Oxygen isotope systematics of chondrules among chondrite groups

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Oxygen isotope ratios of chondrules record those of the dust-enriched protoplanetary disk in the early Solar System, from which their parent asteroids accreted [1-2]. High precision SIMS oxygen isotope analyses of chondrules in the least equilibrated chondrites have been conducted on >300 chondrules from various chondrite groups; LL3, H3, Acfer 094 (ungrouped C), CO3, CV3, CR3, CH3, and R3 [1-9].

Oxygen isotope ratios of chondrules in carbonaceous chondrites [2,4-8] are characterized by enrichment of ^{16}O relative to the terrestrial mantle. Their $\delta^{18}O$ and $\delta^{17}O$ values plot along the slope ~1 primitive chondrule mineral (PCM) line, defined in [2]. They show a wide range of $\Delta^{17}O$, mainly from –6‰ to +1.5‰, and correlate with Mg#. The slope ~1 chondrule trend could be the result of mixing of ^{16}O-rich anhydrous dust and ^{16}O-poor ice in precursor solids within the dust-enriched disk [10], which could be related to extreme mass independent isotope fractionation (MIF) in the earliest solar nebula, as indicated from [11-12].

In contrast, ordinary and R chondrite chondrules show mass dependent isotope fractionation above the terrestrial fractionation line ($\Delta^{17}O$ ~+1‰), toward lower $\delta^{18}O$ values relative to the PCM line [1,3,9]. FeO-poor olivine-rich chondrules (IA) have the lowest $\delta^{18}O$ values [1]. A narrow range of $\Delta^{17}O$ values could indicate isotope reservoirs were well-mixed prior to the chondrule forming event(s). [1] argued that a significant isotope fractionation (≥3 ‰) could be produced between nebula gas and olivine without dust enrichment at ~1200°C. MIF components in inner asteroidal regions could have been homogenized by transient heating events early during disk evolution, before dust accreted and densified.

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