Ni isotope anomalies in meteorites

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With a halflife of 1.49 Myr, the ^{60}Fe-^{60}Ni decay scheme is ideally suited for dating meteorites and planetary processes that occurred in the first 10 Myr of the early Solar System (ESS). Ni has two neutron-rich isotopes, ^{62}Ni and ^{64}Ni, produced through nuclear statistical equilibrium processes occurring in neutron-rich supernova ejecta. Excesses and deficits have been documented for neutron-rich isotopes from iron group elements (^{48}Ca, ^{50}Ti, ^{54}Cr, ^{62}Ni and ^{64}Ni) in normal and FUN calcium-aluminium-rich inclusions (CAIs) as well as primitive and differentiated meteorites, providing information on the scale and extent of isotopic heterogeneity in the ESS.

We have developed analytical protocols for high-precision Ni isotope measurements in metal and silicate materials by MC-ICPMS, enabling typical external reproducibilities of 0.010‰ and 0.015‰ for δ^{60}Ni* and δ^{62}Ni values, respectively. Two terrestrial rock standards (BHVO-1 and DTS-2b) have δ^{60}Ni* and δ^{62}Ni identical within analytical uncertainty to the Ni standard solution, thus validating our approach. One enstatite chondrite (Qingzhen) and a martian dunite (NWA2737) yielded δ^{60}Ni* and δ^{62}Ni values identical to the terrestrial average. Three carbonaceous chondrites (Murchison, Orgueil and Renazzo) have average δ^{60}Ni* and δ^{62}Ni values of 0.0012±0.0057‰ and 0.0341±0.0025‰, respectively. These results suggest that if ^{60}Fe was present in the ESS when these bodies formed, it was homogenously distributed (±20%) within the accretion region of the terrestrial planets and chondrites. Seven iron meteorites show resolvable uniform deficits in δ^{60}Ni* of 0.0233±0.0071‰ and 0.0409±0.0213‰, respectively. Although δ^{60}Ni* deficits in irons are consistent with Fe/Ni fractionation during the lifespan of ^{60}Fe, a whole-rock fragment and olivine separate from the 4.566 Gyr old angrite SAH99555 as well as a chondrule and CAI from Allende with supracanonical ^{26}Al/^{27}Al yielded identical deficits in δ^{60}Ni*, not correlated with their Fe/Ni ratios. We suggest that irons, SAH99555 and the Allende chondrule and CAI analysed here formed in the absence of ^{60}Fe, at a time when ^{26}Al was widespread within ESS solids, reflecting a late injection of ^{60}Fe in the ESS. Injection of ^{60}Fe occurred after accretion of the angrite parent body, ~600,000 yr after CAI-formation, but was homogeneously distributed within the ESS at the time of accretion of chondrite parent bodies. Observed excesses and deficits in ^{62}Ni are correlated with ^{54}Cr anomalies. These results provide important constraints regarding the origin of short-lived nuclides in the ESS, and demonstrate the presence of large-scale coupled Cr and Ni isotopic heterogeneity in ESS materials.