

IRON ISOTOPE GEOCHEMISTRY OF METAL GRAINS IN ORDINARY CHONDRITES. K. J. Gildea¹, R. Burgess¹, I. C. Lyon¹ and D. W. Sears², ¹School of Earth, Atmospheric and Environmental Sciences, The University of Manchester, Manchester, M13 9PL, UK. (karen.j.gildea-1@student.manchester.ac.uk). ²Arkansas Center for Space and Planetary Science, University of Arkansas, Fayetteville, Arkansas 72701, USA

Introduction: Iron isotope variations between components of ordinary chondrites are studied to help understand their source materials and the processes that formed them. Metal/silicate fractionation, chondrule formation, metamorphism, aqueous alteration, and terrestrial weathering have probably all influenced the Fe in chondrites, and there may be other processes. Thus, while the study of Fe isotopes is going to be complicated, the potential return is large. Fortunately, since Fe is a major element present in almost all components, we have much mineralogical, petrographic and geochemical data to help. We are determining the iron isotope ratios of the metallic iron of 29 ordinary chondrites with different classes (H, L and LL), different petrographic types (3-6) and different weathering status (falls and finds) in order to attempt to disentangle the effects of these different processes.

Equipment: Fe isotope ratio analysis was carried out using a Nu Instruments double focusing multiple-collector ICP-MS (Nu Plasma). Sample solutions were introduced via a Nu Instruments DSN-100 Desolvating Nebuliser with argon gas carrier to minimise the isobaric interferences. These interferences result from the combination of argon ions with HNO ions within the plasma to form ArN, ArO and ArOH which are isobaric with ⁵⁴Fe, ⁵⁶Fe and ⁵⁷Fe respectively. They are then further reduced by running the ICP-MS in medium resolution mode (resolving power ~9000). This is sufficient to ensure that the iron isotopes and the interfering isobaric interferences can be resolved to show as a flat topped peak with an iron ‘plateau’ [1].

Reproducibility and accuracy has been determined by obtaining a number of measurements of home-made Johnson-Matthey (JM) iron isotope standard against the IRMM014 iron isotope standard (JRC Reference Laboratory for Isotopic Measurements) over a month long period. The sample/standard bracketing method for the JM standard gives $\delta^{56}\text{Fe} = 0.43 \pm 0.06\text{‰}$ and $\delta^{57}\text{Fe} = 0.69 \pm 0.04\text{‰}$, where:
$$\delta^{56,57}\text{Fe} = \left[\left(\frac{{}^{56,57}\text{Fe}}{{}^{54}\text{Fe}} \right)_{\text{sample}} / \left(\frac{{}^{56,57}\text{Fe}}{{}^{54}\text{Fe}} \right)_{\text{IRMM014}} - 1 \right] * 1000$$

Each measurement cycle consisted of a single block of 30 readings typically repeated 3 times. Both the sample and the standard were signal-strength-matched to within 10% using 1 ppm solutions. Quoted uncertainties are $\pm 1\sigma$.

Samples and sample preparation: 28 of the 29 ordinary chondrite samples had already been crushed, magnetically separated and sealed in separate vials during a previous study [2]. The remaining sample (Barwell) was received only as bulk fragments. Initial experiments were undertaken using small samples (of a few mg) of the magnetic separates and dissolving them in a solution of 10% HNO₃ for 4 hours on a hot plate at approximately 50°C followed by cooling over night. The solutions were then diluted down to 2% HNO₃ by adding 18.2MΩ water.

Results: Each result listed in the following table is the average measurement taken over 5 cycles of 1 block of 30 individual readings. The isotopic values are plotted in Figure 1.

Sample	$\delta^{56}\text{Fe}$	$\delta^{57}\text{Fe}$
Elm Creek H4 find	0.36±0.06	0.55±0.05
Elm Creek H4 find	0.23±0.07	0.39±0.17
Elm Creek H4 find	0.39±0.09	0.72±0.37
Elm Creek H4 find	0.38±0.03	0.62±0.07
Aldsworth LL5 fall	0.22±0.02	0.30±0.12
Aldsworth LL5 fall	0.38±0.12	0.78±0.23
Bremervörde H3 find	0.10±0.08	0.24±0.13
Crumlin L5 fall	0.10±0.03	0.09±0.10
Crumlin L5 fall	0.71±0.33	0.56±0.12

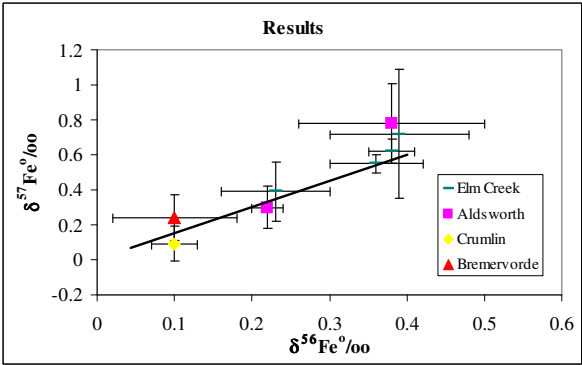


Figure 1. Fe isotopic composition of magnetic separates from ordinary chondrites (data given in table). Mass fractionation line of slope 1.5 shown for reference.

