

THE C, N, Al, AND Si ISOTOPIC COMPOSITIONS OF SiC GRAIN SIZE SEPARATES FROM MURCHISON: INDIRECT EVIDENCE FOR HIGHLY ANOMALOUS GRAINS; S. Amari^{1,2}, E. Zinner¹ and R. S. Lewis²; ¹McDonnell Center for the Space Sciences and the Physics Department, Washington University, One Brookings Drive, St. Louis, MO 63130-4899; ²Enrico Fermi Institute, University of Chicago, 5630 Ellis Ave., Chicago, IL 60637-1433.

Meteoritic silicon carbide is isotopically anomalous in its major elements C and Si [1,2], the minor and trace elements N, Ti, Sr, Ba and Nd [1-6] and is the carrier of Ne-E [7] and Kr-S and Xe-S [8] as well as fossil ²⁶Mg from the decay of ²⁶Al [9]. Although the main advantage of the ion microprobe lies in the analysis of single grains, this is presently possible only for SiC grains larger than ~ 2 μm (if C, N, Mg-Al, and Si are measured). Since different grain size fractions of SiC show large variations in their Kr isotopic compositions [8] which have been interpreted to reflect processes in the He-burning shell of AGB stars [10], we measured C, N, Si and Mg-Al in bulk samples of 5 of the the same SiC grain size separates (KJA to KJE) and compared the results with analyses of single grains (1.6-6.0 μm) from separate KJG. Measurements were made on agglomerates with ion beams (Cs⁺ for C, N, Si, and O⁻ for Mg-Al) between 10 and 20 μm in diameter, each run comprising the analysis of hundreds to thousands of grains. The weighted (by the amount of material consumed) averages of between 9 and 13 runs for each separate as well as the range of values are given in Table 1. The averages are also plotted in the Figures, in Fig. 1 and 2 together with the single grain measurements. What is surprising is the small degree of variations between different size fractions in view of the variation between the Kr isotopes and the enormous scatter of single grain data. The averages of the latter are heavily influenced by a few grains with heavy C and N. The weighted average of $\delta^{13}\text{C}$ for KJG is 14730/00 although only 14 out of 76 grains fall above this value. For N and Si the inclusion or exclusion of a single grain (grain X) has a significant impact on the averages. Although we don't know the distributions of their isotopic compositions, the situation appears to be similar for the fine grained fractions (i.e. a small percentage of grains with high ¹³C/¹²C and ¹⁵N/¹⁴N ratios determine the bulk isotopic compositions). This is indicated by the variations from run to run (and often also during a run) which, as expected, increase with increasing grain size (see Table 1). Unfortunately, we still cannot tell whether the exotic noble gas components are carried by all grains or by a select few.

The variations of ²⁶Al/²⁷Al between grain size fractions are much larger than of the other isotopic ratios. ²⁶Al/²⁷Al is correlated with the Si/Al ratio (Fig. 3), suggesting mixing between indigenous Al with ²⁶Al/²⁷Al = 4-5 × 10⁻³ and extraneous Al. The latter is apparently carried by oxide grains such as corundum and hibonite that have been identified by SEM observations in the coarser size fractions. Furthermore, elemental imaging in the ion probe reveals that most of the Al in KJE is not associated with Si (i.e. SiC). However, there is no systematic trend of ²⁶Al/²⁷Al and Si/Al with grain size, indicating that Al-rich grains either come from distinct populations or are unequally distributed. The latter possibility seems to be supported by the rather wide range of ²⁶Al/²⁷Al in the table, but the small error bars of the mean obscure this relationship. The maximum ²⁶Al/²⁷Al and Al/Si inferred from a mixing model are very similar to the average of KJG single grains, however only if grain X (²⁶Al/²⁷Al = 0.2) is included. A consistent interpretation (although not a unique one) is that all bulk size fractions up to KJG have ²⁸Si/²⁷Al⁺ ≈ 3.5 (corresponding to an Al concentration in SiC of ~ 3.5%) and ²⁶Al/²⁷Al ≈ 4.5 × 10⁻³, but that only a small percentage of grains in each size fraction carries most of the ²⁶Al with ²⁶Al/²⁷Al ratios of up to 1, consistent with expected production ratios [11,12].

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Sample	Size μm	$\delta^{13}\text{C}$ ‰	$\delta^{15}\text{N}$ ‰	$\delta^{29}\text{Si}$ ‰	$\delta^{30}\text{Si}$ ‰	$^{26}\text{Al}/^{27}\text{Al}$ 10^{-3}
KJA	0.05-0.1	1126 \pm 14 (1077 \rightarrow 1177)	-264 \pm 8 (-237 \rightarrow -279)	21.7 \pm 1.2 (18.6 \rightarrow 25.5)	34.5 \pm 2.2 (32.7 \rightarrow 36.5)	4.1 \pm 0.2 (3.1 \rightarrow 4.9)
KJB	0.1-0.2	1404 \pm 31 (1268 \rightarrow 1498)	-474 \pm 57 (-186 \rightarrow -585)	24.7 \pm 0.7 (20.1 \rightarrow 26.4)	37.6 \pm 1.5 (25.3 \rightarrow 39.5)	2.4 \pm 0.2 (1.7 \rightarrow 3.3)
KJC	0.2-0.3	1400 \pm 60 (1132 \rightarrow 1612)	-475 \pm 18 (-399 \rightarrow -581)	29.3 \pm 1.3 (23.6 \rightarrow 32.9)	29.3 \pm 2.7 (23.6 \rightarrow 44.6)	2.8 \pm 0.2 (1.2 \rightarrow 3.5)
KJD	0.3-0.5	1303 \pm 62 (1010 \rightarrow 1590)	-302 \pm 64 (-22 \rightarrow -629)	27.7 \pm 1.8 (24.6 \rightarrow 37.0)	35.0 \pm 3.7 (25.2 \rightarrow 51.3)	3.5 \pm 0.4 (2.1 \rightarrow 6.0)
KJE	0.5-0.8	1271 \pm 48 (967 \rightarrow 1513)	-479 \pm 48 (-153 \rightarrow -689)	31.5 \pm 2.8 (1.3 \rightarrow 47.0)	42.0 \pm 3.4 (1.8 \rightarrow 64.3)	1.4 \pm 0.3 (0.7 \rightarrow 3.2)
KJG 1	1.5-3.0	1473 \pm 290 (-922 \rightarrow 14351)	-367 \pm 196 (-941 \rightarrow 14044)	41.2 \pm 8.2 (-376 \rightarrow 160)	35.6 \pm 9.7 (-585 \rightarrow 135)	4.1 \pm 3.0 (<.05 \rightarrow 200)
KJG 2		1523 \pm 289 (-321 \rightarrow 14351)	-665 \pm 30 (-941 \rightarrow 303)	50.7 \pm 5.7 (-60 \rightarrow 160)	49.6 \pm 4.0 (-38 \rightarrow 135)	1.0 \pm 0.3 (<.05 \rightarrow 20)

All errors are $1\sigma_{\text{mean}}$

KJG 1 Average of 76 single grains

KJG 2 Average without grain X

References:

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