NO IN SITU EVIDENCE FOR ^{60}Fe DECAY IN PRMITIVE METEORITES.

J. Kodolányi[1], P. Hoppe[1] and C. Vollmer[2], [1]Max Planck Institute for Chemistry (Hahn-Meitner-Weg 1, 55128 Mainz, Germany; j.kodolanyi@mpic.de), [2]University of Münster, Institute for Mineralogy (Corrensstrasse 24, 48149 Münster, Germany).

Introduction: Iron-60 is a short-lived radioactive isotope (t½: 2.62 ± 0.04 million years [1]). Its abundance is important for models exploring the evolution of planetesimals, and the provenance of the short-lived radioactive isotopes in the early solar system. Some in situ measurements of nickel isotope and Fe/Ni ratios in primitive chondrite components using SIMS (secondary ion mass spectrometry) and the NanoSIMS suggested that the abundance of iron-60 in the early solar system was 1–2 orders of magnitude higher than the abundance estimated based on the analysis of bulk meteoritic samples (^{60}Fe/^{56}Fe$_{CCAI}$, i.e., the ^{60}Fe/^{56}Fe ratio at the time canonical calcium-aluminum-rich inclusions formed: ~10^{-7} to 10^{-6} vs. ~10^{-8}, respectively; [2–5]). However, both in situ and bulk analyses may suffer from bias related to alteration [6], and in situ measurements have to cope with isobaric interferences. Here we present new in situ nickel isotope data from primitive carbonaceous and ordinary chondrites, to further constrain the abundance of iron-60 in the early solar system, and to better understand the variation of inferred ^{60}Fe/^{56}Fe$_{CCAI}$ observed before. To assess the effect of post-formation element exchange, we also studied some of the isotopically characterized chondrite components by transmission electron microscopy (TEM).

Samples and Experimental: We studied matrix and chondrule troilite as well as chondrule silicate minerals in the carbonaceous chondrites Allan Hills A77307 (CO3), Dominion Range 08006 (DOM 08006; CO3), as well as the unequilibrated ordinary chondrites (UOCs) Meteorite Hills 00526 (L/LL 3.05), Queen Alexandra Range 97008 (LL 3.05), and Semarkona (LL3.0). NanoSIMS isotope analyses were carried out at the Max Planck Institue for Chemistry (Mainz, Germany), using a 75–500 pA primary O^- beam (Hyperion source) on 2 × 2 µm² spots, or on 3 × 3 or 6 × 6 µm² areas in high-resolution (200 nm) imaging mode, while collecting $^{28}Si^+/^{29}Si^+$ (troilite/silicates, respectively), $^{46}Ti^+$, $^{54}Fe^+$, $^{60}Ni^+$, and $^{62}Ni^+$ secondary ions. Electron-transparent slices of 3 troilites and 1 enstatite were prepared by FIB-SEM (focused ion beam milling combined with scanning electron microscopy) and analyzed with an image-corrected FEI/ThermoFisher Themis TEM (University of Münster) at 300 kV acceleration voltage. X-ray images (from energy dispersive spectra) were acquired in Scanning TEM mode using the four-quadrant Super X detector technology.

Results and Discussion: Troilites have generally higher Fe/Ni ratios compared to silicates (maxima at 600,000 vs. 63,000, respectively). Nevertheless, isotope data from neither group of minerals provided evidence for in situ iron-60 decay. This is partially due to the high uncertainties of individual measurements resulting from low nickel count rates in targets with high Fe/Ni ratios, but some of the Fe/Ni ratios were so high (above 100,000) that an enrichment in nickel-60 resulting from iron-60 decay should have been detectable (the expected anomaly should have been larger than 2σ, i.e., the measurement uncertainty representing 95% confidence level), had the initial ^{60}Fe/^{56}Fe been at the maxima estimated previously (~10^{-6}; e.g., [2]). Pooled data do not yield inferred ^{60}Fe/^{56}Fe outside 2σ, either. The best-constrained initial ^{60}Fe/^{56}Fe of an individual object was estimated for a chondrule troilite in DOM 08006 (3.1 (± 2.1) × 10^{-8}; n = 6; χ^2 = 0.25; all uncertainties hereafter represent 68% confidence level, 1σ). Troilite data together give an inferred initial ^{60}Fe/^{56}Fe of 2.0 (± 1.6) × 10^{-8} (n = 78; χ^2 = 1.1). These results are in stark contrast with the ^{60}Fe/^{56}Fe inferred for Semarkona troilites by [2], 9.2 (± 1.2) × 10^{-7} (n = 19), but similar to the ratio that can be inferred from the recalculated troilite data of [7] (recalculation by [8]) from the UOCs Krymka and Bishunpur: 1.2 (± 2.4) × 10^{-8} (n = 32; χ^2 = 0.44). Similarly, ^{60}Fe/^{56}Fe ratios inferred for our silicates are not resolved from 0 at the 2σ level, whether we consider individual chondrules and chondrule fragments (from −3.1 (± 8.9) × 10^{-6} to 1.5 (± 2.1) × 10^{-6}), or the dataset as a whole (1.6 (± 7.5) × 10^{-8}; n = 56; χ^2 = 1.12). Note that aggregated, internally not-normalized SIMS and NanoSIMS isotope data of silicates from the literature [3,4,9,10] have a large scatter and give a significantly negative initial ^{60}Fe/^{56}Fe ratio: −4.3 (± 0.3) × 10^{-8} (n = 593; χ^2 = 12.14). Observations by TEM revealed that nickel- +/− iron-rich veins as thin as a few tens of nm across occur in silicates and troilites, which could hinder the estimation of true initial ^{60}Fe/^{56}Fe ratios, if included in the analysis volume. However, all but the thinnest of these veins can be readily avoided during NanoSIMS analyses or data reduction, if measurements are done in imaging mode, as was the case for most of our measurements. We propose that the highest ^{60}Fe/^{56}Fe ratios inferred previously based on SIMS and NanoSIMS data are gross overestimations, which potentially resulted from inadequate background and/or interference corrections.

References: [1] Rugel G. et al. (2009) *Physical Review Letters* 103:072502. [2] Mostefaoui S. et al. (2005) *The Astrophysical Journal* 625:271–277. [3] Mishra R. K. et al. (2016) *Earth and Planetary Science Letters* 436:71–81. [4] Telus M. et al. (2018) *Geochimica et Cosmochimica Acta* 221:342–357. [5] Tang H. and Dauphas N. (2015) *The Astrophysical Journal* 802:22. [6] Telus M. et al. (2016) *Geochimica et Cosmochimica Acta* 178:87–105. [7] Tachibana S. and Huss G. R. (2003) *The Astrophysical Journal* 588:L41–L44. [8] Telus M. et al. (2012) *Meteoritics and Planetary Science* 47:2013–2030. [9] Mishra R. K. and Goswami J. N. (2014) *Geochimica et Cosmochimica Acta* 132:440–457. [10] Mishra R. K. and Chaussidon M. (2014) *Earth and Planetary Science Letters* 398:90–100.