Sr and Ba isotopic compositions of the Cold Bokkeveld (CM2) meteorite

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Sr and Ba isotopes consist of s-, r- and p-process isotopes. In addition, ^{87}Sr and ^{135}Ba include radiogenic components decayed from ^{87}Rb ($t_{1/2}$ = 4.88 Ga) and ^{135}Cs ($t_{1/2}$ = 2.3 Ma), respectively. Therefore, isotopic studies of Sr and Ba in primitive planetary materials provide hints of the possibly additional inputs of nucleosynthetic components of solar system materials and the chronological approaches using ^{87}Rb-^{87}Sr and ^{135}Cs-^{135}Ba decay systems (Hidaka and Yoneda, 2011; Yokoyama et al., 2015; Sakuma et al., 2018). The Sr and Ba isotopic data of primitive planetary materials are important to discuss the evolution processes of the early solar system. In this study, isotopic analyses of Sr and Ba and quantitative analyses of Rb, Sr, Cs, Ba and REE elemental abundances from the acid leachates of the Cold Bokkeveld (CM2) meteorite were performed to discuss Sr and Ba isotopic variations.

About 800 mg of powdered sample was leached by 10 mL of 0.1M CH_3COOH-CH_3COONH_4, 0.1M HCl, 2M HCl and aqua regia, successively. The acid residue was finally decomposed by HF-$HClO_4$ about 140℃ for 3 days. This sequential acid-leaching procedure was based on the previous methods (Hidaka and Yoneda, 2011). Separately from the above leaching treatment, about 100 mg of powdered sample was decomposed by HF–$HClO_4$, and treated as a whole rock for analysis. Each fraction was evaporated to dryness, and redissolved in 5 ml of 2M HCl. The solution was divided into two portions; a major portion for Sr and Ba isotopic analyses by themal ionization mass spectrometry (TIMS) and another minor portion for the determination of Rb, Sr, Cs, Ba and REE elemental abundances by inductively coulped plasma mass spectrometry (ICP-MS). For the isotopic analysis, each major portion was treated with conventional resin chemistry to purify the Sr and Ba fractions (Hidaka and Yoneda, 2014). The sample solution was loaded onto cation exchange resin packed column (AG50WX8, 200–400 mesh, H^+ form, 50 mm length × 4.0 mm diameter). The column was washed with 3.5 mL of 2 M HCl for the elution of major elements, and then it was washed with 3.5 mL of 2 M HCl for the elution of the Sr fraction. Finally, the column was washed with 3 mL of 2 M HNO_3 for the elution of the Ba fraction. For further purification, the Sr and Ba fraction was loaded onto a Sr resin packed column (Eichrom, Sr resin, particle size of 100–150 μm, 100 mm length × 2.5 mm diameter). In the cace of Sr fraction, the column was washed with 2.5 mL of 3 M HNO_3, and was washed with 3 mL of ultrapure water for the elution of Sr. In the case of Ba fraction, the column was washed with 3.5 mL of 3 M HNO_3, and was washed with 6.5 mL of 7.5 M HNO_3 for the elution of Ba.

The Ba isotopic data of whole rock show isotopic excesses of ^{135}Ba and ^{137}Ba. The Ba isotopic data of CI and CM chondrites showed isotopic ecxess coupled ^{135}Ba and ^{137}Ba, caused by additional nucleosynthetic components out of the solar system (Carlson et al., 2007; Bermingham et al., 2016). On the other hand, the Ba isotopic data of the leachates show variable isotopic excesses of ^{130}Ba, ^{132}Ba, ^{135}Ba, ^{137}Ba and ^{138}Ba, while those of the acid residue show isotopic deficits of ^{130}Ba, ^{132}Ba, ^{135}Ba, ^{137}Ba and ^{138}Ba. These Ba isotopic anomalies suggest a heterogeneous distribution of s- and r-process nucleosynthetic components in the early solar system. The Sr isotopic data of acid residue show a signidicant isotopic deficit of ^{84}Sr (ε^{84}Sr = -5.50 ± 0.56). This Sr data suggest the enrichment of presolar SiC grains, which is a representative carrier of s-process isotope (Podosek et al., 2004). The ^{135}Ba and ^{137}Ba isotopic data of acid residue can be explained by the enrichment of s-process nucleosysnthetic components. On the other hand, ^{138}Ba isotopic data sugget the presence of several nucleosynthetic components possibly including the presolar materials like X grains having large isotopic excess of ^{138}Ba (Stephan et al., 2018).

References

Bermingham, K. R., K. Mezger, E. E. Scherer, M. F. Horan, R. W. Carlson, D. Upadhyay, T. Magna, and A. Pack, Barium isotope abundances in meteorites and their implications for early Solar System evolution, Geochim. Cosmochim. Acta, 175, 282-292, 2016.

Carlson R. W., M. Boyet, and M. Horan M, Chondrite barium, neodymium, and samarium isotopic heterogeneity and early Earth differentiation, Science, 316, 1175–1178, 2007.

Hidaka, H. and S. Yoneda, Diverse nucleosynthetic components in barium isotopes of carbonaceous chondrites: Incomplete mixing of s- and r-process isotopes and extinct ^{135}Cs in the early solar system, Geochim. Cosmochim. Acta, 75, 3687-3697, 2011.

Hidaka, H. and S. Yoneda, Isotopic excesses of proton-rich nuclei related to space weathetring observed in a gas-rich meteorite Kapoeta, The Astrophysical Journal, 786,138 (8pp), 2014.

Podosek, F. A., C. A. Prombo, S. Amari, and R. S. Lewis, s-Process Sr Isotopic Compositions in Presolar SiC from the Murchison Meteorite, The Astrophysical Journal, 605, 960–965, 2004.
Sakuma, K., H. Hidaka, and S. Yoneda, Isotopic and Chemical Evidence for Primitive Aqueous Alteration in the Tagish Lake Meteorite, The Astrophysical Journal, 853, 92 (8pp), 2018.
Stephan, T., R. Trappitsch, A. M. Davis, M. J. Pellin, D. Rost, M. R. Savina, M. Jadhav, C. H. Kelly, F. Gyngard, P. Hoppe, and N. Dauphas, Strontium and barium isotopes in presolar silicon carbide grains measured with CHILI—two types of X grains, Geochim. Cosmochim. Acta, 221, 109-126, 2018.
Yokoyama, T., Y. Fukami, W. Okui, N. Ito, and H. Yamazaki, Nucleosynthetic strontium isotope anomalies in carbonaceous chondrites, Earth Planet. Sci. Lett, 416, 46-55, 2015.