The initial abundance and distribution of ^{92}Nb in the Solar System

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Niobium-92 is an extinct proton-rich nuclide, which decays to ^{92}Zr with a half-life of 37 Ma. Because Nb and Zr can fractionate from each other during partial melting of the mantle, mineral crystallization and metal-silicate separation, the Nb–Zr system can potentially be used to determine the timescales of silicate differentiation and core segregation for infant planets. In addition, the initial ^{92}Nb abundance in the Solar System provides constraints on the nucleosynthetic site(s) of *p*-nuclei (*p*- denotes proton-rich). These applications require the initial abundance and distribution of ^{92}Nb (expressed as ^{92}Nb/^{93}Nb) in the Solar System to be defined. Yet previously reported initial ^{92}Nb/^{93}Nb values range from ~10^{-5} to >10^{-3} [1-6], and remain to be further constrained. All but one of the previous studies estimated the initial ^{92}Nb/^{93}Nb using Zr isotope data for single phases with fractionated Nb/Zr in meteorites such as zircons and CAIs, assuming that their source materials and bulk chondrites possessed identical initial ^{92}Nb/^{93}Nb and Zr isotopic compositions [1-5]. To evaluate the homogeneity of the initial ^{92}Nb abundance, however, it is desirable to define internal mineral isochrons for meteorites with known absolute ages. Although Schönbächler et al. [6] applied the internal isochron approach to the chondrite Estacado and the mesosiderite Vaca Muerta, these meteorites include components of different origins and their formation ages are uncertain, which prohibits a precise determination of the solar initial ^{92}Nb abundance.
Here we present Nb-Zr data for mineral fractions from four unbrecciated meteorites, which originate from distinct parent bodies and whose U-Pb ages were precisely determined: the angrite NWA 4590, the eucrite Agoult and the ungrouped achondrites Ibitira. Our results show that the relative Nb–Zr isochron ages of the three meteorites are consistent with the time intervals obtained from the Pb–Pb chronometer for pyroxene and plagioclase, indicating that ^{92}Nb was homogeneously distributed among their source regions. The Nb–Zr and Pb–Pb data for NWA 4590 yield the most reliable and precise reference point for anchoring the Nb–Zr chronometer to the absolute timescale: an initial ^{92}Nb/^{93}Nb ratio of (1.4 ±0.5) x10^{-5} at 4557.93 ±0.36 Ma, which corresponds to a ^{92}Nb/^{93}Nb ratio of (1.7 ±0.6) x10^{-5} at the time of the Solar System formation. On the basis of this new initial ratio, we demonstrate the capability of the Nb–Zr chronometer to date early Solar System objects including troilite and rutile, such as iron and stony-iron meteorites. Furthermore, we estimate a nucleosynthetic production ratio of ^{92}Nb to the *p*-nucleus ^{92}Mo between 0.0015 and 0.035. This production ratio, together with the solar abundances of other *p*-nuclei with similar masses, can be best explained if these light *p*-nuclei were primarily synthesized by photodisintegration reactions in Type Ia supernovae.
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