1992

New Ideas for SiC: Mg Burning in AGB Shell Flashes

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Recommended Citation

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NEW IDEAS FOR SiC: Mg BURNING IN AGB SHELL FLASHES;

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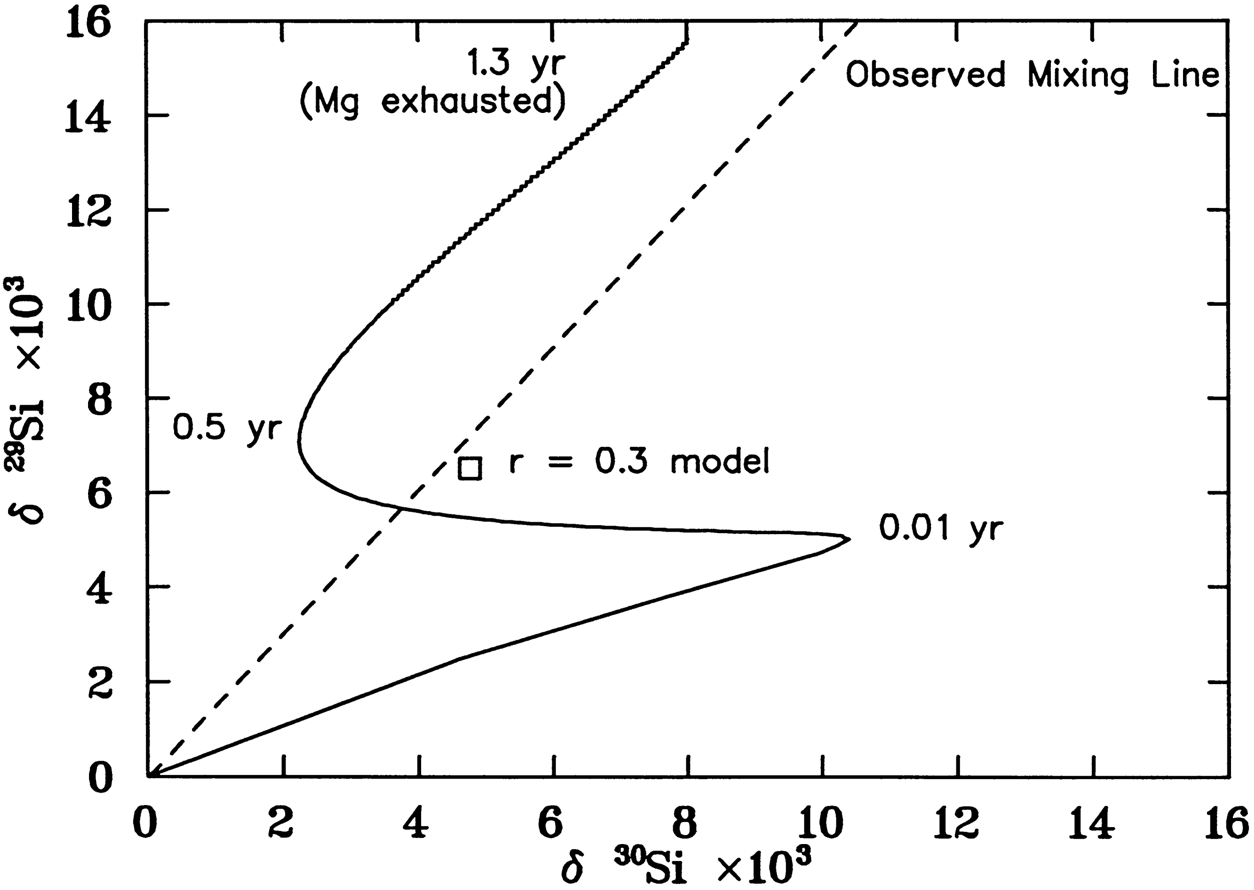
In our last report [1] on isotopic composition of SiC particles from AGB stars we expressed skepticism that observed isotopic compositions [2,3] could be made consistent with an AGB star origin. In particular, the observed correlation slope (near 1.4) of δ^{29}Si *vs.* δ^{30}Si is much steeper than the calculated slope (near 0.5). We have been searching for a possible way to salvage the AGB-star idea. What we report here is an evaluation of the extended nuclear reaction network that would be relevant if the peak shell temperatures in massive AGB shell flashes are about 10% greater than estimates from the few models that exist. The key idea is the ^{26}Mg(alpha,n)^{29}Si and ^{25}Mg(alpha,n)^{28}Si reactions, which greatly augment the ^{29}Si and ^{28}Si abundances and greatly change the isotopic correlations.

The figure below shows (solid curve) the evolution of Si isotopes for He burning at the constant temperature T=450x10^{6}K, about 10% greater than the peak shell temperature from model-based estimates. Early evolution is along the slope-0.5 line as ^{22}Ne neutrons are being released while ^{22}Ne is converted to ^{25,26}Mg. The ^{33}S(n,alpha)^{30}Si reaction causes δ^{30}Si to dominate this phase. This is the standard AGB-shell situation [1] leading to a conflict with the isotopic composition of the particles [2,3]. This burning requires 0.01yr at



this temperature. However, during the next 0.5yr the ^{25,26}Mg also burn by (alpha,n) reactions to enhance both ^{28,29}Si in such a way that δ^{29}Si does not much change but the underproduced ^{30}Si now falls. The correlation moves leftward and crosses the slope-1.4 line, which is shown for comparison. Not evident from the figure is another interesting consequence; *viz.* that the Si abundance is also increased in an absolute sense because ^{22}Ne was much more abundant than the initial Si. As this burning continues to t=1.3yr the values ^{29,30}Si continue to increase along a displaced slope-1.4 line, finally terminating when the Mg is totally exhausted. What has happened is that the initial CNO content of the star has been converted substantially to Si isotopes. It is immediately evident that if pulsing AGB stars can do this the interpretation of the SiC particles is refreshed.

In an actual star, the temperature is a function of time during a flash and of position in the convective He shell. Using the results of Iben [4] we have constructed a model He shell flash having a peak base temperature of 450×10^6K. We included this in a pulse-and-mix AGB model and followed its evolution for a remix fraction r=0.3 (a plausible remaining fraction for successive pulses). As is well known, the shell composition tends to "saturate" to an almost constant composition owing to the admix of envelope matter. The square in the figure shows that asymptotic composition for this "model". It falls near the slope-1.4 line with δ^{30}Si=5000. We think that this finding reopens questions about the AGB models themselves, at least if one plans to form the observed SiC particles within them. Whether massive AGB models actually reach $T_{peak}=450\times10^6$ should be actively investigated.

If this resolution is possible it leads to other very interesting consequences. Why are the observed SiC particles of this type rather than of the composition expected for the more common low-mass AGB stars? We offer two potential responses. Perhaps the low-mass AGB stars cannot form large SiC particles because their Si concentrations are too small. They may form graphite instead. Then only massive stars undergoing this peculiar isotopic evolution that enhances Si abundance more than tenfold can grow large SiC. On the other hand, one may turn to the ideas of Cameron [5] and suspect that one has here only SiC particles from a single masssive AGB star that was implicated in solar cloud core collapse. Another feature of this evolution is that massive AGB stars may have moderate "hot-bottom burning" of Si in the H convective envelope. We find this to produce an atmospheric endmember having positive δ^{30}Si but negative δ^{29}Si, so that the mixing line would pass to the right of the origin (solar composition), as suggested by the particles.

This research was supported by NASA grants in Planetary Materials and Geochemistry and by the Origins of Solar Systems.

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