FREE FUN WITH Mg IN ALLENDE GROUP II INCLUSIONS

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We report on Mg isotopes in 5 Allende inclusions labelled 3529-40, -43, 5242, 5284 and 4691 obtained by courtesy of Brian Mason. These inclusions are characterized by highly fractionated RE distribution patterns and have been classified as Group II inclusions by Mason and Taylor [1]. In addition, there appears to be some correlation between Mg isotopic fractionation and the anomalous REE distribution [2]. All, except one, of these inclusions are fine-grained aggregates composed of compacted individual grains, $\lesssim 40$ μm in diameter, and fragmented debris. Wark and Lovering [3,4] have shown that individual grains within these inclusions exhibit microscopic layering, composed of similar materials as those found rimming the coarse-grained inclusions. The coarse-grained inclusion 4691 consists largely of melilite, with abundant, micrometer sized, spinel inclusions, minor fassaite and anorthite. Due to the small grain size and heterogeneous nature of the fine-grained aggregates, individual, well defined, minerals cannot easily be separated. Even in the coarse-grained inclusion 4691 the melilite is highly altered. However, spinel could be separated by dissolving chunks of interior material free from meteorite matrix. Clumps of micron-sized spinels were directly loaded for Mg analysis. The 61-cm, multi-cup mass spectrometer used for the present study is free from Al interference in the Mg mass region and δ^{26}Mg can be determined with high precision, by direct loading [2]. The complementary soluble portions were analyzed in a similar manner, without chemical separation. Some experiments were also done by direct loading small chunks (< 50 μm) of prime interior material. The Mg results are listed in Table 1. In Fig.1 we show histograms of unnormalized ratios for Mg normals and for two spinel samples. Each point in the histograms corresponds to a set of 122 ratios with an integration period of about 100 msec for each isotope. It is evident that we can clearly distinguish natural mass fractionation in Mg, from instrumental fractionation, down to a level of about 4‰ per amu. The data in Table 1 indicate: a) non-uniform Mg isotopic fractionation within each inclusion; b) no apparent systematic variation in Mg fractionation between spinels and the soluble mineral phases, or chunks, between different inclusions; c) small but distinct non-linear excesses in δ^{26}Mg. The excess in δ^{26}Mg could be due to ^{26}Al decay or alternately due to nuclear effects complementary to negative δ^{26}Mg found in FUN inclusions. As the Group II inclusions appear to exhibit Fractionated Rare Earth Element abundances and both isotopic Fractionation and Unidentified Nuclear effects we label them FREE FUN inclusions. The FREE part also alludes to the rather "loose" behaviour of Mg fractionation within each inclusion. We note that the magnitude of Mg fractionation, previously determined by sampling bulk powdered material from each inclusion, is in some cases distinct from the maximum value listed in Table 1. On the basis of the present data the extent and scale of the Mg heterogeneities cannot be established. In inclusion 3529-40 a repeat spinel analysis shows identical fractionation but a slightly different δ^{26}Mg value. The Mg heterogeneities, in one coarse-grained and four fine-grained Group II inclusions are in direct contradiction to uniform Mg anomalies, established for all coexisting phases, within each of the FUN inclusions C-1, EK-1-4-1 and EGG-3 [5]. We note that EK-1-4-1 has a Group II REE distribution. In contrast to Mg, heterogeneities in oxygen isotopic composition among coexisting mineral phases, in Allende coarse-grained inclusions, are well established. Models, so far proposed, to account for simultaneous ^{16}O heterogeneity and Mg uniformity, postulate an external back reaction mechanism either in the

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solar nebula or possibly in a small proto-planet [6]. The back reaction mechanism, now requiring the addition of normal Mg, to account for the variability in Mg, is inconsistent with the isotopic data in Table 1. At least in one case 3529-43 and possibly for 5242, spinel shows normal Mg whereas the soluble portion is fractionated requiring the addition of anomalous Mg. However, 4691 and 3529-40 display the opposite pattern. Further difficulties arise with the similarity of REE patterns in both fine- and coarse-grained inclusions. Our prefered model for accounting for the diverse properties of the Group II inclusions is as follows: a) they are direct secondary condensates from the solar nebula following an original condensation episode to remove the heavier REE [7]; b) condensation occured at a moderate temperature (< 1000°C) and rapidly, resulting in widespread nucleation of very small bodies [4]; c) the variability in Mg within each inclusion resulted from the aggregation of isotopically distinct material without complete homogenization; d) coarse-grained Group II inclusions (EK-1-4-1) which show uniform Mg anomalies require thorough homogenization. The present results appear to have opened another and perhaps a more securely locked Pandora's Box hidden within the original [8]. We may have just managed to take a "peek" through a hairline crack.

