OXYGEN AND MAGNESIUM ISOTOPIC RATIOS OF PRESOLAR SPINEL GRAINS. E. Zinner[1], L. R. Nittler[2], P. Hoppe[3], R. Gallino[4] and R. S. Lewis[5]. [1]Laboratory for Space Sciences, and the Physics Department, Campus Box 1105, Washington University, One Brookings Drive, St. Louis, MO, 63130, USA (ekz@wustl.edu), [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, NW Washington DC, 20015, [3]Max-Planck-Institut für Chemie, Kosmochemie, P.O. Box 3060, D-55020 Mainz, Germany, [4]Dipartimento di Fisica Generale, Università di Torino, Via P. Giuria 1, I-10125 Torino, Italy, [5]Enrico Fermi Institute, University of Chicago, 5630 Ellis Avenue, Chicago IL 60637 USA.

Introduction: In the past, most Mg isotopic measurements of presolar grains have been made in SiC and corundum, which have high Al/Mg ratios [1-3]. In such grains the Mg isotopic ratios are dominated by radiogenic ^{26}Mg and, because of low Mg concentrations, the ^{25}Mg/^{24}Mg ratios have large uncertainties. In contrast, analysis of Mg-rich spinel allows more precise determination of Mg ratios in presolar grains. Nittler et al. [4] reported O and Mg isotopic data for 7 spinels from ordinary chondrites (OC). Here we present O and Mg measurements on 20 Al-Mg spinel grains from the CM carbonaceous chondrite Murray and on one Al-Mg and 2 Cr-rich spinels from the CI carbonaceous chondrite Orgueil.

Experimental: Presolar spinel grains from the Murray separate CG (average size 0.5 μm) [5] were identified by single grain O isotopic analysis in the Washington University NanoSIMS ion microprobe, the Orgueil grains by automated isotopic measurements in the Carnegie ims-6f ion probe [6]. Seven Murray grains whose O-isotopic compositions had been reported previously [7] and the Orgueil grains were analyzed for their Mg isotopic ratios in the NanoSIMS at the Max-Planck-Institute in Mainz, the remaining 13 Murray grains in the WU NanoSIMS. These measurements were made in multicollection mode by detecting the three Mg isotopes simultaneously along with ^{27}Al. Other spinel

Figure 1
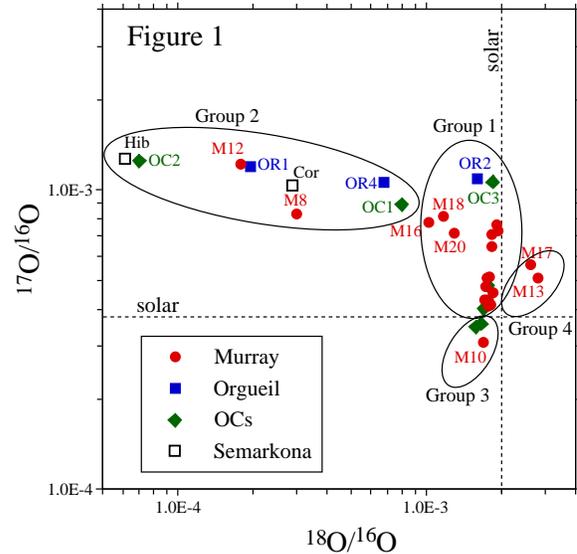
grains on the same grain mounts, whose O isotopic compositions identified them as being of solar system origin, were used as Mg isotopic standards.

Results: The O and Mg isotopic ratios of the analyzed spinel grains are plotted in Figs. 1 and 2 together with those of the 7 previously reported

Figure 2
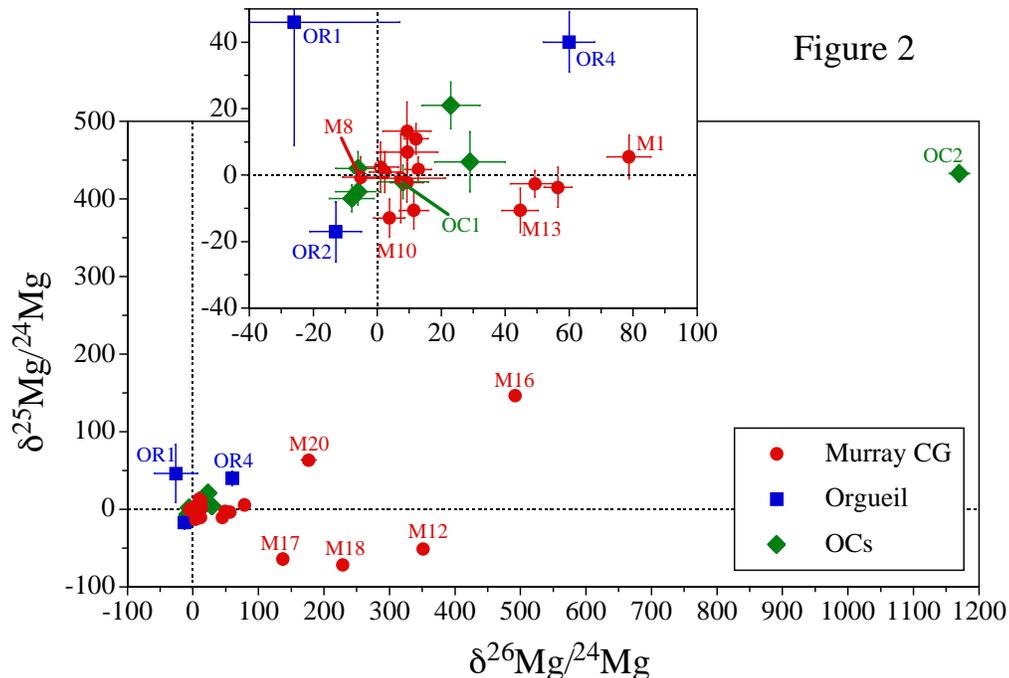
spinels [4] and two Semarkona grains [3]. Error bars are 1σ. In Fig. 1 we indicate different groups identified by Nittler [2]. Three Murray grains have substantial ^{25}Mg deficits and large ^{26}Mg excesses, two Murray and one Orgueil grains have excesses in both of these isotopes, whereas four Murray grains have only ^{26}Mg excesses while their ^{25}Mg/^{24}Mg ratios are solar within 2σ errors. The other newly analyzed grains have close-to-normal Mg ratios. Grain OC2 has been discussed before [4].

