THE TRIGGERING SUPERNOVA AND ISOTOPIC ANOMALIES IN METEORITES, A. G. W. Cameron and J. J. Cowan, Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, and J. W. Truran, Department of Astronomy, University of Illinois, Urbana, IL 61801.

The discovery[1] of evidence for the presence of ^{26}Al in the early solar system led two of us[2] to interpret many isotopic anomalies within solar system materials as possibly produced within a supernova which was responsible for triggering the collapse of an interstellar cloud and the formation of the solar system. This interpretive paper was quite qualitative, since detailed nucleosynthetic calculations had not been carried out for most of the interior scenarios that were discussed, so to some extent the paper can be considered to have outlined a course of action for further research. Additional motives for this research are provided by the recent discoveries of isotopic anomalies in Ca, Ba, and Nd[3,4] which appear to exhibit anomalous r-process effects.

Our present knowledge of magnesium anomalies now appears to be quite instructive. Evidence for early ^{26}Al comes from ^{26}Mg excesses which are correlated with the Al/Mg ratio in Allende inclusions. This extinct radioactivity is made in explosive carbon-burning; two of us[5] have estimated the production ratio $^{26}\mathrm{Al}/^{27}\mathrm{Al}$ to be 1×10^{-3} with a probable error of a factor two in carbon-burning, provided we require the neighboring isotopes to be made in relative solar proportions. It is now not clear that this is a valid requirement, so that the probable error on the production ratio should be increased by a significant factor. This might extend the possible interval between the supernova explosion and the formation of meteoritic material in Allende to as much as 5 or 6×10^6 years.

In the inclusions exhibiting the Ca, Ba, and Nd anomalies, Wasserburg and his colleagues describe the ^{26}Mg as depleted relative to the normal $^{25}\mathrm{Mg}/^{24}\mathrm{Mg}$ ratio. However, in the raw measurements the $^{25}\mathrm{Mg}/^{24}\mathrm{Mg}$ ratio is greatly enhanced, so that the ^{26}Mg depletion hypothesis would require a highly abnormal fractionation. We prefer to interpret these inclusions as having an enrichment of both ^{25}Mg and ^{26}Mg.

This enrichment can occur in the course of helium-burning in the presupernova star. Hydrogen-burning concentrates the original CNO nuclei as ^{14}N, and subsequent alpha-particle captures convert this to ^{22}Ne. The next alpha-particle can produce either the reaction $^{22}\mathrm{Ne}(\alpha,\gamma)^{26}\mathrm{Mg}$ or the reaction $^{22}\mathrm{Ne}(\alpha,n)^{25}\mathrm{Mg}$,

TRIGGERING SUPERNOVA

A. G. W. Cameron <u>et al</u>

leading to the enrichment of both of these heavier magnesium isotopes. If the final step of helium-burning takes place slowly, then the neutrons that are produced will transform the heavier nuclei by the s-process. On the other hand, if the final step of helium-burning occurs rapidly as a result of the passage of a supernova shock wave, then the neutrons will produce an r-process.

We have run nuclear reaction networks to examine the effects of the helium-driven r-process. We have found[6] that the heavier nuclei are likely to capture many more neutrons than were qualitatively expected in the supernova trigger discussion [2]. We would expect quite different r-process abundance patterns in high and low mass supernovae; nevertheless we were pleasantly surprised to see that our calculation had reproduced some of the main features of the solar system r-process abundance distribution. We now believe that the r-process is a natural feature of the helium zones in supernovae. When this process occurs, all heavier nuclei become r-process products, and there is a substantial flow of nuclei toward very high mass numbers (A=300 or more).

It is clear that the two Allende inclusions showing r-process effects do not contain material which has been very extensively exposed to neutrons. We suggest that one of the inclusions (EK1-4-1) contains material from a region where slow helium-burning was nearly complete when the supernova shock passed through, so that only a weak flux of neutrons was produced. The other inclusion (C1) actually shows negative r-process anomalies, so that it probably obtained material from a helium-exhausted region that did not get sufficiently heated by the shock to burn carbon explosively.

This poses a major question for meteoritic research. Did material from the helium-driven r-process region get into the solar system in significant amounts? If so, where is it? Did it contribute the bulk of the extinct radioactivities which are roughly evenly distributed throughout solar system material? If so, how does this transform our picture of cosmochemical evolution in the galaxy?

We are continuing to investigate the helium-driven r-process with different abundance and thermodynamic initial conditions.

TRIGGERING SUPERNOVA

A. G. W. Cameron, *et al*

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