Tungsten Isotopic Compositions of Phosphates from Meteorites: Melting in the Early Solar System

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Introduction

The short-lived radionuclide, $^{182}$Hf ($t_{1/2} = 8.9$ million years) decays to $^{182}$W (natural abundance 26%), with an initial $^{182}$Hf/$^{180}$Hf ratio of $1\times10^{-4}$ [1]. The ideal radiometric dating of a meteorite requires finding two phases in that meteorite, 1) one phase enriched in $^{182}$Hf (usually pyroxene), and 2) another phase high in W with Hf/W~0 which records the initial isotopic composition of W (e.g., metal). Metal-bearing meteorites easily satisfy this requirement and have been widely used in $^{182}$Hf-$^{182}$W dating [1]. However, angrites, and many other stony meteorites, contain little metal posing a challenge for $^{182}$Hf-$^{182}$W dating of melting on their parent asteroids. In pursuing the distribution of W and similar elements in angrites [2], we have discovered that Ca-phosphates and silico-phosphates, which abundant accessory phases in many igneous silicate meteorites, are major hosts for W with very low Hf/W ratios. Although phosphates are hard to find, we pursued a strategy of acid extraction. In this report, we discuss new results obtained on $^{182}$Hf-$^{182}$W dating of angrites, a class of stony meteorites that are known to have experienced melting within 3-8 million years of the formation of the first solids in the solar system [3].

Experimental

Angrite samples from Northwest Africa (NWA) 4590 and D’Orbigny were gently crushed and sieved into four grain-size fractions. Phosphate was extracted using nitric acid with 1% H$_2$O$_2$ (to complex W), and silico-phosphate was extracted using nitric acid containing 0.01% HF. Tungsten was extracted from solution using anion-exchange procedures, with a modified cation-exchange clean-up step to remove excess Ca [2]. Tungsten isotopic compositions were determined on a Thermo Neptune™ multi-collector ICP-MS at the Plasma Analytical Facility, NHMFL.

Results and Discussion

Tungsten abundances in phosphates and silico-phosphates were determined by laser ablation ICP-MS to be in 20-300 ppm range, high compared with bulk-rock values of 0.1 ppm. Isotopic compositions are shown using the epsilon notation [3]. The tungsten isotopic composition of the bulk solar system follows the black line in Figure 1. The blue lines show the isotopic composition of a bulk system from which metal was removed at 1, 3, or 5, million years after solar system formation. Tungsten isotopic compositions of D’Orbigny phosphates are shown as red symbols, with the inferred initial W isotopic composition derived from an isochron shown as black or blue symbols. Data for NWA 4590 is shown as the green symbols, together with inferred initial W isotopic composition from the literature shown as the orange symbol. Agreement with literature values are good, but our NWA 4590 data collected on several leachate fractions show a large range, possibly due to terrestrial contamination of this desert meteorite.

Conclusions

The formation of the core of the Angrite parent asteroid occurred within the first 3-5 million years of solar system history, a very rapid timescale for melting in the early solar system.

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References