Evidence for an ^{16}O-poor gaseous reservoir during formation of a fine-grained CAI from Northwest Africa 8613

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Fine-grained, Ca-Al-rich inclusions (FGIs) in CV chondrites are thought to be direct condensates from the solar nebular gas [1]. ^{16}O-rich compositions of minerals in FGIs from primitive carbonaceous chondrites demonstrate the presence of ^{16}O-rich nebular gas from which they condensed [3]. On the other hand, ^{16}O-poor signatures for minerals in FGIs have been suggested to be originated from chemical exchanges of O-isotopes in the nebular gas and/or on the parent body after their condensation formation [3–5]. Here, we present an original ^{16}O-poor signature found from a FGI from the reduced CV chondrite Northwest Africa 8613, named HKD01, by a coordinated study of in situ O-isotope analysis and detailed petrographic observations.
The FGI HKD01 has an irregular shape with a size of approximately 10 ×12 mm and composed mainly of melilite, hibonite, and spinel. O-isotope compositions of the constituent minerals plot along the CCAM line, ranging between $\Delta^{17}O$ ~ −23‰ and 0‰. The FGI is petrographically four layered structure from core to rim as hibonite-rich core, spinel-rich core, melilite-rich mantle, and hibonite-spinel-melilite-rich mantle. Each petrographic domain contains melilite, hibonite, and spinel with variable proportions of those minerals. The FGI is rimmed by thin spinel and diopside layers. The spinel and hibonite grains in the FGI are uniformly ^{16}O-rich ($\Delta^{17}O$ = −23‰). Melilite crystals in the two cores exhibit normal chemical zoning with O-isotope zoning from $\Delta^{17}O$ ~ −23‰ to −14‰. Melilite crystals in the hibonite-spinel-melilite-rich mantle exhibit normal chemical zoning with O-isotope zoning from $\Delta^{17}O$ ~ −17‰ to 0‰. Melilite crystals in the melilite-rich mantle show chemical oscillatory zoning with uniform ^{16}O-poor ($\Delta^{17}O$ ~ 0‰) value despite their chemical variations (Åk2–14). Crystal sizes of melilite in the core and the hibonite-spinel-melilite-rich mantle are generally less than 10 μm, while those of melilite in the melilite-rich mantle are typically 15 to 25 μm.
Therefore, in the FGI, intra-crystalline distribution of O-isotopes is homogeneous in larger melilite, but heterogeneous in smaller melilite. This contrast for O-isotope distribution indicates that the O isotopic compositions in melilite of the FGI HKD01 have not been disturbed significantly by secondary processes because the exchange rate is dependent on crystal sizes [6, 7]. The O-isotope distribution of melilite in the FGI HKD01 correspond to those of nebular gas at the FGI condensed. Our data imply that both ^{16}O-rich and ^{16}O-poor gaseous reservoirs co-existed in the forming region of the FGI HKD01. The Al–Mg systematics of the FG-CAI indicate that these formation events occurred at 0.09 ±0.02 Myr after the formation of canonical CAIs [8], if ^{26}Al was homogeneously distributed.

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