High precision Mg isotopic measurement of chondrules from ordinary chondrite meteorite using MC-ICPMS

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Aluminum-26, a short lived-nuclide with a half life of 0.73 My, has been widely used for discussing relative ages of planetary materials. Based on precise measurements of Al-Mg isotopes in Calucium-aluminum-rich inclusions (CAIs, the oldest solids of the solar system), the initial $^{26}Al/^{27}Al$ ratio at the birth of the solar system has been determined to be 5.25 x10^{-5} [1,2]. It has also been argued that chondrules, a major component of chondritic meteorites, formed at 150 to 400 My after CAI formation [3]. Recently, however, precise U-Pb dating suggested that some chondrules might have ages as old as CAIs [4]. Furthermore, recent Al-Mg isotopic measurements of angrites (achondrites) of known U-Pb ages gave a much lower value of 1.33 x10^{-5} for the initial $^{26}Al/^{27}Al$ ratio of the solar system [5]. These conflicting data suggest a possibility of heterogeneous distribution of ^{26}Al in the early solar system. Distribution of ^{26}Al in the early solar system has crucial importance chronologically (i.e., justification of the Al-Mg chronometer) and also in view of an important heat source for understanding evolution of planets (e.g., their differentiation processes). In order to discuss its distribution, precise measurements of Al-Mg isotopes for various components (CAIs, chondrules, etc.) in various types of chondrites. Among them, there have been very few analyses for chondrules, and they are limited to those in carbonaceous chondrites [e.g., 6,7]. In order to better understand spacial distribution of ^{26}Al in the early solar system, we have developed a high precision Mg isotope analysis technique using MC-ICPMS. Using this technique, we have analyzed three CV CAIs to examine if our analysis give a canonical $^{26}Al/^{27}Al$ ratio consistent with previous works. We have also applied the technique to chondrules in an ordinary (LL) chondrite and compared the results with those of carbonaceous chondrite (CC) chondrules and discussed distribution of ^{26}Al in the early solar system.

The analyzed samples were two CAIs from NWA 3118 (CV3), a CAI from Allende (CV3) and 6 chondrules from NWA 7936 (LL 3.15). We have prepared a Mg isotope standard DSM-3 (pure solution of terrestrial Mg [8]), and all the Mg isotope results (excess ^{26}Mg) were expressed as $\mu^{26}Mg^*$ (i.e., ppm deviation from the result of DSM-3). The results for two terrestrial standards, BCR-2 and JB-2, gave $\mu^{26}Mg^*$ values of -5.9 ±11.2 and 2.3 ±20.0, respectively, i.e., good precision and accuracy comparable to those by other laboratories [e.g., [9]]. If we apply a single isochron for the data of three CAIs, we obtain $(^{26}Al/^{27}Al)_o$ = (5.08 ±0.84) x10^{-5} from the slope and $\mu^{26}Mg^*$ = -25 ±103 ppm from the y-intercept, which are consistent with previous studies [1,2].

Five out of 6 LL chondrules show Al/Mg ratios (0.091-1.04), similar to the solar composition (~0.10). If we assume homogeneous $(^{26}Al/^{27}Al)_o$ =5.23 x10^{-5} and homogeneous stable Mg isotopic composition in the early solar system, chondritic material with solar Al/Mg ratios must have $\mu^{26}Mg^*$ values of ~0 ppm. However, the present results for the 5 chondrules with solar-like Al/Mg show variable $\mu^{26}Mg^*$, and some of them show negative values beyond the error limit (2 σ). The results for LL chondrules tend to show $\mu^{26}Mg^*$ values even lower than those for CC chondrules. This suggests heterogeneous distribution of ^{26}Al in the early solar system.

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