Further investigation revealed that there was a significant quantity of magnesium within the solution. This may be sufficient to produce a matrix effect that could explain some of the variation of the results. Con-

taminant species in the plasma may change the plasma temperature and collision rates within the plasma so altering the ionization probability of the desired species and hence the isotopic fractionation. To understand these matrix effects more clearly and to see whether they could be corrected for, a number of additional analyses were performed after adding known amounts of a Johnson-Matthey magnesium solution to the JM iron solution. These data are shown in figure 2.

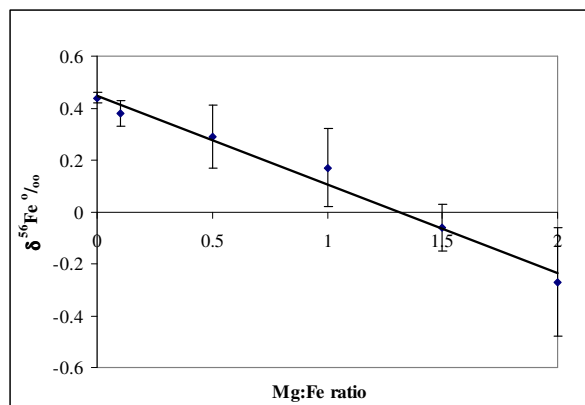


Figure 2. Measured $\delta^{56}\text{Fe}$ of the Johnson-Matthey iron standard with varying quantities of Mg solution normalised to IRMM014. Mg:Fe for the meteorite sample were all less than 0.1.

Increasing Mg content of the solution caused a depression of the measured $\delta^{56}\text{Fe}$ value and the data became much more scattered. The $\delta^{56}\text{Fe}$ values shown in figure 1 were corrected for the effects of the Mg matrix effect from figure 2 (corrections 0.01-0.03‰) producing the preliminary data shown in Fig 3.

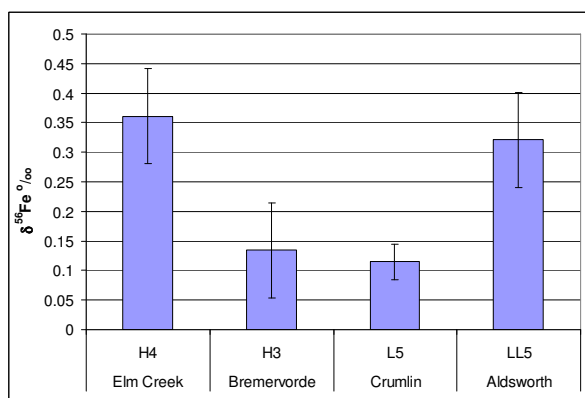


Figure 3. $\delta^{56}\text{Fe}$ values for 4 different meteorites corrected for Mg matrix effect.

Mg:Fe ratios in the meteorite solutions of 0.1 to 0.04 may indicate that there was still a small amount of intergrown silicate attached to the magnetic grains

which partly acid leached Mg into the solution. Thus the results may portray not only the isotopic composition of the metal iron fraction of the meteorite but also a small contribution from the silicate. Magnesium matrix effects also produced more scatter in the data and so current work is concentrating upon removal of the Mg and silicate contaminants.

Discussion: The samples are currently being re-processed by crushing in acetone and the metal grains handpicked with the aid of a microscope. Any Mg will then be separated by anion exchange chromatography [3] after dissolution overnight in 7M HCl instead of 10% HNO₃. The dissolved solutions then only need be evaporated once before being analysed using the ICP-MS. This decreases the number of procedural steps and thereby reduces the risk of chemical fractionation occurring during these processes.

Although it is not yet possible to establish any patterns occurring in these results, these early results indicate that when comparing the metal fraction of these ordinary chondrites to analyses of silicates, [e.g. 4, 5], they consistently show enrichment in the heavier iron isotopes whilst their separated chondrules appear to show enrichment in the lighter isotopes. Since bulk figures for most meteorites [4, 5] generally show very little fractionation with reference to terrestrial igneous standards and IRMM014, it is evident that the isotopic fractionation of these different components may be averaging out giving similar bulk values for different meteorites. Analyses of components may be more fruitful for understanding isotopic fractionation that must occur during evaporation, condensation and accretion within the solar nebula.

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References: [1] Weyer S. & Schweiters J.B. (2003) *Int. J. of Mass Spec*, 226, 355-368. [2] Sears D. W. & Axon H. J. (1976) *Nature* 260, 34-35. [3] Mullane E. et al (2003) *Plasma Source Mass Spec*, 351-361. [4] Kehm K. et al (2003) *GCA*, (67) 15, 2879-2891. [5] Zhu X. K. et al (2001) *Nature* 412, 311-312.