

## IRON ISOTOPE SYSTEMATICS OF REFRACTORY INCLUSIONS.

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**Introduction:** Calcium-aluminum-rich inclusions (CAIs) are the first solids to condense in the protoplanetary disk and their isotopic compositions can provide insights about the formation and evolution of the early Solar System. Previous work has shown that isotopic differences exist between normal (non-FUN) CAIs and terrestrial rock standards for a variety of elements spanning a large mass range [e.g., 1-5]. These variations include differences in the amount of nucleosynthetic (mass-independent) endmembers (*p*-, *s*-, and *r*-processes) in CAIs relative to terrestrial standards [1-5], as well as differences in mass-dependent isotope signatures [e.g., 5-6]. Previous work has reported both mass-dependent variations as well as nucleosynthetic variations in CAIs for Fe-peak elements like Ti, Ca, Cr, and Ni [e.g., 4, 6-7] although Fe has largely been ignored because of its susceptibility for contamination in CAIs from secondary processes. To this point, only one study has reported Fe isotope nucleosynthetic variability in non-FUN CAIs [8].

This study seeks to further investigate the Fe isotopic system by analyzing Fe isotopes in refractory inclusions and their components for both mass-dependent and nucleosynthetic variations. The sample set analyzed in this study has been studied for a wide range of elements with isotopic anomalies previously observed for many isotope systems [e.g., 2] including large excesses in the neutron-rich isotopes of Ti and Cr [4] that are formed in the Fe-peak of nucleosynthesis. Additionally, we revisit the large excesses of <sup>58</sup>Fe that were previously reported in the bulk CAI composition in one sample by [8].

**Samples and Methods:** Along with the terrestrial rock standards BCR-2 and BHVO-2, aliquots of bulk Allende and a variety of CAIs previously analyzed for other isotopic systems were selected. This sample set includes CAIs from Allende and other CV3 meteorites [1-2] as well as CAIs removed from CK meteorites [3]. In addition, minerals separated by magnetic susceptibility from the historical Allende CAI Egg-2 were also measured. Iron was separated from all samples using AG1-X8 (100-200 mesh) anion exchange resin following the procedure from [9]. Two passes through this procedure was sufficient for the removal of critical elements (e.g., Cr, Ni) that may affect Fe-isotopic measurement.

**Isotopic measurement:** The Fe isotopic compositions of the samples and standards were measured on a Thermo-Scientific Neptune Plus MC-ICP-MS in Hannover. Samples and standards were measured in high mass resolution mode (mass resolving power of ~12,000) as to fully resolve the Fe peaks from molecular interferences. In order to collect information about both the mass-independent and mass-dependent variation in the samples, the measurement solutions were doped with Cu to monitor instrumental mass bias during the run [9]. Instrumental mass bias was corrected using both external and internal normalization (<sup>63</sup>Cu/<sup>65</sup>Cu = 2.24359 and <sup>56</sup>Fe/<sup>54</sup>Fe = 15.69786) [10].

**Results and Discussion:** The mass-dependent Fe isotope compositions of the terrestrial rock standards (BCR-2 and BHVO-2) and bulk Allende measured in this study agree with literature data [11]. No mass-independent isotopic variations are detected in the terrestrial samples or bulk Allende, in agreement with [12].

In contrast, some CAIs display correlated, mass-dependent and mass-independent Fe isotopic variations, the latter indicating nucleosynthetic heterogeneities. Interestingly, magnetic separates of the Allende CAI Egg-2 show large  $\epsilon^{57}\text{Fe}$  and  $\epsilon^{58}\text{Fe}$  (i.e. nucleosynthetic) variations relative to bulk Allende, however, opposite in direction to those previously published for the bulk Egg-2 CAI [8]. The more magnetic separate shows larger isotopic variation than the non-magnetic separate, relative to bulk Allende. The coupling of mass-dependent and nucleosynthetic anomalies in Fe may indicate mixing between the original Fe-isotope composition of the CAI and that of later condensed (and more abundant Fe) that is represented by bulk Allende and terrestrial standards. In such a scenario, the magnetic portions of CAIs would be less susceptible to alteration and therefore higher in Fe indigenous to the CAI, whereas the less magnetic fraction is more susceptible to Fe replacement during secondary processes.

**References:** [1] Burkhardt et al. (2011) *Earth & Planetary Science Letters*, 312, 390. [2] Brennecke et al. (2013) *Proceedings of the National Academy of Sciences*, 110, 17241. [3] Shollenberger et al. (2015) *LPSC*, 46, #2593. [4] Mercer et al. (2015) *LPSC*, 46, #2920. [5] Mane et al. (2014) *LPSC*, 45, #1685. [6] Simon et al. (2016) *LPSC*, #1397. [7] Birck & Lugmair (1988) *Earth & Planetary Science Letters* 90, 131. [8] Völkening & Papanastassiou (1989) *The Astrophysical Journal*, 347, L43-L46. [9] Schuth et al. (2015) *Chemical Geology*, 392, 74-86. [10] Rosman and Taylor (1998) *Journal of Physical & Chemical Reference Data*, 27, 1275. [11] Craddock & Dauphas (2011) *Geostandards & Geoanalytical Research*, 35, 101-123. [12] Dauphas et al. (2004) *Analytical Chemistry*, 76, 5855-5863.