MASS INDEPENDENT NI ISOTOPIC VARIATIONS IN CHONDRITIC AND IRON METEORITES. Marcel Regelous[1,2], Tim Elliott[2] and Chris Coath[2], [1]Department of Geology, Royal Holloway University of London, Egham, Surrey, TW20 0EX, UK (m.regelous@gl.rhul.ac.uk), [2]Bristol Isotope Group, Department of Earth Sciences, Wills Memorial Building, Queen's Road, University of Bristol, BS8 1RJ, UK (tim.elliott@bris.ac.uk, chris.coath@bris.ac.uk).

Introduction: The Ni isotopic system is an attractive target for studying processes occurring in the early solar system. Ni has 5 stable isotopes of which one (^{60}Ni) is the daughter of the short lived ^{60}Fe ($t_{1/2}$ ~1.5My). Thus Ni isotopic studies can be used to investigate the timing of early Fe-Ni fractionation via measurements of ε^{60}Ni and heteroegeneity in neutron rich, iron-group nuclides (as has previously been identified in ^{54}Cr) via ε^{62}Ni.

Earlier Ni isotopic analyses by thermal ionization mass-spectrometry (TIMS) indicated the presence of live ^{60}Fe from the presence of elevated ε^{60}Ni in high Fe/Ni eucrite meteorites [1]. Mass independent variations in ε^{62}Ni were documented by TIMS in calcium aluminium rich inclusions and argued to reflect incomplete mixing of a neutron rich nucleosynthetic component [2]. Recent work on the Ni isotopic system by multi-collector inductively coupled plasma mass spectrometry (MC-ICPMS) has yielded conflicting results [3-5]. Some studies have found no discernible differences in the ε^{60}Ni between chondritic and iron meteorites, which is surprising given the early formation [e.g. 6] and the strong Fe-Ni fractionation associated with the formation of some iron meteorites. However, Bizzarro et al (2007) report significantly lower ε^{60}Ni and ε^{62}Ni in iron meteorites relative to chondrites and suggest this is compatible with the late injection of ^{60}Fe into the solar nebula.

We have developed a new analytical procedure to measure Ni isotopes to high precision and address these puzzles.

Analytical: We separated Ni from bulk meteorites using a three column procedure, with a highly Ni specific dimethylglyoxime (DMG) solution in the first step. This technique yields very high Ni yields and minimal residual matrix. Ni is analysed on a ThermoFinnigan Neptune MC-ICPMS in 'medium resolution' ($M/\Delta M$ >6000 peak edge width from 5-95% full peak height) with ~900pA beams of ^{58}Ni. Samples are analysed between measurements of NIST SRM986. Ni isotope ratios are (exponentially) internally normalised to ^{61}Ni/^{58}Ni and subsequently normalized to interpolated values of the NIST SRM986. We thus report ^{60}Ni/^{61}Ni and ^{62}Ni/^{61}Ni in the epsilon notation relative to the terrestrial standard. In a typical run, each sample is measured four times using a ~20min analysis routine. The two standard errors of our analyses are typically ±0.03 ε^{60}Ni and ±0.06 ε^{62}Ni. Terrestrial peridotite, basalt and metal separates are within error of NIST SRM986 passed through the same chemistry.

Results: We find small (<30ppm), but significant Ni isotopic variability in both magmatic iron and chondritic meteorites. The most common magmatic iron groups (IIAB, IIIAB, IVA) have slightly negative ε^{60}Ni (~ -0.05) and ε^{62}Ni (~ - 0.1). In contrast, IVB irons have more negative ε^{60}Ni (~ -0.15) and positive ε^{62}Ni (~ + 0.1). In general the irons define a rough negative trend in ε^{60}Ni vs ε^{62}Ni and this is range is overlapped by the analyses of chondrites. Notably ordinary chondrites have negative ε^{60}Ni and ε^{62}Ni, like the main magmatic irons, whereas the carbonaceous chondrites have positive ε^{62}Ni. In detail, the carbonaceous chondrites define a rough positive array of ε^{60}Ni vs ε^{62}Ni, with CV/CO/CM groups having similar compositions to the IVB irons. Only the enstatite chondrites have Ni isotopic ratios that are the same as the Earth.

Discussion: Our results contrast with those of Bizzarro et al (2007), showing smaller variability and no distinct contrast between iron and chondritic meteorites. Our findings thus do not support a late injection of ^{60}Fe to the solar nebula. Instead our results are compatible with earlier MC-ICPMS analyses but our higher precision analyses are able to resolve detail that was within error of the previous work.

The clear ε^{62}Ni heteroegenity shows imperfect mixing of different nebular nucleosynthetic components between the precursor materials of different meteorite groups. This variability causes difficulties in using variations in ε^{60}Ni for chronology. We can use chondrites and magmatic iron meteorites with similar ε^{62}Ni, assume a segregation time from Hf-W isotope systematics [e.g.6] and therefore infer an initial ^{60}Fe/^{56}Fe. This approach is most effective with the low Fe/Ni IVB irons compared to the CV/CO chondrites. Since these meteorites have overlapping ε^{60}Ni, we thus infer an low initial ^{60}Fe/^{56}Fe in carbonaceous chondrites of <1 x 10^{-7}, considerably lower than that determined by *in-situ* measurements on ordinary chondrites. At face value, this suggests radial heteroegeneity in nebular ^{60}Fe/^{56}Fe, which is not incompatible with the observed variability in ε^{62}Ni.

Ni is a major, moderately refractory element, present in sufficient abundance for analysis in most meteorites. Ni isotopic variability thus yields a valuable tool for tracking the provenence of precursor material of different meteorites and linking chondritic and iron groups. Significantly, the Ni isotopic similarity of enstatite chondrites and the Earth further supports the common heteritage of material that comprises these two bodies. Deriving modern silicate Earth from an enstatite chondrite protolith places important constraints on the processes that occurred on the early Earth.

References:

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