Development of a chemical separation procedure for determining the initial niobium-92 abundance of chondritic components

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Introduction

One of the long-standing issues in the study of material evolution in the early solar system is "where did the nuclides come from, when were they injected into the solar system, and how were they transported to form the planets?" The short-lived nuclide niobium-92 (^{92}Nb), which originated from core-collapse Type II supernovae (SNII) [1], holds the key to solving this issue.

In this study, I investigate the initial abundance of ^{92}Nb amongst the chondritic components and determine the distribution of SNII origin components in the early solar system. A special focus is on the oldest solid material Ca-Al-rich inclusion (CAI) which is likely to have existed over a wide area in the protoplanetary disk [2], and the initial abundance of ^{92}Nb including the genetic information of CAI is determined by combining the results from the high-precision Cr and Ti stable isotope measurements.

In order to clarify a detailed picture of the SNII-origin-material influx and transportation processes at the birth of the solar system by applying this method to various primitive components in the future, I develop here a chemical separation of Cr, Ti and Zr from a single digest for the high precision isotope measurements of chondritic components using mass spectrometry.

Results & Discussion

Samples were prepared by mixing terrestrial basalt (JB-1b) and peridotite (JP-1) in ratios that would yield the approximate compositions (for major elements and Zr) of chondrules and CAIs. The typical compositions of chondrules and CAIs were calculated based on the sizes and major element compositions reported in the previous studies [3, 4]. Following digestion with conc. HF-HNO_3, samples were dried down and re-dissolved in 6 M HCl for the first step of column chemistry. The chemical separation and purification of Cr, Ti and Zr from the samples were established based on the procedure described by [5-7].

The newly developed separation procedure comprises four steps: (i) Fe removal using AG1-X8 anion exchange resin; (ii) Zr separation using Ln-resin; (iii) Ti separation using TODGA resin; (iv) Cr separation using AG50W-X8 cation exchange resin. In the first step, Fe was separated using small resin volumes of ~0.5 mL. The recovery rates for Cr, Ti, and Zr were 93-100% for all studied samples. The elution was evaporated until the total volume reached ~1 mL and then converted to 3 mL of ~2 mol L^{-1} HCl solution by dilution with H_2O. Subsequently, Cr and Ti were separated from the column using 2 mol L^{-1} HNO_3 + 1 wt.% H_2O_2, followed by the elution of Zr in 0.5 mol L^{-1} HCl + 0.06 mol L^{-1} HF. The recovery rates for Cr and Ti were ~100%, and that for Zr was 97-98% for all the studied samples. The elution containing Cr and Ti was then evaporated to dryness and dissolved in 1 mL of 12 mol L^{-1} HNO_3 for the third separation step. In the third step, Ti was separated from Cr-fraction using the pre-packed 1 ml cartridges containing TODGA resin associated with the cartridge reservoirs. The recovery rates for Cr and Ti were 95-100% for all the studied samples. Prior to the final step, I used a Cr pretreatment procedure [8] involving exposure to 1 mol L^{-1} HNO_3 + 1 wt.% H_2O_2 >3 days so that Cr(III) remained as the dominant species in the acid. In the final step, Cr was purified from matrix elements. The recovery rates of Cr were 98-100% for all the studied samples.

Hence, we can expect that the above new method separates Cr, Ti, and Zr with >88%, >93%, and >90%, respectively. I am now planning to apply this method to individual CAIs extracted from primitive meteorites and assess the nature of proto-planetary disk through the combined Cr, Ti, and Zr isotope analyses.

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Keywords: niobium-92, Type II supernova, CAIs, column chromatography, mass spectrometry