Osmium Isotope Anomalies in Group IVB Irons: Cosmogenic or Nucleosynthetic Contributions

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Introduction

The elements that constitute matter were mainly synthesized in stars, each isotope created by a unique stellar nucleosynthetic process, and then assembled to form the solar system. Information about this nucleosynthetic pathway is recorded by the presence of isotope anomalies in meteorites. There are two current hypotheses about isotope anomalies present in bulk meteorites: 1) the initial cloud of dust and gas from which the solar system formed (the solar nebula) was isotopically heterogeneous, with different meteorites recording different parts of this cloud; or 2) matter was isotopically homogenized at the nebular scale but retained a knowledge of its nucleosynthetic pathway, in the form of individual presolar grains, which may be recovered by selective chemical attack [1]. The latter hypothesis requires that iron meteorites that have experienced extensive melting must not retain any nucleosynthetic isotope anomalies. Isotope anomalies in ruthenium (Ru) and molybdenum (Mo) were reported from the Group IVB iron meteorites. We performed a search for isotope anomalies in osmium (Os), an element that shares similar cosmochemical properties with Ru and Mo.

Experimental

Osmium extracted from Group IVB irons, and from terrestrial standards (Mix A and Mix B), was analyzed by multicollector inductively coupled plasma mass spectrometry (MC-ICP-MS) at the Plasma Analytical Facility at the NHMFL. Precision of the isotope ratios was 6-20 parts per million (±0.0006-0.0020 %, 2σ).

Results and Discussion

Osmium has seven isotopes, of which $^{186}$Os and $^{187}$Os have substantial radiogenic contributions from the decay of $^{186}$Pt or $^{187}$Re isotopes. Figure 1 shows correlated isotopic anomalies in the non-radiogenic isotope ratios $^{189}$Os/$^{188}$Os and $^{190}$Os/$^{188}$Os. The anomalies are depicted using the epsilon notation with Mix A as the terrestrial standard, e.g., $\varepsilon^{189}$Os = (R/R$_{std}$−1)×10$^4$, where R = $^{190}$Os/$^{188}$Os. The iron meteorites show a deficit of $^{189}$Os and a complementary excess of $^{190}$Os. This pattern is NOT consistent with nucleosynthetic isotope anomalies, but is evidence of cosmic-ray neutron capture modification of the isotopic composition of Os. The dark line in Fig. 1 is the calculated isotopic effect of neutron capture for epithermal neutrons, and provides a close match to the data. All the Group IVB irons exhibit some $^{189}$Os deficit, from −0.1 to −0.3 epsilon units, indicating that all of the samples have experienced some cosmic-ray neutron capture on their Os [2]. For comparison, the expectation from nucleosynthetic anomalies consistent with the anomalies observed in Ru and Mo would have resulted in excesses of $^{189}$Os of several epsilon units.

Conclusions

Osmium isotope anomalies observed in Group IVB iron meteorites are explained by cosmic-ray exposure, and not by nucleosynthetic anomalies. The discrepancy with reports of isotope anomalies in Ru and Mo poses a challenge to the hypothesis of nebular heterogeneity that remains to be resolved.

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References