Li-Be-B and Al-Mg isotopic compositions of Ca, Al-rich inclusions: Implications for the evolution of the proto-solar disk.

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Observations of solar-type Young Stellar Objects (YSOs) have shown enhanced X-ray luminosities, ~5 orders of magnitude stronger than that of the contemporary Sun [e.g., 1, 2], suggesting that solar cosmic ray irradiation also occurs on the surrounding accreting disk. In our solar system, the presence of a short-lived radionuclide ^{10}Be in Ca, Al-rich inclusions (CAIs) also indicates that solar cosmic rays may have interacted with at least some CAIs or their precursors in the earliest stage of the solar system. It should be noted, however, that most of initial ^{10}Be abundances in the solar system were deduced from the Be-B analyses of CAIs in CV chondrites [3-9]. In order to understand details of irradiation processes in the early solar system, it is important to investigate Li-Be-B isotope systematics of meteoritic components in various types of chondrites. Here, we report Li-Be-B and Al-Mg isotopic compositions of CAIs in CH, and CH/CBb chondrites measured with Secondary Ion Mass Spectrometry (SIMS). Based on the dataset and ones previously reported, we discuss the origin of the variation in ^{10}Be/^{9}Be ratios recorded in CAIs.

We studied eight CAIs from the Sayh al Uhaymir 290 (CH) and the Isheyevo (CH/CBb) chondrites. CAIs in CH and CH/CBb chondrites show highly variable initial ^{10}Be/^{9}Be ratios ranging from 1.7 to 40.5 x 10^{-4}. These CAIs have nearly chondritic Li isotopic compositions independent of their ^{10}Be/^{9}Be ratios. In addition, all CAIs studied here show no resolvable excesses in ^{26}Mg decayed from a short-lived radionuclide ^{26}Al.

In contrast to the case for CAIs in CH and CH/CBb chondrites, CAIs in CV chondrites show a relatively narrow range of ^{10}Be/^{9}Be ratios (4.6 - 12.2 x 10^{-4} [3-9]) and have nearly canonical ^{26}Al/^{27}Al ratios (^{26}Al/^{27}Al = 4 - 5 x 10^{-5} [e.g., 8]). To explain the differences between CH and CH/CBb CAIs and CV CAIs, we propose that the variations in ^{10}Be/^{9}Be ratios may reflect fluctuations of the cosmic ray flux from early active Sun. Considering a relationship between accretion rates and X-ray luminosities in T Tauri stars [10, 11], episodic accretion events (i.e., FUori-type or EXori-type outbursts [e.g., 12, 13]) would be a candidate of the cause for the variation in the number flux of protons. If this is correct, the variations in ^{10}Be/^{9}Be ratios of CAIs would give important constraints on the evolution of the proto-solar disk. Observations suggest that FUori-type outbursts are confined to the first few tens of thousands of years [14], which correspond to class I at the stage of the protoplanetary disk evolution [15]. We propose that high and variable ^{10}Be/^{9}Be ratios recorded in CH and CH/CBb CAIs reflect episodic cosmic ray fluxes caused by FUori-type outbursts. On the other hand, relatively low ^{10}Be/^{9}Be ratios recorded in CV CAIs may reflect less episodic accretion events, possibly the EXori-type outbursts, which are confined to the evolution stage a few million years after the formation of the protoplanetary disk (= class II). If the above argument is correct, the injection of ^{26}Al in the solar system would have occurred between the evolutionary stages class I and class II of the proto-Solar disk.

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