}O in CAIs from CV3 Allende (circles), NWA 4502 (squares), Efremovka (diamonds). Mel=melilite, sp=spinel, px=pyroxene (Al-Ti diopside), fo= forsterite. δ^{18}O 2σ error bars are typically smaller than the symbol size. 10% uncertainty is assumed for water concentrations.

Discussion and Conclusions: CAI minerals are assumed to be nominally anhydrous. However, melilites in CTA CAI E49 show ~1000 times more water than the CTA CAI AJEF355 melilites and a similar enrichment can be seen in FoB CAI E60 vs SJ101. The elevated water contents in Efremovka and NWA 4502 can be attributed to terrestrial weathering as they are finds from hot deserts and hydration is a common feature in chondrite finds [8]. Finds are thus unreliable to study any nebular and/or asteroidal water signature in the CAIs. It is however important to note that under terrestrial environments, these minerals can accommodate considerable amounts of water. There is no apparent correlation between the water content and δ^{18}O in the CVs including Allende which is a fall. ^{16}O-depleted melilites from Allende are dry (<10 ppm water) indicating that water-mediated exchange may not be a key process in changing oxygen isotope compositions, or that the conditions were not suitable for the hydration of these CAIs. More CAIs from falls are necessary to assess the viability of water as a tracer to explain the O-isotope range.

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