BULK OXYGEN ISOTOPIC COMPOSITIONS OF ANHYDROUS INTERPLANETARY DUST PARTICLES: INDICATION OF AN ^{16}O-POOR RESERVOIR IN THE OUTER SOLAR SYSTEM.

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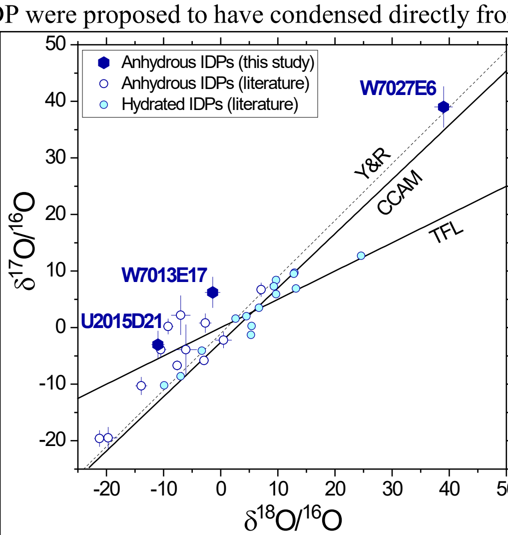
Introduction: The oxygen isotopic ratios of ancient solar system materials reflect the isotopically distinct reservoirs in which they formed or were altered. These compositions are generally explained by mixing of material derived from an ^{16}O-rich reservoir and material from an ^{16}O-poor reservoir thought to be isotopically heavy H_2O. Evidence of this ^{16}O-poor reservoir is scarce and includes cosmic symplectite (COS) [1, 2], probable silicates in an interplanetary dust particle (IDP) [3], and sulfates in a cometary xenolith [4]. These materials have ^{17}O and ^{18}O enrichments between ~150–200 ‰, which agree with predictions for self-shielding and photodissociation of CO [5]. The 'cometary' ^{16}O-poor materials indicate alteration or formation in the outer solar system [3, 4]. The bulk O isotopic compositions of IDPs thought to have cometary origins may also harbor evidence of this primordial ^{16}O-poor reservoir. Here we report the bulk O compositions of anhydrous IDPs and discuss the nebular reservoirs from which they derived.

Experimental: We conducted coordinated TEM and NanoSIMS isotopic analyses of 70-nm thick microtome sections of three anhydrous IDPs (U2015D21, W7013E17, W7027E6) that were previously studied for their bulk chemistry and mineralogy [6]. Following full TEM characterization of select sections, the Cu TEM grids were reinforced on the backside with ~10 nm of Au and affixed onto Al stubs with C paint for NanoSIMS analysis. Isotopic imaging was conducted using the NanoSIMS 50L at NASA JSC on 3 slices of IDP W7027E6 (~12 μm in size), 7 slices of U2015D21 (~17 μm), and 4 slices of W7013E17 (~18 μm). A ~1 pA, ~100 nm Cs^+ primary ion beam was rastered over the samples for 35-90 layers. A dwell time of 4000 μs/pixel was used and each image consisted of 512 × 512 pixels. Negative secondary ions of ^{16}O, ^{17}O, ^{18}O, $^{12}C^{14}N$, $^{12}C^{15}N$, and ^{28}Si were simultaneously acquired with electron multipliers. The $^{16}OH^-$ peak was separated from the $^{17}O^-$ peak, with hydride contributions < 1 ‰. San Carlos olivine and 1-hydroxy benzotriazole hydrate served as external standards for O and N isotopes, respectively.

Results and Discussion: Results of the TEM analyses and isotopic ratios of presolar and solar system grains were reported previously [7, 8]. Here we focus on the bulk O isotopic ratios, calculated as the weighted average of all sections analyzed for each IDP. IDP U2015D21 has the most ^{16}O-rich bulk composition ($\delta^{17}O = -3 \pm 2.4$ ‰, $\delta^{18}O = -11 \pm 1.1$ ‰; 1σ), followed by W7013E17 ($\delta^{17}O = 6 \pm 2.7$ ‰, $\delta^{18}O = -1 \pm 1.3$ ‰) and W7027E6, which has a very ^{16}O-poor bulk composition ($\delta^{17}O = 39 \pm 3.6$ ‰, $\delta^{18}O = 39 \pm 1.6$ ‰) distinct from other IDPs. U2015D21 and W7013E17 plot above the CCAM line, as do some other anhydrous IDPs [9]. Collectively these IDPs form a slope ~1 trendline that is offset from the CCAM line. For many of these IDPs, the ^{17}O enrichment cannot be explained by contributions from ^{17}O-rich presolar grains [8] nor ^{16}OH. The source of these ^{17}O enrichments is thus unclear.

The bulk composition of IDP W7027E6 lies on the Y&R line and is even more ^{16}O-poor than hydrated IDPs [9-11]. Unlike U2015D21 and W7013E17, it does not show an ^{17}O enrichment. While most ^{16}O-poor materials and hydrated IDPs were likely altered by isotopically heavy water [1-4, 10], TEM observations of W7027E6 show no evidence of hydration [7]. The ^{16}O-poor silicates in an anhydrous IDP were proposed to have condensed directly from an ^{16}O-poor reservoir in the outer solar nebula rather than being altered by one [3]. That the bulk W7027E6 is ^{16}O-poor with no discrete ^{16}O-poor grains suggests the IDP constituents, excluding the presolar grain [7], all formed from an ^{16}O-poor reservoir in the outer solar nebula. Alternatively, the heavy O could be carried by the organic matter, which is intimately mixed with the inorganic material. Much more extreme compositions ($\delta^{17}O$ up to 530 ‰) traced to organic matter in a chondrite were likely produced by photodissociation at the envelope of the proto-solar nebula [12].



Bulk O isotopic ratios of anhydrous and hydrated IDPs (this study, [9-11]).

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