Li-Be-B isotopic compositions of CAIs in the Yamato 81020 CO3.05 chondrite: Implication for the origin of ^{10}Be in the early solar system.

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Introduction: Beryllium-10, which decays to ^{10}B with a half-life of 1.4 Myr [1], is considered as a key indicator of irradiation processes in the early solar system (ESS). However, recent numerical studies have shown that ^{10}Be can be produced by neutrino reactions with core-collapse supernovae [2,3], which rendered reconsideration of the origin of ^{10}Be in the ESS. The stable isotopes of Li, Be, and B are also made by irradiation and neutrino processes [e.g., 2-4]. Thus, the quantitative understanding of initial ^{10}Be abundances and stable Li-Be-B isotopic compositions would provide important constraints on the origin of ^{10}Be in the ESS. Previous studies have provided hints for in-situ irradiation signatures of ^{7}Li/^{6}Li, initial ^{10}B/^{11}B and initial ^{10}Be/^{9}Be ratios in coarse-grained Ca-Al-rich Inclusions (CAIs) in CV3 chondrites [e.g., 4-9]. Up to now, limited data set have been reported for CAIs in other types of chondrites, most likely due to the small grain sizes. To further understand the origin and distribution of ^{10}Be, we have conducted Li-Be-B measurements on CAIs in the Yamato 81020 (hereafter Y81020) CO3.05 chondrite using high spatial resolution SIMS.

Experimental: Two melilite-rich CAIs, Y20-1X1 and Y20-9-1, were selected from the Y81020 meteorite. Petrographic observations and major element concentrations of these CAIs were obtained with JXA-8530F FE-EPMA at Department of Earth and Planetary Science, the University of Tokyo. Lithium and Be-B isotopic measurements were performed with the NanoSIMS 50 installed at Atmosphere and Ocean Research Institute, the University of Tokyo. The NanoSIMS measurements were performed in a multi-collection mode. An ^{16}O$^-$ primary ion beam, ~5nA intensity and ~7 μm in diameter, was rastered over 10 x 10 μm^2 sized areas. For the Li isotopes, secondary ions of ^{6}Li$^+$, ^{7}Li$^+$, and ^{30}Si$^+$ were detected simultaneously with three electron multipliers. For the Be-B measurements, secondary ions of ^{9}Be$^+$, ^{10}B$^+$, ^{11}B$^+$, and ^{30}Si$^+$ were detected simultaneously with four electron multipliers. The ^{9}Be/^{11}B relative sensitivity factor was determined from measurements of synthetic melilitic glasses [10].

Results and Discussion: Y20-1X1 and Y20-9-1 CAIs yield isochrons with initial ^{10}Be/^{9}Be ratios of (3.02 ± 0.37) x 10^{-3} and (2.16 ± 0.97) × 10^{-3}, respectively. The initial ^{10}Be/^{9}Be ratios of CO CAIs are slightly higher than those of CV canonical CAIs (e.g., 0.88 × 10^{-3} [4]). If the variation in the initial ^{10}Be/^{9}Be ratios between CO and CV CAIs were produced by in-situ cosmic ray irradiation, initial ^{10}B/^{11}B and ^{7}Li/^{6}Li ratios would be affected by spallation products. However, Y20-1X1 and Y20-9-1 show chondritic ^{10}B/^{11}B ratios within uncertainties (0.251 ± 0.004 and 0.269 ± 0.093, respectively). In addition, these CAIs also show chondritic ^{7}Li/^{6}Li isotopic ratios (12.18 ± 0.17 and 12.04 ± 0.28, respectively). These results are broadly consistent with our previous work of CAIs in CH and CH/CB primitive chondrites [11]. In order to understand the observed relationship with the initial ^{10}Be/^{9}Be, ^{10}B/^{11}B, and ^{7}Li/^{6}Li ratios, we estimated spallation effects on ^{10}B/^{11}B and ^{7}Li/^{6}Li in CAI-like compositions using the observed initial ^{10}Be/^{9}Be ratios and spallation production ratios [12]. Considering concentrations of Li, Be, and B in Y20-1X1 and Y20-9-1, this simple calculation suggests that the observed ^{10}B/^{11}B and ^{7}Li/^{6}Li ratios are inconsistent with in-situ irradiation of CAI-like materials. If CAI-like materials (e.g., Li ~600ppb, Be ~700ppb, and B ~10ppb) were irradiated and ^{10}Be was produced at a level of ~3.02 x 10^{-3} in the initial ^{10}Be/^{9}Be ratio, the expected ^{7}Li/^{6}Li and initial ^{10}B/^{11}B ratios are ~1.8 and ~0.43, respectively. The inconsistency between observed isotopic ratios and calculated ratios could be attributed to: (a) ^{10}Be was not produced by solar cosmic ray irradiation, but by stellar processes [3], (b) partial loss of spallogenic B and Li and isotopic exchange with a chondritic gas, and (c) condensation from an irradiated chondritic gas. (a) is unlikely because the stellar model proposed by [3] cannot explain such high ^{10}Be/^{9}Be ratios observed in this study. (b) is a possible scenario for the Y20-1X1 CAI because petrographic observations suggest that Y20-1X1 was probably once molten. (c) is a simple interpretation. If this is the case, the initial ^{10}B/^{11}B and ^{7}Li/^{6}Li ratios were less effected by solar cosmic ray irradiation. More data from primitive CAIs that have not been thermally processed (e.g., Fluffy Type A CAIs) will be needed to shed light on the origin of ^{10}Be in the ESS.

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