C-, N-, O-, Si-, AND Ti-ISOTOPIC RATIOS OF LOW DENSITY GRAPHITE GRAINS FROM MURCHISON INDICATE A SUPERNOVA ORIGIN;
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Interstellar graphite grains larger than 3 μm and with densities 1.57-2.12 g/cm^3 have extremely large $^{18}O/^{16}O$ ratios, ranging up to 100× solar. These excesses, together with large variations in the Si-isotopic ratios and ^{49}Ti excesses, suggest a supernova origin for these grains.

Interstellar graphite from the Murchison CM2 meteorite has shown a bewildering variety of isotopic compositions in C, N, O, Mg, Si and the noble gases, indicating that it originated from several types of stellar sources [1,2]. One problem with identifying particular stellar sources is that, unlike interstellar SiC, graphite generally has low concentrations of other elements, which makes it difficult if not impossible to make correlated isotopic measurements of several elements in single grains. An exception are grains of low density, which have higher trace element contents and thus offer the chance to measure O, Si and Mg isotopes in addition to those of C and N [3,4]. Here we report correlated isotopic measurements of C, N, O, Mg and Si in individual grains from Murchison separate KE3 (1.57-2.12 g/cm^3; nominal grain size ≥ 3 μm). Of the grains found in KE3 we selected round grains for isotope analyses by ion microprobe spectrometry. In a few unusually large grains we succeeded in also analyzing Ca and Ti isotopes.

The C- and N-isotopic compositions of 47 grains are shown in Fig. 1. Most grains have isotopically heavy to normal C, and heavy to normal N. Si-isotopes were measured in 46 grains; 14 of them have anomalies outside of 2σ errors (Fig. 2). While most grains have deficits in ^{29}Si and ^{30}Si, a few have excesses in ^{29}Si and two grains excesses in both ^{29}Si and ^{30}Si, which are larger than 400 ‰ in grain 563. We determined $^{16}O/^{18}O$ ratios in 40 grains (Fig. 3); 26 of them have ^{18}O excesses, ranging up to a factor of 100, much larger than ^{18}O excesses previously observed [4,5]. We also measured $^{16}O/^{17}O$ ratios in 23 grains; they are normal with the sometimes fairly large errors. However, it is clear that, if anomalies in the $^{16}O/^{17}O$ ratio exist, they are much smaller than those in $^{16}O/^{18}O$. There is a rough correlation between the $^{16}O/^{18}O$ and $^{14}N/^{15}N$ and $^{12}C/^{13}C$ ratios; grains with ^{18}O excesses have the tendency to be enriched in ^{12}C and ^{15}N (Fig. 3). Of 38 grains analyzed for Mg-Al, 27 have large ^{26}Mg excesses with inferred $^{26}Al/^{27}Al$ ratios ranging up to 0.15 (Fig. 4). While $^{25}Mg/^{24}Mg$ ratios are usually normal, three grains have ^{25}Mg excesses: #022: 654 ± 250‰; #157: 1585 ± 602‰; #753: 562 ± 111‰ (2σ errors). Of the 8 grains in which we measured Ca and Ti, all have ^{49}Ti excesses, ranging up to 1720±972‰ (2σ) in grain 141. Grain 662, the grain with the largest $^{12}C/^{13}C$ ratio and largest ^{18}O excess (Fig. 3) has, in addition to a ^{49}Ti excess of 862±90‰, excesses of 175±72‰ and 429±132‰ (2σ) in ^{42}Ca and ^{43}Ca, respectively. The low density graphite grains show a similarity in their C, N, Si and Ti isotopic compositions to SiC grains of type X for which a supernova origin has been invoked [6]. The case for a SN origin of the graphite grains is strengthened by the large ^{18}O excesses observed in these grains. While Wolf-Rayet stars can have ^{18}O enrichments on their surface during the WN-WC transition, it appears doubtful that ^{18}O excess of more than a factor 10 can be achieved [7]. Massive pre-SN stars, on the other hand, have a $^{16}O/^{18}O$ ratio of ~5 in the He-burning zone, the only layer with C/O>1 [8]. This ratio is comparable to the smallest ratios observed in the carbon grains of this study.

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