BARIUM ISOTOPE ABUNDANCES IN METEORITES: IMPLICATIONS FOR EARLY SOLAR SYSTEM EVOLUTION

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Introduction

Various nucleosynthetic processes contributed to the abundances of the elements and their isotopes in the Solar System. How distinct nucleosynthetic materials were mixed to form the solar nebula is currently unclear. In this study, the distribution of Ba isotopes in 26 different whole rock meteorites (eucrites, diogenites, ordinary chondrites, Martian meteorites, enstatite chondrites and carbonaceous chondrites) was determined to constrain the level(s) of Ba isotope heterogeneity on the regional scale in the Solar System. Early papers [2-4] reported anomalous (i.e., Ba isotopes that differ from terrestrial values) Ba isotopic composition in carbonaceous chondrites, however, these anomalies may have originated from incomplete dissolution of highly isotopically anomalous presolar grains (Fig. 1). A melting method using aerodynamic levitation, combined with CO₂-laser heating was used in our study to oxidize the primary presolar grain Ba isotope carrier (Sic) in carbonaceous chondrites, thereby enabling complete digestion of these samples (Fig. 2). Our Ba data are contrasted with a range of multi-isotope elements (Ti, Cr, Ni, Mo, Ru, Te, Ba, Nd, Sm, W and Os) to address the question as to why some elements are isotopically homogeneous on the bulk sample scale while other elements are isotopically variable.

Results

All samples, except for 6 carbonaceous chondrites, possess terrestrial Ba isotope compositions. All samples, except for 6 carbonaceous chondrites, possess terrestrial Ba isotope compositions. Various nucleosynthetic processes contributed to the abundances of the elements and their isotopes in the Solar System. How distinct nucleosynthetic materials were mixed to form the solar nebula is currently unclear. In this study, the distribution of Ba isotopes in 26 different whole rock meteorites (eucrites, diogenites, ordinary chondrites, Martian meteorites, enstatite chondrites and carbonaceous chondrites) was determined to constrain the level(s) of Ba isotope heterogeneity on the regional scale in the Solar System. Early papers [2-4] reported anomalous (i.e., Ba isotopes that differ from terrestrial values) Ba isotopic composition in carbonaceous chondrites, however, these anomalies may have originated from incomplete dissolution of highly isotopically anomalous presolar grains (Fig. 1). A melting method using aerodynamic levitation, combined with CO₂-laser heating was used in our study to oxidize the primary presolar grain Ba isotope carrier (Sic) in carbonaceous chondrites, thereby enabling complete digestion of these samples (Fig. 2). Our Ba data are contrasted with a range of multi-isotope elements (Ti, Cr, Ni, Mo, Ru, Te, Ba, Nd, Sm, W and Os) to address the question as to why some elements are isotopically homogeneous on the bulk sample scale while other elements are isotopically variable.

Discussion

A trialing laser fusion to achieve complete sample dissolution, no dependence on digestion method is observed in the Ba isotopic composition. This conclusion need not apply to other isotope systems (e.g., Ti and Mo). The Ba isotopic compositions are similar to, or slightly smaller, than previously reported [2-4]. For example, our data for Cold Bokkěveld shows a 137Ba ~38ppm and 135Ba ~15ppm excesses, whereas [2] reported 137Ba ~58 ppm and 135Ba ~31 ppm variations. The isotopic variability of Ba in C-chondrites may reflect inadequate homogenization of the presolar component in these meteorites at the ~0.5 g sample scale, indicating larger samples are required to assess the scale of nucleosynthetic anomalies (~1 g). The largest differences are found in the abundance of 135Ba. Given the observed small excesses in 137Ba, most of the 135Ba excess likely is due to a small s-process deficiency at the whole rock scale, but the magnitude of 135Ba variation compared to 137Ba variability also allows for the contribution of 135Cs to 135Ba via Cs/ Ba decay could not be measured because of loss of Cs during laser heating. The Ba isotope data are compared with data for isotopically anomalous (e.g., Ti, Cr, Ni, Mo, Ru, Nd, Sm, and W) and non-anomalous elements (e.g., Te and Os) on the whole rock scale. Elements with small or undetectable isotopic anomalies, e.g., Ba, Te and Os are dominated by one nucleosynthetic pathway (Table 1). However, if an element (e.g., Ti, Mo, Ru) is anomalous and does not have equal proportions of the different components in the disk is longer for those elements with near equal mixes than for an element dominated by one or the other nucleosynthetic path (Fig. 4).