Isotopic records in CM hibonites: Implications for timescales of mixing of isotope reservoirs in the solar nebula

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Abstract

The magnesium isotopic compositions of 26 hibonite-bearing inclusions from the CM chondrite Murchison, as well as isotopic measurements on a subset of these samples for oxygen, titanium, and lithium–beryllium–boron are reported along with oxygen isotopic data for an additional 13 hibonites that were previously investigated for other isotope systems (magnesium, potassium, calcium, and titanium) and rare earth element concentrations. Magnesium isotopic compositions divide CM hibonites into two distinct populations which correlate perfectly with their mineralogy and morphology, as previously discovered by Ireland [Ireland T. R. (1988) Correlated morphological, chemical, and isotopic characteristics of hibonites from the Murchison carbonaceous chondrite. Geochim. Cosmochim. Acta 52, 2827–2839]: Spinel-HIBonite spherules (SHIBs) bear evidence of in situ \(^{26}\)Al decay, whereas PLAty-Crystals (PLACs) and Blue AGgregates (BAGs) either lack resolvable \(^{26}\)Mg-excesses or exhibit \(^{26}\)Mg deficits by up to \(\sim-4\%\). High precision, multiple collector SIMS analyses show that 6 of 7 SHIBs investigated fall on a single correlation line implying \(^{26}\)Al/\(^{27}\)Al = \((4.5 \pm 0.2) \times 10^{-5}\) at the time of isotopic closure, consistent with the “canonical” \(^{26}\)Al abundance characteristic of internal isochrons in many calcium–aluminum-rich inclusions (CAIs). One SHIB sample exhibits \(\Delta^{26}\)Mg* consistent with a “supracanonical” \(^{26}\)Al/\(^{27}\)Al ratio of \((6.4 \pm 0.5) \times 10^{-5}\). The PLAC hibonites contain highly anomalous titanium isotopic compositions, with \(\delta^{50}\)Ti values ranging from \(-80\%\) to almost \(+200\%\), whereas SHIBs generally lack large Ti isotopic anomalies.

Eight out of 11 \(^{26}\)Al-free PLAC hibonite grains record \(^{10}\)Be/\(^{9}\)Be ratios that correlate with Be/B; the inferred initial \(^{10}\)Be/\(^{9}\)Be ratio of \((5.1 \pm 1.4) \times 10^{-4}\) is lower than the best-constrained \(^{10}\)Be/\(^{9}\)Be of \((8.8 \pm 0.6) \times 10^{-4}\) in a CV CAI. The data demonstrate that \(^{10}\)Be cannot be used as a relative chronometer for these objects and that most of the \(^{10}\)Be observed in CAIs must be produced by irradiation of precursor solids in the early solar system. The lack of \(^{26}\)Al in PLAC hibonites indicates that significant amounts of \(^{26}\)Al were not formed in the same spallogenic processes that made \(^{10}\)Be in PLAC precursors. This is most easily understood as indicating very early formation of the PLAC hibonites, prior to the incorporation and mixing of \(^{26}\)Al into the solar nebula, although an alternative scenario, which invokes irradiation under different solar flare conditions, cannot be ruled out. Lithium isotopes are normal within uncertainties, probably reflecting contamination and/or postcrystallization exchange.

The oxygen isotopic compositions of SHIBs and PLACs are all highly \(^{16}\)O-enriched, but are not derived from a homogeneous reservoir: \(\Delta^{17}\)O values span a range of \(\sim-28\%\) to \(-15\%\). The ranges of \(^{16}\)O-enrichment in SHIBs and PLACs overlap and are less “anomalous” than the most \(^{16}\)O-enriched compositions found in meteorites [Kobayashi S., Imai H. and Yurimoto H. (2003) New extreme \(^{16}\)O-rich chondrule in the early solar system. Geochim. J. 37, 663–669]. Both PLACs and SHIBs

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