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Rapid condensation of the first Solar System solids inferred from silicon isotopes in amoeboid olivine aggregates

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Chondrites are primitive meteorites leftover from the evolution of the Solar protoplanetary disk. They comprise chondrules, fine-grained matrix, and the oldest known solids of the solar system, refractory inclusions in the form of Ca- and Al-rich inclusions (CAIs, millimeter- to centimeter-sized high-temperature complex assemblages of refractory oxides and silicates) and amoeboid olivine aggregates (AOAs, fine-grained aggregates of olivine grains associated with variable proportions of CAI-like materials). The mineralogy of refractory inclusions resembles that of the earliest condensates predicted to form from a cooling gas of solar composition, with AOAs appearing to be somewhat lower-temperature objects than CAIs [1]. However, little is known about the timescales of condensation because of secondary heating processes that erased their primordial signature [2].

AOAs have never been melted and have undergone minimal thermal annealing [3] and thus might have retained the conditions under which they condensed. We determine the silicon isotopic compositions of AOAs in order to constrain the conditions under which they condensed and the information they bear on the structure and evolution of the Solar protoplanetary disk. High-precision silicon isotopic measurements of seven AOAs from weakly metamorphosed carbonaceous chondrites show large, mass-dependent, light Si isotope enrichments (-9 ‰ $< \delta^{30}Si < -1$ ‰). Based on physical modeling of condensation within the protoplanetary disk, we attribute these isotopic compositions to the rapid condensation of AOAs over timescales of days to weeks [4]. Such short condensation times for AOAs are inconsistent with disk transport timescales, indicating that AOAs, and likely other high-temperature condensates, formed during brief localized high-temperature events [4]. This implies that the earliest solids of the Solar System condensed, aggregated and were processed over short timescales, perhaps on the order of days, in a dynamic and thermally nonuniform disk region. Nowhere was the primordial condensation sequence quiescent.

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