SIMS oxygen isotope study of chondrules in the least metamorphosed CV3 chondrite Kaba.

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Introduction: Oxygen isotope ratios of chondrules indicate that a variety of isotope reservoirs existed in the protoplanetary disk (e.g., precursor silicate dust, water-ice, ambient gas) and, in addition, provide information on the extent of isotopic exchange between chondrule melt and the ambient gas [1–5]. Recent high-precision SIMS oxygen three-isotope studies of chondrule minerals in primitive carbonaceous chondrites (CC) [5–8] have demonstrated that (i) the $\delta^{17,18}$O values define a distinct linear array (PCM line) in the oxygen three-isotope diagram; (ii) the Δ^{17}O (= δ^{17}O–0.52×δ^{18}O) values of olivine and pyroxene within individual chondrules (excluding relict grains) are often indistinguishable from each other and (iii) FeO-rich (type II; Mg# < 90) chondrules are ^{16}O-depleted (higher Δ^{17}O values) relative to Fe-poor (type I; Mg# ≥ 90) chondrules. For type I chondrules in CR3 chondrites, Tenner et al. [6] identified a continuous increase in chondrule-averaged Δ^{17}O values with decreasing Mg#s. CV3 chondrites are one of the most extensively studied chondrite groups and mineral-scale oxygen isotope data of low-Ca pyroxene and/or forsteritic olivine are available for Kaba (2 analyses of $Fo_{99.5}$, [9]), Mokoia [9–12], Vigarano and Efremovka [11, 12], as well as Allende [7, 12]. Especially Allende experienced significant thermal metamorphism, thus complicating the evaluation of the Mg#-Δ^{17}O relationship because of Mg-Fe diffusion in olivine. We carried out a combined SIMS oxygen isotope and EPMA study of chondrules in Kaba CV_{OXB}, one of the least thermally metamorphosed CV3 chondrite [13], in order to further investigate oxygen isotope systematics of chondrules in CV chondrites.

Methods: Oxygen three-isotope analyses of olivine and pyroxene were carried out using a Cameca IMS 1280 at the WiscSIMS laboratory. Analytical routines followed those described in [3] including correction procedures for instrumental bias. The primary Cs^+ beam was set ~3 nA with 12-15 µm diameters. Typical external reproducibility determined from bracket of standard analyses was: δ^{17}O, δ^{18}O, Δ^{17}O; ~0.3, ~0.4, ~0.4 ‰. In most chondrules, 8 spots were analyzed in order to examine internal isotope homogeneity.

Results and Discussion: 25 porphyritic chondrules/fragments (24 type I, Mg#: ~99.5-98.5; 1 type II, Mg# ~85, PP) and a single olivine mineral fragment (Fo ~63) from the Kaba CV3 chondrite were analyzed. Mg#s of olivine and pyroxene in Fe-poor chondrules/fragments are mostly identical within a single chondrule and constantly high (Mg# >98), which is consistent with their low degree of thermal metamorphism. In general, $\delta^{17,18}$O values plot on or slightly below the PCM line (except for the type II PP chondrule). Multiple analyses including olivine and pyroxene are in most cases indistinguishable in respect to the Δ^{17}O values, as reported in [7]. Exceptions are ^{16}O-rich relict olivine grains that appear in almost half of the chondrules in Kaba. A few chondrules comprise internally homogeneous olivine that is isotopically distinct from likewise homogeneous pyroxene, while olivine grains are likely to be relict and show both higher and lower Δ^{17}O values compared to those of pyroxene. Thus, the average Δ^{17}O values that may represent those of the final chondrule melt are calculated excluding relict olivine. Most type I chondrules yield chondrule-averaged Δ^{17}O values in a narrow range from –6 to –4 ‰ except for two with values of ~ –8‰. The type II PP chondrule and the FeO-rich olivine fragment have significantly higher average Δ^{17}O values of ~0 ‰ and ~ –2 ‰, respectively. Present dataset is generally consistent with those of Allende by [7], though the lowest Δ^{17}O values extended to –8 ‰ but no type I chondrules with Δ^{17}O above –3‰ were found in Kaba CV3 so far.

Summary: The principal oxygen isotope systematics of chondrules in Kaba CV3 are similar to those in Acfer 094 and CO3 reported by [5, 8] in terms of the Mg#-Δ^{17}O relationships that show abundant chondrules with Δ^{17}O values of –6 to –4 ‰ and high Mg# (>96). Consistency of Mg# between olivine and pyroxene from type I chondrules observed in this study further confirmed the low degree of thermal metamorphism experienced by this meteorite making Kaba one of the most pristine CV3 chondrite and an interesting target for further isotope studies.

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