RECYCLING OF CAIS IN AN ^{16}O-DEPLETED RESERVOIR: EVIDENCE FROM CAIS IN METAL-RICH CARBONACEOUS CHONDRITES. A. N. Krot[1,2], K. Nagashima[1], and M. Bizzarro[2]. [1]HIGP/SOEST, University of Hawai'i at Mānoa, USA. [2]Center for Stars & Planets, Natural History Museum of Denmark, Denmark.

Introduction: It is generally accepted that CAIs formed during the initial stages of the solar system evolution, in a high-temperature nebular region (> 1350 K), probably near the proto-Sun [1]. Subsequently, they were radially transported throughout the protoplanetary disk and accreted together with chondrules and matrices into chondrite parent bodies. Most CAIs in primitive chondrites are uniformly ^{16}O-rich (Δ^{17}O ~ –25‰) and high abundance of ^{26}Mg excess corresponding to the initial ^{26}Al/^{27}Al ratio ((^{26}Al/^{27}Al)$_0$) of ~ 5.25×10^{-5} [2,3]. In contrast, most chondrules are ^{16}O-depleted (Δ^{17}O > –10‰) and characterized by low initial ^{26}Al/^{27}Al ratios (<1×10^{-5}) [1 and ref. therein]. CAIs affected by chondrule formation (e.g., relict CAIs inside chondrules) are very rare [4–6] and, therefore, have not been systematically studied. In contrast to CAIs in typical chondrites, CAIs in CHs show a range of Δ^{17}O values (–35‰ to ~ –1‰; individual CAIs are isotopically uniform) and a bi-modal distribution of (^{26}Al/^{27}Al)$_0$, ~5×10^{-5} and <3×10^{-6} [7,8]. The nature of these O- and Mg-isotope heterogeneities is not understood. It could be a primary signature of nebular dust, suggesting heterogeneous distribution of ^{26}Al and coexistence of ^{16}O-rich and ^{16}O-poor reservoirs at the beginning of solar system formation [9,10], or a result of late-stage recycling of ^{16}O-rich CAIs in an ^{16}O-poor gaseous reservoir. Here we report on mineralogy, petrography, and O-isotope compositions of ~ 30 CAIs from the CH chondrites Acfer 182/214 and Isheyevo, which were remelted to varying degrees in an ^{16}O-depleted gaseous reservoir during chondrule formation.

Analytical procedures: The mineralogy and petrography of CAIs were studied using JEOL JXA-8500F FE-EPMA. O-isotope compositions were measured *in situ* with the UH Cameca ims-1280 SIMS using three different analytical protocols, depending on grain size: (*i*) multicollection FC-EM-FC; spot size ~15 µm; (*ii*) combination of multicollection and peak-jumping: ^{16}O$^-$ and ^{17}O$^-$ were measured simultaneously using multicollection FC and monocollection EM, respectively; subsequently, ^{18}O was measured with monocollection EM; spot size ~ 7 µm; (*iii*) multicollection FC-EM-EM; spot size ~2 µm; (*iv*) for grains < 2 µm.

Results: The CH CAIs remelted in an ^{16}O-depleted reservoir can be divided into four major categories: (*i*) CAIs surrounded by igneous *an-px* rims or mantles, (*ii*) relict CAIs in chondrules, (*iii*) relict *sp-an* regions in chondrules, and (*iv*) CAIs remelted without addition of chondrule-like precursors. Oxygen isotopic compositions of the CAIs studied are plotted as δ^{17}O *vs.* δ^{18}O (Fig. 1a) and as Δ^{17}O (Fig. 1b).

(*i*) Three inclusions surrounded by igneous *an-px* rims or mantles – *grs-px* CAI *1573-4-7* rimmed by *sp*, *hib-rich* CAI *1580-1-8*, and *sp-hib-mel-pv* CAI *MB4-2-6* are uniformly ^{16}O-rich (Δ^{17}O ~ –20‰ to –25‰); the *px* rims are ^{16}O-depleted (Δ^{17}O ~ –7‰ to +4‰). The *hib-sp-mel* CAI *C-4* and *8-4-8* are ^{16}O-depleted (Δ^{17}O ~ –10‰); the *px* and *an* are more ^{16}O-depleted (Δ^{17}O up to +1‰).

(*ii*) Relict CAIs inside chondrules include *grs*-rich, *hib*-rich and *sp*-rich inclusions. The *grs*-rich and *hib*-rich relict CAIs are typically surrounded by a *sp* layer (remnants of the Wark-Lovering (WL) rims) and a layer of *an* (possibly replaced *mel*) intergrown with the host chondrule silicates. The relict CAI minerals (*grs, sp, hib, mel*) are typically uniformly ^{16}O-rich (Δ^{17}O ~ –35‰ to –20‰); the host chondrule silicates are ^{16}O-poor (Δ^{17}O ~ –7‰ to +3‰). Relict *hib-mel* CAI *1-3-5* rimmed by *sp* is ^{16}O-depleted (Δ^{17}O ~ –5‰); the host chondrule *px* is more ^{16}O-depleted (Δ^{17}O ~ +3‰).

(*iii*) Several chondrules contain *an*-rich regions with abundant small *sp* grains, which may represent remelted *mel-sp* CAIs. The *sp* grains show large variations in O-isotope compositions: Δ^{17}O ranges from ~ –20‰ to ~ –5‰. The host chondrule silicates are ^{16}O-depleted compared to *sp* grains. Sp grains in chondrules *1580-2-5* and *8-2-1* are corroded by the surrounding silicates and probably relict; these grains have the most ^{16}O-rich compositions. The relatively ^{16}O-depleted *sp* grains in chondrules *MB2-2-21* and *MB4-1-1* are euhedral and at least partly crystallized from the host chondrule melt. In contrast, the most ^{16}O-depleted *sp* grains in chondrules *1-3-3* and *1573-4-9* are coarse, extensively corroded, and clearly relict.

