6.3.14

Combined Mg-Fe isotope analysis of solar system materials

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We report combined high-precision Mg-Fe isotope measurements of a range of meteoritic and planetary materials including CAIs and chondrules from Allende (CV3) and Dar al Gani 313 (LL3), whole-rock chondrites, and achondrites from the EPB, APB, Mars and Moon. Mg and Fe were purified from the same sample digestion by cation and anion exchange chromatography, respectively. Mg isotopes are determined by sample–standard bracketing, with data reported relative to DSM-3 (δ^{26}Mg ± 0.1‰; ^{26}Mg excess ± 0.02‰). Fe isotopes are measured with a ^{58}Fe-^{54}Fe double spike and, in some cases, by sample-standard bracketing, and results are reported relative to IRMM-14 (δ^{56}Fe ± 0.05‰)

CAIs and chondrules: δ^{26}Mg for six CAIs varies by 19.4‰ (after correction for decay of ^{26}Al), while chondrules from Dar al Gani 313 and from Allende have a more restricted range in δ^{26}Mg of 1.1‰ (n = 7). These variations are interpreted as reflecting isotope fractionation related to partial evaporation and condensation processes during the chondrule- and CAI-forming events. CAIs and chondrules show variations in δ^{56}Fe of 2.5‰ and 1.3‰, respectively, which are amongst the largest fractionations reported for Fe in high-T environments. δ^{26}Mg and δ^{54}Fe values are correlated for five of the seven chondrules, suggesting that similar processes are responsible for generating Fe and Mg isotope fractionations. In contrast, Fe and Mg isotopes are decoupled for all CAIs and two chondrules. Uniquely, through Fe isotope analysis by the double spike method and sample-standard bracketing we are able to constrain that any ^{58}Fe excess in the analysed CAIs is <0.1‰.

Achondrites and chondrites: δ^{26}Mg for volcanic samples from Earth's mantle, and achondrites from the EPB, APB, Moon and Mars are ca. 0.2‰ heavier than the chondrite average, implying that planetary differentiation and/or partial melting may produce the small difference. We are currently assessing if small variations (<0.1‰) in excess ^{26}Mg characterise samples from different planetary bodies in a manner similar to Cr isotopes, and can be used to identify heterogeneous distribution of ^{26}Al in the early accretion disc. High precision Fe isotopic analysis of these materials is underway.

6.3.15

The Ni isotope geochemistry of chondrites and iron meteorites

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We report on the geochemistry of Ni stable isotopes (^{58}Ni, ^{61}Ni, ^{62}Ni, ^{64}Ni) and the presence of ^{60}Ni excesses resulting from the decay of the radioactive nuclide ^{60}Fe (1.5 My) in chondrites and iron meteorites. The metal phase of ordinary chondrites (LL, L, and H) with different degrees of metamorphic alteration (3 to 6) and three magmatic and non-magmatic iron meteorites have been analysed. Three silicate phases were also analysed but the samples were too small for a precise signal to be obtained at masses 61, 62, and 64. The fractionation of ^{61}Ni/^{58}Ni, ^{62}Ni/^{58}Ni, and ^{64}Ni/^{58}Ni is mass dependent. The range of mass fractionation per mass difference unit in the metal phase of chondrites extends over 300 ppm (0.3 ‰). The mean value appears to vary in the order: +0.05 ‰ for LL, +0.15 ‰ for L, and +0.25 ‰ for H. The iron meteorite samples seem to be heavy (+0.15 to +0.21 ‰). The few silicate samples analysed so far clearly fall to the negative side (-0.14 to -0.72 ‰). Clear evidence is obtained that, as for Fe [1] and Zn [2], the stable isotopes of nickel fractionate out of a common metal pool. When both the silicate and metal phases are considered, the total range of Ni isotopic variation in the Solar System must be in excess of 1 ‰. Since most of the Ni inventory of the sample is hosted in the metal phase, the range of isotopic variations in the bulk material is rather 0.3 ‰. The apparently increasingly systematic enrichment of the heavier Ni isotopes observed in the metal phase from LL, L, and H chondrites suggests that volatility controls isotopic variations. There are currently not enough Ni isotope data on silicates to draw a strong conclusion, but if the metal-silicate fractionation observed for the present samples holds for the Earth, the Ni isotope composition of the Earth's core–and of the Earth as a whole–may be close to that of H chondrites and possibly heavier (E?). The overall spread of the ^{60}Ni anomaly about the mass fractionation line is about 0.1‰ for one a.m.u. ^{60}Ni excesses and deficits in the metal phase of chondrites with respect to terrestrial silicate (our standard) can be used to date the onset of segregation of the Earth's core. The ^{60}Ni anomaly with respect to the mean ordinary chondrite is very weak. Since most of the Earth's Ni inventory is in the core, the present results may signal that core segregation only started after a substantial fraction of the initial ^{60}Fe had decayed away (a few My).

References

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