The Timing of Moderately Volatile Element Depletion in Planetesimals and Planets

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Calcium-aluminium-rich inclusions (CAIs) provide an important estimate for the initial $^{87}Sr/^{86}Sr$ ratio of the solar system, which is a key value for calculations of ^{87}Rb-^{87}Sr model ages for volatile depletion. However, nucleosynthetic ^{84}Sr anomalies in CAIs [1, 2] impose an uncertainty on this initial ratio that translates to a 7 Ma offset. This uncertainty dictates whether the depletion of moderately volatile elements occurred in the protoplanetary disk or as a protracted event over planetesimal accretion timescales. It arises from the analytical inability to differentiate between s-, r-, and p-process ^{84}Sr effects [1]. Here, we present multi-element data to constrain the origin of the ^{84}Sr variations.

Fifteen CAIs were analysed; fourteen from Allende (CV3) and one from Mokoia (CV3). Petrographic analysis was performed by SEM and trace element compositions were analysed by ICP-MS (Element). Strontium, Ti, and Zr were separated by ion exchange chromatography [1, 3, 4]. Strontium isotopes were measured by TIMS (Triton) with a dynamic acquisition protocol; Zirconium and Ti isotopes were measured by MC-ICP-MS (Neptune Plus) at ETH Zürich.

Nine CAIs display unfractionated rare earth element (REE) patterns, and six CAIs have Group II REE patterns. The combined Sr, Ti, and Zr isotopic compositions of the Group II CAIs hint that the ^{84}Sr nucleosynthetic anomaly in CAIs is an excess in p-process material, rather than an r-process excess or an s-process depletion. A key impact of this finding is that no correction to the initial $^{87}Sr/^{86}Sr$ ratios of CAIs is necessary, as recently suggested by [1]. Consequently, the range in initial $^{87}Sr/^{86}Sr$ ratios measured in CAIs, eucrites, and angrites is real. It indicates that the loss of moderately volatile elements did not occur solely in the nebula-phase but extended over the first ~7 Ma of the solar system, likely by impacts and degassing of small planetary bodies.

[1] Hans et al. (2013) *EPSL* **374**: 204-214; [2] Moynier et al. (2012) *APJ* **758**: 45; [3] Nebel et al. (2005) *IJMS* **246**: 10-18; [4] Schönbächler et al. (2004) *Analyst* **129**: 32-37.