Iron-60 in ferromagnesian chondrules in least equilibrated ordinary chondrites

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Iron-60, which decays to 60Ni with a half-life of 1.49 Myr, is one of the now-extinct short-lived radionuclides in the solar system, and is produced efficiently only in stars. Its presence in the early solar system indicates that stellar nucleosynthesis shortly before or soon after the solar system formation contributed to the inventory of short-lived radionuclides. It is thus important to determine the initial abundance of 60Fe in the early solar system in order to evaluate a stellar source, which brought short-lived radionuclides to the early solar system, and a birth environment of the solar system.

Tachibana et al. (2006) analyzed 60Fe-60Ni systems in ferromagnesian pyroxene-rich chondrules from Semarkona and Bishunpur to estimate the initial abundance of 60Fe in the solar system. The obtained (60Fe/56Fe)0 ratios range from (2.2 +/- 1.0) x 10-7 to (3.7 +/- 1.9) x 10-7, but it has not been clear if there is a variation of (60Fe/56Fe)0 within ferromagnesian chondrules, which might be related to duration of chondrule forming events, because only four rare pyroxene-rich cryptocrystalline chondrules have been so far analyzed. In this study, in order to obtain more data on 60Fe-60Ni systems of ferromagnesian chondrules, we analyzed seven FeO-rich chondrules from least equilibrated ordinary chondrites.

We selected four FeO-rich chondrules from Semarkona and three FeO-rich chondrules from Bishunpur. Nickel isotopic analyses of chondrules were carried out using the Cameca imf-1280 ion microprobe at University of Hawaii at Manoa.

SMK1-5 is an FeO-rich porphyritic olivine-pyroxene chondrule from Semarkona. It shows marginal excesses of 60Ni and its (60Fe/56Fe)0 ratio is estimated to be (3.2 +/- 1.6) x 10-7. SMK1-6 is an FeO-rich porphyritic olivine chondrule from Semarkona. It shows no resolvable excess of 60Ni. SMK3-2 is an FeO-rich barred olivine chondrule from Semarkona. Its (60Fe/56Fe)0 ratio is estimated to be (2.7 +/- 2.7) x 10-7, and it is not clear if there is an excess of 60Ni in this chondrule. SMK3-6 is an FeO-rich barred pyroxene chondrule with olivine phenocrysts from Semarkona, with an inferred (60Fe/56Fe)0 ratio of (1.7 +/- 1.1) x 10-7. BIS-1is an FeO-rich porphyritic olivine-pyroxene chondrule from Bishunpur. It does not show resolvable excesses of 60Ni. BIS-32 is an FeO-rich porphyritic olivine-pyroxene chondrule from Bishunpur with marginal excesses of 60Ni. Its (60Fe/56Fe)0 ratio is estimated to be (1.9 +/- 1.1) x 10-7. BIS-38 is an elongated FeO-rich barred pyroxene chondrule. The (60Fe/56Fe)0 ratio is estimated to be (1.2 +/- 0.9) x 10-7 for this chondrule.

Four out of 7 ferromagnesian chondrules, which are not cryptocrystalline pyroxene-rich chondrules, show excesses of 60Ni. The estimated (60Fe/56Fe)0 ratios of the four chondrules range from (1.2 +/- 0.9) x 10-7 to (3.2 +/- 1.6) x 10-7. Considering that (60Fe/56Fe)0 ratios have large uncertainties, the range of (60Fe/56Fe)0 ratios in this study seems to be consistent with that reported by Tachibana et al. (2006).

Three chondrules show little or no excess of 60Ni, two of which are olivine-rich ferromagnesian chondrules (SMK1-6 and SMK3-2). The following reasons may be considered for the lack of 60Ni excess in olivine-rich chondrules; (1) olivine grains tend to contain more Ni than low-Ca pyroxene, which made it difficult to detect small excesses of 61Ni, (2) diffusion rates of Fe and Ni in olivine would be much higher than those in low-Ca pyroxene, so that the 60Fe-60Ni systems in olivine grains may have been disturbed even by very weak thermal metamorphism on the parent body, (3) 60Fe was present heterogeneously in the early solar system, and olivine-rich chondrules somehow did not contain 60Fe in their precursor materials, or (4) 60Fe was injected in the chondrule-forming epoch, and some chondrules formed before the injection of 60Fe.