Mg ISOTOPIC COMPOSITION OF LOW Al/Mg PHASES IN CAIS: THE INITIAL SOLAR $^{26}Mg/^{24}Mg$?
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Introduction: We report preliminary results from a study of the Mg isotopic composition in mineral phases with low Al/Mg in Type B CAIs. The purpose was to establish whether these phases are in accord with an ^{26}Al-^{26}Mg isochron as determined by plagioclase and melilite with an initial $^{26}Mg/^{24}Mg$ ratio consistent with solar Mg. From an assumed uniform initial $^{26}Al/^{27}Al$ in the Solar System, it is straightforward to interpret lower $^{26}Al/^{27}Al$ values as due to the passage of time, however, higher values would require a higher initial ^{26}Al abundance or heterogeneity in the distribution of ^{26}Al in the solar nebula. Several recent studies have presented data indicating "supra-canonical" values of $^{26}Al/^{27}Al$ (up to ~30% higher than the canonical 5×10^{-5} value) [1-3]. These results are the subject of on-going debate [4-8]. From the canonical value of $^{26}Al/^{27}Al$, it is expected that the bulk solar ^{26}Mg inventory should have increased over its initial value by 36 ppm. Evidence of significantly lower initial values of $^{26}Mg/^{24}Mg$ would raise serious concerns about both the initial ^{26}Al inventory and the sources of ^{26}Al. Production of ^{26}Al by energetic particle bombardment (X-wind and variants thereof [9, 10]), would produce materials with a wide range in $^{26}Al/^{27}Al$, from far above the canonical value to far below it.

We recently reported [4, 5, 11] new, high precision MC-ICP-MS analyses of Mg isotopes in Allende CAIs. Our data for both bulk CAIs and mineral separates are consistent with an initial $^{26}Al/^{27}Al$ of 5×10^{-5} and do not support suggestions of a supra-canonical value. Insofar as many of the data supporting a supra-canonical value were collected using SIMS, we believed it worthwhile to carry out *in situ* analyses of the same CAIs studied by [4, 5, 11] using MC-SIMS. Egg 3 (a Type B CAI) was included as it has an excellent isochron with $^{26}Al/^{27}Al$~5×10^{-5} [12; Hutcheon, unpublished data] and contains both mass-fractionated Mg (7‰ per amu) and Ti isotope anomalies [13]. An intensive study of Egg 3 pyroxenes and spinels by Esat et al. [14] using TIMS showed that pyroxenes exhibited a range in $\delta^{26}Mg$ of -0.9 to +0.8‰ with typical 2σ errors of 0.3‰. A line fitted to data for spinel and pyroxene, extrapolated to $^{27}Al/^{24}Mg = 0$, hinted at an initial $\delta^{26}Mg$ significantly below 0. These results were then of major concern [15], but have since been overlooked. Due to the importance of this unresolved matter, we have directed our efforts at testing the validity of the Esat et al. [14] results and elucidating the initial solar $^{26}Mg/^{24}Mg$ value. The technical problem is directly related to the external precision and the ability to resolve small differences in $^{26}Mg/^{24}Mg$.

Results: Mg isotope compositions were measured with the UCLA ims 1270 SIMS using multicollector Faraday cups [16]. Gravimetrically enriched ^{26}Mg isotope standards were measured by MC-ICPMS and MC-SIMS, demonstrating excellent agreement (better than 0.5‰) between the two techniques. The $^{27}Al/^{24}Mg$ ratios were determined using sensitivity factors based on electron microprobe analyses of mineral standards. The corrections for mass-dependent isotope fractionation were made using an exponential law and assuming a natural mass fractionation factor for Mg isotopes in the CAIs of 0.514 [16]. Comparison with different "laws" did not alter the results significantly. Data were obtained on melilite, spinel and pyroxene for all five CAIs. The melilites in all CAIs showed a considerable scatter, indicating disturbance to this mineral system, as found by previous workers [e.g., 17, 18]. New MC-SIMS data on spinel and pyroxene for the same four Type B CAIs studied by [4, 5, 11] are shown in Fig. 1. The larger uncertainty for pyroxene data reflects primarily poorer reproducibility for the standard. For sample A44A the results on four spinel grains had a total spread of $0.88‰ < \delta^{26}Mg < 0.96‰$ with $2\sigma = 0.14$-$0.37‰$; for six pyroxene grains $0.79‰ < \delta^{26}Mg < 1.08‰$ with $2\sigma = 0.37‰$. For sample AJEF the spinels were tightly custered $0.89‰ < \delta^{26}Mg < 0.98‰$ with $2\sigma = 0.13$-$0.37‰$. For sample A43 the spinels were also tightly custered $0.73‰ < \delta^{26}Mg < 0.87‰$ with $2\sigma = 0.13$-$0.17‰$. For A39 two spinel grains had a spread of $0.83‰ < \delta^{26}Mg < 0.95‰$ with $2\sigma = 0.12$-$0.14‰$. For 4 pyroxene grains $0.58‰ < \delta^{26}Mg < 0.89‰$ with $2\sigma = 0.40$-$.62‰$. These data are shown in Fig. 1 in a ^{26}Mg-^{27}Al evolution diagram with the corresponding $^{27}Al/^{24}Mg$ for each data point.

