OXYGEN ISOTOPES IN THE ULTRA-REFRACTORY CAI EFREMOVKA 101.1 AND THE SOLAR NEBULA

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Introduction: E101.1 is a unique compact type A Ca-Al-rich inclusion (CAI) characterized by an ultra-refractory Rare Earth Element (UR-REE) pattern and the presence of fassaitic clinopyroxene (cpx) highly enriched in Sc and Zr [1]. It contains multiple fragments attributed to previous generations of CAI trapped in the host melt such as (1) sinuous cpx-rich fragments, (2) partially resorbed perovskite (pv)-metal associations, rimmed by the Sc-Zr cpx, and (3) two apparent subinclusions mineralogically similar to the host CAI. All these components share the same UR-REE pattern. Other notable features include a well-developed Wark-Lovering rim (WLR) with accretionary rim (AR) fragments and two glassy areas attributed to an impact melt. In order to better understand the complex history of E101.1 and to explore the implications for the O isotopic variations in the protosolar nebula, we acquired O isotope analyses on 129 spots using the UCLA IMS1270 ion microprobe.

Results and discussion: (1) Detailed analyses of melilite (mel) show that it is dominantly ^{16}O-poor but that there exist domains with residual heterogeneity distinct from each other in Δ^{17}O by more than 3σ. These domains have sizes > 200 μm, in the range of the mel crystal size. ^{16}O-enriched mel (Δ^{17}O < -10‰) is systematically gehlenitic (Åk content < 10 mol%) and is closely associated with spinel. This suggests that melilite recorded the O isotope change of the crystallizing melt during CAI cooling with the first mel being ^{16}O-rich gehlenite and the last being ^{16}O poor ~$Åk_{30}$ in composition. The domains were later partially homogenized by solid-state diffusion (2) Al-diopside in sinuous fragments is ^{16}O-rich but intimately associated FeO-rich minerals are ^{16}O-poor. Because FeO-rich minerals are confined to the sinuous fragments and because metal in the host is unaltered, a parent-body oxidative event is unlikely. Rather, the data are better explained by trapping of CAI fragments previously altered in the nebula in a reservoir of high fO_2 depleted in ^{16}O. (3) The glassy areas have intermediate ^{16}O-excesses consistent with a proposed origin by late melting of ^{16}O-rich Al-diopside and ^{16}O-poor mel. (4) pv has variable O isotopic compositions suggesting precursors with different thermal histories but the associated Sc-Zr-cpx is the most ^{16}O-poor mineral in E101.1. Only nepheline, which replaces anorthite that itself replaces mel in the CAI, has a similar ^{16}O-poor composition. This poses a problem given the expected early crystallization of Sc-Zr-cpx and the sluggish self-diffusion of O in cpx. (5) The two subinclusions do not appear to be isotopically different from the host. (6) Finally, the WLR and AR are systematically ^{16}O-rich.

Conclusions: Our O isotope results both confirm and challenge some of the previous conclusions reached on E101.1. When integrated in a petrological model that correctly takes into account the isotopic composition of all phases, notably that of pv and Sc-Zr-cpx, they will provide insights on the thermal history of CAIs and gas-melt interactions in the nebula.

References: [1] El Goresy A. et al. 2002. *GCA* 66:1459.