^{60}Ni excesses in Allende CAIs and chondrules

G. QUITTÉ[1], A.N. HALLIDAY[1], B. ZANDA[2,3] AND F. OBERLI[1]

[1] Institut für Isotopengeologie und Mineralische Rohstoffe, ETH-Zurich, Switzerland (quitte@erdw.ethz.ch)
[2] Dep. of Geological Sciences, Rutgers University, USA.
[3] Laboratoire de Minéralogie, MNHN, Paris, France

The short half-life of ^{60}Fe (1.49 Myr) makes the Fe-Ni system a powerful tool to investigate events in the very early solar system and to determine the difference in ages between the refractory inclusions, called CAIs, and chondrules.

Four CAIs have been analyzed (three from Allende and one from Efremovka, both CV3 chondrites). The same samples have already been investigated with Zr isotopes [1] in a search for nucleosynthetic anomalies. The Allende CAIs contain a ^{60}Ni-excess of +0.9 to +1.8 ε, in agreement with previous results on some other Allende CAIs [2], whereas Efremovka CAI shows a +6.3 ε excess in ^{60}Ni. The Pb-Pb age of Efremovka inclusion E60 is 4567.2±0.6 Ma [3] and an initial ^{26}Al/^{27}Al ratio of 4-5*10^{-5} has been reported for it [4]. E60 thus must have formed at the very start of the solar system, with its large Ni anomaly recording a very early and major Fe-Ni fractionation event. CAI USNM 3529-44 also shows an apparent ^{61}Ni-depletion of –1.3±0.5 ε. As we normalize all our results relative to ^{62}Ni/^{58}Ni, this observation can be interpreted as an excess in ^{62}Ni, in agreement with ^{62}Ni and ^{64}Ni excesses already reported for some Allende CAIs [2]. Interestingly, the CAI #44 is also the only one that shows a positive ^{96}Zr anomaly [1]. The other CAIs show neither ^{61}Ni-depletion nor ^{96}Zr excess.

Three Allende chondrules have also been analyzed: one of type I (reduced) and two of type II (oxidized). Preliminary data show that they are all characterized by a slight ^{60}Ni-excess of +0.4±0.1 to +1.0±0.1 ε (3 analyses each). The shift from the value of the standard (external reproducibility at 2σ: ±0.2 ε) is small but well resolved. If these results are confirmed, it means that ^{60}Fe was still present when the chondrules crystallized. We note, however, that the anomalies are apparently not correlated with Fe/Ni ratio. This could be due to alteration processes (thermal and aqueous) that may have caused redistribution of Ni. It is well known that Ni migrates with metamorphism [5] which allows the estimation of the metamorphic temperature of pentlandite-bearing chondrites. As this temperature is estimated to be ~335°C for Allende [6], the Fe-Ni sytem has probably been disturbed in this meteorite. The isotopic signatures of the chondrules, however, have not been completely reset by this process.

References

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