OXYGEN ISOTOPIC COMPOSITIONS OF REFRACTORY MINERALS FROM THE MURCHISON AND AGUAS ZARCAS CHONDrites: RESERVOIRS AND PROCESSING IN THE SOLAR NEbula

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Introduction: The mineralogy and isotopic compositions of the Solar System’s oldest solids, refractory minerals, indicate formation at different times and locations in the early Solar System [1]. The oxygen isotopic composition preserved in refractory minerals, including Ca-Al-rich inclusions (CAIs), provides snapshots of the different stages of isotopic evolution in the protoplanetary disk [1–5]. For example, the very tight distribution of O-isotopic compositions of spinel-hibonite inclusions (SHIBs) compared to the platy hibonite crystals (PLACs) can be best explained if the SHIBs formed in a isotopically more homogenized solar nebula compared to PLACs [4, 5]. The discovery of both 26Al-rich and 26Al-poor corundum-bearing inclusions may indicate that they formed from different reservoirs or as two generations [2, 6]. Here we present new oxygen isotopic data on corundum, corundum-hibonite, hibonite, and spinel grains, freshly extracted from separations of Murchison and Aguas Zarcas.

Materials and Methods: Fragments from a 71 g sample of Murchison (FMNH ME 2644 #23.20) and a 79 g sample of Aguas Zarcas (FMHN ME 6112) were freeze-thaw disintegrated [7], separated by density with heavy liquids, and acid processed [8]. One corundum, two corundum-hibonite, thirteen hibonite, and twelve spinel grains were extracted from the separation, then mounted in indium and hand-polished. Their mineralogy was confirmed by energy-dispersive X-ray spectroscopy and Raman spectroscopy. The oxygen isotope analyses were performed with the WiscSIMS CAMECA IMS 1280 following a previously developed protocol [4–5, 9].

Results and Discussion: The thirteen isolated hibonite grains can be divided into two groups based on their \( \Delta^{18}\text{O}_{\text{CCAM}} \) value (\( \Delta^{18}\text{O}_{\text{CCAM}} = \delta^{18}\text{O} + (\Delta^{17}\text{O} – \text{Intercept}_{\text{CCAM}})/(\text{Slope}_{\text{MFL}} - \text{Slope}_{\text{CCAM}}) \)) [10], which quantifies the degree of mass-dependent fractionation as the deviation in \( ^{18}\text{O} \) from the CCAM (carbonaceous chondrite anhydrous mineral) line. Eight hibonite grains show \( \Delta^{18}\text{O}_{\text{CCAM}} < 7^\circ \), similar to PLAC-like CAIs in previous studies [5, 11]. Five hibonite grains as well as two hibonite-corundum inclusions and one isolated corundum display a \( \Delta^{18}\text{O}_{\text{CCAM}} > 50^\circ \), reflecting significant mass-dependent fractionation. The spinel grains do not have large mass-dependent fractionation and fall into two groups according to their \( \Delta^{17}\text{O} \) values that range from \( -22.2^\circ \) to \( -24.4^\circ \) (±1.0%) for the first group (pure Al-Mg spinel), resembling SHIBs’ isotopic composition [4] and \( -6.3^\circ \) to \( -2.4^\circ \) (±1.0%) for the second group, that can be more Cr, Fe-rich and representing chondrules’ composition [12, 13].

Corundum, the earliest condensate from a nebular gas of near-solar composition under equilibrium conditions [14], exhibits a wide range of \( ^{17}\text{O} \) values in UOC and CC meteorites, \( -13^\circ \) to \( -30^\circ \) [2, 6], which coexisted with the 26Al-poor and 26Al-rich reservoirs, indicating a highly heterogeneous solar nebula and possible episodic formation. In particular, corundum condensates could have reacted with nebular gas to form hibonite or have formed from hibonite as an evaporative residue [14, 15]. Here we report corundum grains and corundum-hibonite show \( \Delta^{17}\text{O} > -25^\circ \) and \( \Delta^{18}\text{O}_{\text{CCAM}} > 50^\circ \), and the large mass-dependent fractionation favors the latter one for corundum grains in this study. Individual hibonite grains with the similar large mass-dependent fractionation further confirm the formation mechanism.

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