Discussion: All grains except two belong to groups 1-3 and such grains have been interpreted to have an origin in red giant (RG) or asymptotic giant branch (AGB) stars [2]. There is no obvious correlation between the O and Mg isotopic compositions. For example, M12 and OR1 have essentially the same O isotopic ratios but very different Mg ratios (Figs. 1 and 2). Likewise, M16 and M18 have similar O ratios but have ^{25}M g excesses and deficits, respectively. A correlation between the O and Mg isotopic ratios is not necessarily expected because these two elements are affected by different nucleosynthetic processes. The O isotopes in the parent star's envelope are modified by proton capture in the deep envelope followed by 1st and 2nd dredge-up [8]. Shell H and He burning and 3rd dredge-up do not much affect the O isotopes, but cool bottom processing (CBP) in low-mass [9] and hot bottom burning (HBB) in intermediate-mass (>~4M$_\odot$) AGB stars [10, 11] can drastically reduce the ^{18}O/^{16}O ratio. In fact, the low ^{18}O/^{16}O ratios in group 2 grains have been interpreted as the result of CBP. On the other hand, the Mg isotopic ratios in the envelope are not expected to change before the AGB phase. Excesses in the heavy isotopes are predicted to result from α-reactions on ^{22}Ne and neutron capture. Proton reactions in the H shell are not expected to have a significant effect. However, such reactions during CBP [9] and especially HBB can drastically change the Mg isotopic ratios [10, 12]. Furthermore, ^{26}Mg excesses result from the decay of short-lived ^{26}Al, which can be produced by H shell burning [13], CBP [9] or HBB [12]. In addition, galactic chemical evolution (GCE) affects the original Mg isotopic ratios of the grains' parent stars [4].

The fact that so many possible processes affect the Mg isotopes makes it a challenge to explain the Mg isotopic compositions of all the grains satisfactorily, especially if they are considered in conjunction with the O ratios of the grains. Predicted changes in Mg ratios in low-mass (≤3 M$_\odot$) stars due to α-reactions and n-capture are smaller (≤40‰) than observed as long as O>C in the envelope, and shifts in ^{25}Mg are larger than those in ^{26}Mg. Depletions in ^{25}Mg probably have an origin in stars of lower-than-solar metallicity. Mg isotopic shifts for low-metallicity AGB stars are large but they occur after the stars turned into carbon stars after a few thermal pulses. In any case, it is difficult to explain the large ^{26}Mg excesses without assuming that they are of radiogenic origin. Some intermediate-mass models predict ^{26}Mg excesses and even ^{25}Mg depletions during early pulses [6M$_\odot$ models in 11] but

eventually ^{25}Mg excesses (even larger than those of ^{26}Mg) are obtained. Furthermore, the HBB in such stars would destroy essentially all the ^{18}O, which in most grains is not seen. Also, the O isotopic compositions of the grains indicate masses smaller than 2M$_\odot$. A radiogenic origin for the ^{26}Mg excesses implies ^{26}Al/^{27}Al ratios of up to ~0.025. This is an order of magnitude higher than has been predicted from H shell burning in the envelope of a 3 M$_\odot$ AGB star [13 and recent results] but similar to the highest ratios seen in a corundum grain (0.031) and in a hibonite grain (0.02) from Semarkona [3]. For these two grains, whose O isotopic ratios are plotted in Fig. 1 (Hib and Cor), CBP has been invoked to explain their ^{26}Al/^{27}Al ratios and this process is also the most likely cause for the larger ^{26}Mg excesses of the spinel grains of this study. According to the model calculations of Nollet et al. [9], the range of 0.01 to 0.021 for the inferred ^{26}Al/^{27}Al ratios for grains M17, M18, and M12 implies temperatures of ~5x10^7 K, still too low for ^{24}Mg to capture protons and to lead to the production of ^{25}Mg [12]. If we assume solar Al/Mg ratios in the parent stars, the ^{25}Mg depletions expected from ^{26}Al production are smaller (8 to 16‰) than the deficits seen in these three grains, thus GCE probably played a role in determining the Mg isotopic compositions of these grains. Grain M17 presents a problem in that its ^{25}Mg depletion indicates a parent star with lower-than-solar metallicity while its O isotopic compositions (it belongs to group 4) would imply higher-than-solar metallicity. However, there is still the possibility of heterogeneous mixing of stellar ejecta in the interstellar medium [4, 14]. Although errors are large, astronomical observations indicate a large range of Mg isotopic ratios in main sequence stars [e.g. 15,16], perhaps reflecting in part such heterogeneous mixing. The ^{25}Mg excesses in grains M20 and M16 are larger than what is predicted for 3M$_\odot$ stars of solar metallically, thus the parent stars are either more massive or GCE was important also for these grains.

In conclusion, a variety of processes determine the O and Mg isotopic ratios of presolar spinel; CBP plays a major role among them.

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