The new SIMS data for these four CAIs are in excellent agreement with previous MC-ICP-MS results [4,5,11] and provide no evidence for supra-canonical $^{26}Al/^{27}Al$ values. The mean $^{26}Al/^{27}Al$ for these CAIs from this study is $(5.17\pm0.24)\times10^{-5}$, compared to $(5.20\pm0.10)\times10^{-5}$ from [4, 5, 11].

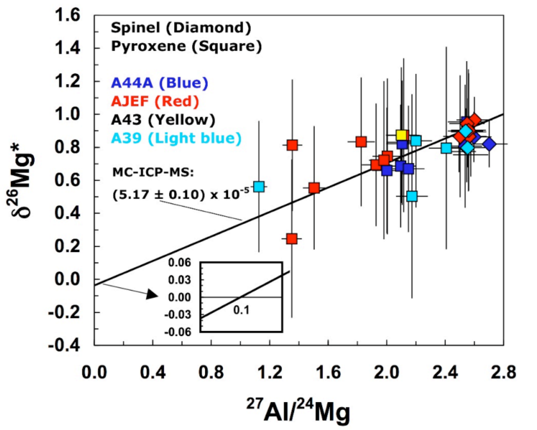

Fig. 1. MC-SIMS data obtained for pyroxenes and spinels in four Type B CAIs from Allende. Inset shows the projected solar initial ^{26}Mg/^{24}Mg composition.

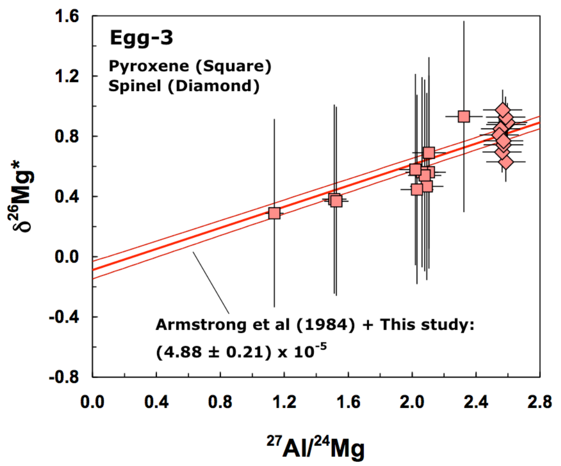

Fig. 2. Plagioclase data from Armstrong et al [12] regressed through MC-SIMS data of pyroxenes and spinels of Egg-3 from this study (pink line). The intercept = -0.089±0.058‰ is barely resolvable from the solar initial of -0.036‰.

The data for Egg 3 are shown in Fig. 2. The data for ten spinels are tightly grouped with 0.63‰< δ^{26}Mg <0.97‰ with a mean δ^{26}Mg = 0.82±0.22‰ (2σ). Measurements on 11 fassaitic pyroxenes give similar results with 0.29‰< δ^{26}Mg<0.58‰ a mean δ^{26}Mg = 0.58±0.36‰ (2σ). No data were obtained on spinels or fassaites which indicated δ^{26}Mg of less than –0.3‰ and we conclude that we can find no evidence of negative δ^{26}Mg values in Egg 3. Furthermore, there is no evidence of negative δ^{26}Mg values in any of the pyroxenes or spinels from the other CAIs analyzed here. We believe that δ^{26}Mg = -1‰ would certainly have been detected. We cannot offer any reason why the data reported by Esat et al. [14] should be in error. It is conceivable that error propagation from uncertainties in the fractionation factor determined from the in-run ^{26}Mg/ ^{24}Mg values might be the cause. With an intrinsic fractionation of 7‰/amu, an uncertainty of 1‰ might propagate as an error of -1‰ in δ^{26}Mg.

The issue of obtaining more precise Mg isotopic results with the ability to distinguish small differences in δ^{26}Mg for pyroxenes and spinels is of key importance. Placing limits on the initial ^{26}Al/^{27}Al in the solar system by the extrapolated initial δ^{26}Mg (for no Al) requires the resolution of better than 36 ppm (0.03 per mil). From the data reported here, no strict bounds can be set on that value.

Substantial efforts to obtain high precision data for Mg have been made with MC-ICP-MS (Ben Jacobsen et al., in prep; [19, 20]). It is possible that by further exploiting such methods we should be able to obtain data that will resolve differences of <0.01 ‰. This must be tested by measurements in enriched gravimetric standards at that level of resolution.

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