(*iv*) *Px-sp-mel* CAI *1573-4-4* lacks WL-rims and is isotopically heterogeneous: *sp* is ^{16}O-enriched (Δ^{17}O ~ –11‰) relative to *px* (Δ^{17}O ~ –3‰). Two *px-sp-mel* CAIs rimmed by a single layer of Ca-rich *fo*, *1580-2-1* and *1580-4-3*, are uniformly ^{16}O-depleted (Δ^{17}O ~ –8‰ and –2‰, respectively). These CAIs are mineralogically similar to the uniformly ^{16}O-depleted CAIs surrounded by *fo* rims from CH & CB chondrites reported by [11].

Discussion: Most CH CAIs recycled in an ^{16}O-depleted reservoir during chondrule formation have Δ^{17}O values ranging from –35‰ to –5‰. These O-isotope compositions represent their original, prior to the last melting event, compositions. The mineralogy and O-isotopic compositions of these CAIs are similar to the CH CAIs which appear to have escaped chondrule melting, e.g., isotopically uniform CAIs surrounded by the WL-rims. Based on these observations and the fact that CH CAIs form the mineralogically and isotopically distinct population of objects [12], we infer that (*i*) CH CAIs were present in the region of CH porphyritic chondrule formation, (*ii*) the scale of the chondrule-forming event(s) was relatively small and a number of chondrule-forming events in a localized nebular region where these chondrules formed was limited. (*iii*) The presence of ^{16}O-depleted CAIs among relict objects in chondrules is consistent with the coexistence of ^{16}O-rich and ^{16}O-poor reservoirs at the beginning of the solar system formation [10]. (*iv*) There is no evidence that CH CAIs recycled during chondrule formation experienced selective O-isotope exchange in *mel* or *an*, as commonly observed in CV CAIs [13]; instead, the outer portions of these CAIs, including *px* and *mel* layers of the WL-rims, experienced melting and O-isotope exchange. (*v*) It is unclear whether the uniformly ^{16}O-depleted (Δ^{17}O ~ –7±3‰), igneous CAIs surrounded by *fo* rims commonly observed in CB and CH chondrites and attributed to remelting during impact plume origin of magnesian cryptocrystalline and skeletal chondrules in CHs and CBs [11], were recycled during formation of the CH porphyritic chondrules.

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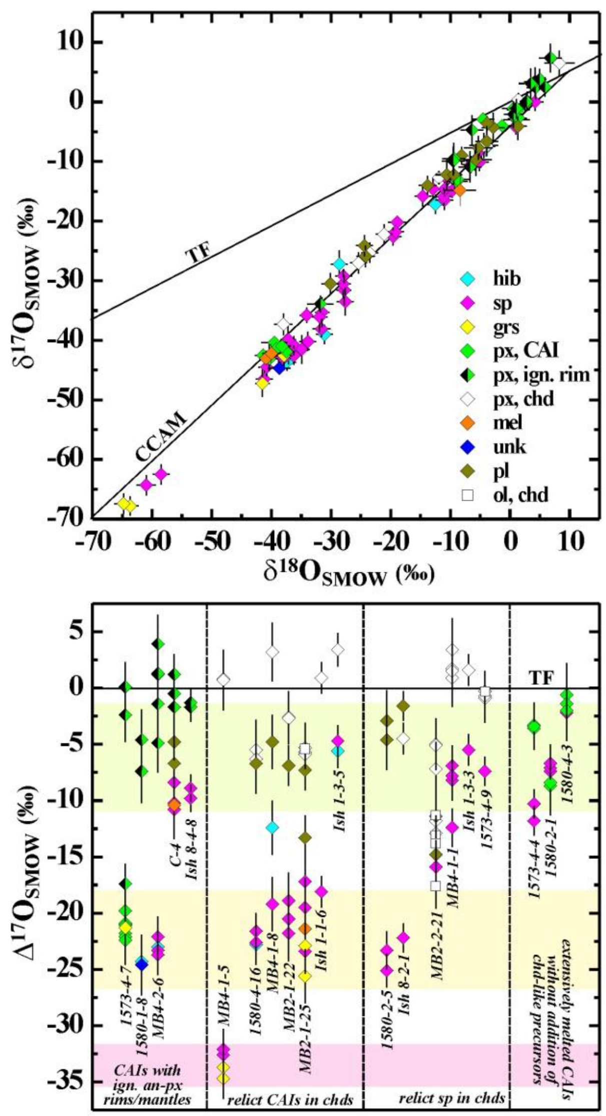

Fig. 1. Three-isotope oxygen plot (a) & $\Delta^{17}O$ values (b) of CH CAIs recycled in an ^{16}O-poor reservoir, their igneous rims & host chondrules (chd). an = anorthite; grs = grossite; hib = hibonite; mel = melilite; ol = olivine; px = pyroxene; sp = spinel; unk = Ca,Al,Ti,Mg-silicate. Outlined (from top to bottom) are the average values ± 2 standard deviations of the uniformly ^{16}O-depleted, uniformly ^{16}O-rich, & very ^{16}O-rich CAIs from CH chondrites [8,9,11].

Fig. 2. BSE images of CH CAIs recycled during chondrule formation. Measured SIMS spots & corresponding $\Delta^{17}O$ values are indicated. Red & yellow circles in "c" & "d" correspond to relict CAIs & host chondrules, respectively.