The evolution of the solar nebula as recorded by hibonite-rich CAIs

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We studied O, Ca, Ti and ^{26}Al-^{26}Mg isotopic systematics of hibonite-rich Ca-, Al-rich inclusions (CAIs) from the Murchison (CM) meteorite. These CAIs can be divided into three isotopic populations: (1) PLACs (platy hibonite crystals) which are ^{26}Al-depleted, have δ^{48}Ca from –61 to +81‰, δ^{50}Ti from –71 to +171‰, and Δ^{17}O from –28‰ (solar) to –17‰. PLACs with solar Δ^{17}O lack large anomalies; with increase of Δ^{17}O, the range of Ca- and Ti-isotope anomalies increases. (2) CAIs with mass-fractionated O, Ca, Ti, or Mg have inferred initial ^{26}Al/^{27}Al ratios ($(^{26}Al/^{27}Al)_0$) of ~(0–5)×10^{-5}; those with low $(^{26}Al/^{27}Al)_0$ have δ^{48}Ca and δ^{50}Ti from –14 and +43‰ and variable Δ^{17}O. CAIs with evidence for ^{26}Al incorporation have Δ^{17}O of ~–23‰ and have no resolved anomalies in Ca and Ti. (3) Spinel-hibonite inclusions (SHIBs) have uniform Δ^{17}O of ~–23‰. Internal isochrons for 8 SHIBs show $(^{26}Al/^{27}Al)_0$ = (2.5–5)×10^{-5}. 5 SHIBs studied for Ca and Ti have anomalies of <5‰.

If ^{26}Al-depletions in hibonite-rich CAIs indicate formation before arrival of fresh ^{26}Al, then they suggest that carriers of ^{50}Ti and ^{48}Ca anomalies were initially heterogeneously distributed in the ^{26}Al-poor, early solar nebula. Both isotopically anomalous (in O, Ca and Ti) and solar (in O, Ca and Ti) PLACs formed in the ^{26}Al-poor nebula. Data for fractionated CAIs suggest that prior to arrival of ^{26}Al, the CAI formation region evolved towards a nonsolar, yet uniform Δ^{17}O of ~–23‰ and that anomalies in Ca and Ti were diluted to ≤~5‰. SHIBs formed in a similarly homogeneous reservoir. The variable $(^{26}Al/^{27}Al)_0$ in SHIBs could indicate formation during admixture of ^{26}Al or prolonged formation/processing after its significant decay.

The data suggest that highly fractionated CAIs were able to form prior to and during admixture of ^{26}Al. PLACs (often sizable single crystals or aggregates of chemically uniform hibonite) only formed in the ^{26}Al-poor nebula, while the more fine-grained and highly chemically zoned hibonites found in SHIBs formed in the more evolved nebula.