Table 1. Mg Isotopes in Allende Group II Inclusions

Sample	Fractionation[a] $\Delta(^{25}Mg/^{24}Mg)$‰mu^{-1}	$\delta^{26}Mg$[b] ‰
3529-43:		
Spnl[c]	+1.0	0.06±0.05
Soltn[d]	-5.5	2.52±0.09
4691:		
Spnl[c]	+5.0	0.68±0.05
Soltn[d]	+2.2	1.59±0.09
3529-40		
Spnl[c]	-4.8	2.55±0.05
Spnl[cf]	-4.5	2.03±0.06
Chunk[e]	-2.7	1.16±0.09
5242:		
Spnl[c]	-3.0	0.60±0.07
Chunk[e]	-8.4	1.60±0.07
5284:		
Spnl[c]	-0.4	0.13±0.08
Soltn[d]	-2.2	0.86±0.14

[a] $\Delta(^{25}Mg/^{24}Mg) = [(^{25}Mg/^{24}Mg)_{meas}/(^{25}Mg/^{24}Mg)_{GM} - 1] \times 10^3$; where GM is the grand mean value 0.12378 determined from repeat analyses of normals. [b] Excess ^{26}Mg following normalization to remove fractionation: the quoted errors are $2\sigma_{mean}$. [c] Insoluble residue consisting mainly of spinel. [d] Soluble portion. [e] Typically a 50 μm interior chunk. [f] Repeat analysis.

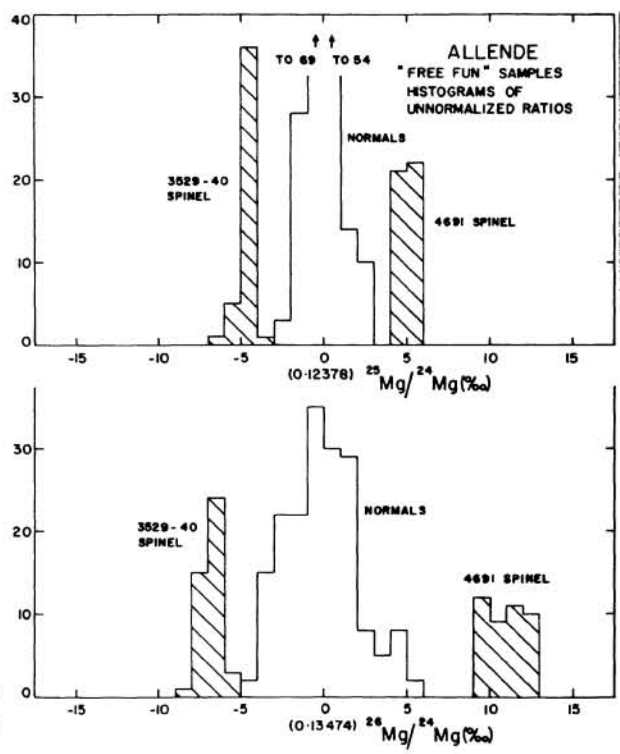

Fig.1. Histograms of unnormalized ratios for spinel from FREE FUN inclusions which contain fractionated Mg of about -4.8‰ and +5.0‰ per amu. They are distinctly outside the instrumental fractionation range defined by the histograms of normals.

REFS: [1] Mason & Taylor, Smithsonian Contrib.Earth Sci.25(1982); [2] Esat & Taylor, this vol.; [3] Wark & Lovering PLSC VIII(1977)95; [4]____LPSC XI(1980) 1211; [5] Wasserburg & Papanastassiou, in Essays in Nucl.Astrophysics, Camb. Univ.Press(1981); [6] Meeker et al., Geochim.Cosmochim. Acta 47(1983)707; [7] Boynton, Meteoritics 12(1977)183; [8] Papanastassiou et al., LPSC IX(1978)859.