CARBON AND NITROGEN IN TYPE II SUPERNOVA DIAMONDS:
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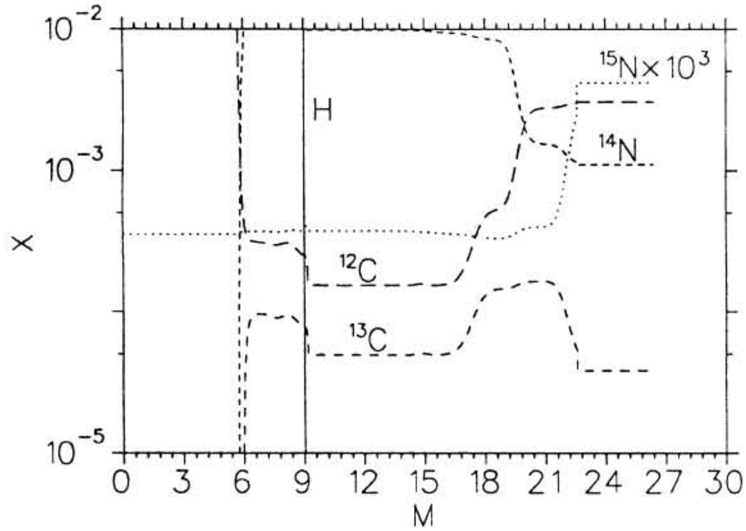
Abundant diamonds found in meteorites seem either to have condensed within supernova interiors during their expansions and coolings or to have been present around those explosions. Either alternative allows implantation of Xe-HL prior to interstellar mixing [1,2,3]. A puzzling feature is the near normalcy of the carbon isotopes, considering that the only C-rich matter, the He-burning shell, is pure ^{12}C in that region. That last fact has caused many to associate supernova carbon with ^{12}C carbon, so that its SUNOCONS have been anticipated as very ^{12}C-rich. We show that this expectation is misleading because the ^{13}C-rich regions of Type II's have been largely overlooked in this thinking. We here follow the idea [1,2] that the diamonds *nucleated* in the ^{12}C-rich He shell, the only C-rich site for nucleation, but then *attached* ^{13}C-rich carbon during turbulent encounters with overlying ^{13}C-rich matter. That is, the initial diamonds continued to grow during the same collisional encounters that cause the Xe-HL implantation. Instead of interacting with the small carbon mass having 13/12=0.2 in the upper He zone [2], however, we have calculated the remnants of the initial H-burning core, which left behind ^{13}C-rich matter as it receded during core hydrogen burning. Howard *et al.* [3] described why the velocity mixing would be essential to understanding the implantation of both the Xe-H and Xe-L components. Velocity mixing is now known to occur from the X-ray and gamma-ray light curves of supernova 1987A.

Using the stellar evolution code developed at Göttingen [4] we calculated at Clemson the evolution of a grid of massive stars up to the beginning of core He burning. We paid attention to all H-burning reactions throughout the star, to the treatment of both convection and semiconvection, and to the recession of the outer boundary of the convective H-burning core as the star expands toward a larger redder state. This program was to generate a careful map of the CNO isotope distribution as He burning begins. Figure 1 shows our result for the $30M_\odot$ star, which does not become a Wolf-Rayet star according to our prescription for mass-loss rate but evolves at almost constant mass. The H-burning shell ignites near $8M_\odot$ when the final core has been exhausted of H. Very significant is the ^{13}C-rich matter evident in Fig. 1 between 17 and $22M_\odot$. The ^{13}C concentration was fixed by semiconvective mixing episodes from the top of the receding H-burning core. The heretofore unemphasized feature of this is that as that convective core receded, it left behind matter that had undergone only very slight H burning, so that ^{13}C had been enriched from ^{12}C(alpha,gamma)^{13}N but the ^{12}C abundance itself had not been burned down to the low value to which it ultimately falls in equilibrium in the CNO cycles. That is, the mass between 17 and $22M_\odot$ resembles matter that has only just begun to burn hydrogen. This composition remains almost unaltered outside the He core while it continues its entire presupernova evolution. Figure 1 also shows that within $18M_\odot$ the ^{12}C and ^{13}C are both depleted by their more complete conversion to ^{14}N. This causes the 17-$22M_\odot$ region of this $30M_\odot$ star to have disproportionate influence on the 12/13 ratio outside the He core. The comparison with the initial solar abundances at the surface (now near $27M_\odot$ of this initially $30M_\odot$ star) shows that the matter outside the He core at $9M_\odot$ is actually ^{13}C-rich. It is the attachment of this carbon to the nucleated diamonds that prevents the SUNOCONS from remaining highly ^{12}C-rich. This solution was previously suggested [2] in a more qualitative discussion. If the $0.0016M_\odot$ of ^{13}C ejected finally is mixed with the roughly $0.14M_\odot$ of ^{12}C created later in the He-burning shell, there would result a 12/13 ratio near 90 outside the carbon core. So only slight ^{12}C richness is to be expected.

Additional ^{12}C is synthesized later in the He-exhausted core, raising the 12C yield and making the bulk supernova yield roughly 12/13= 2-3 times solar. But if we can speculate that only the carbon outside the final carbon core attaches effectively to the diamonds, perhaps owing to the catalytic necessity of hydrogen for diamond growth in a plasma [5], we can glimpse a reason for the near normalcy of carbon in the diamonds.

Next consider the nitrogen isotopes in Figure 1. Within $19M_\odot$ the ^{14}N is augmented to values near X(14)=0.02, with the result that M(14)=$0.21M_\odot$ is contained at that time--approximately a factor 10 larger than the initial N content of the outer $10M_\odot$ of that star. About half of this ^{14}N is later destroyed by He burning creating the ^{18}O yield of Type II's. The ^{15}N on the other hand later ejected. This bulk nitrogen yield is 14/15= 0.10/3.4 x10^{-5} = 3000, roughly tenfold greaterthan solar. This easily accounts for the ^{14}N-richness of the diamonds, but excessively so since they have $^{15}\delta$=-340 [6]. An unidentified factor has favored inserting N from the outer part of stars in preference to the pure ^{14}N in the He shell. The answer will depend in part on whether N must, like Xe, be implanted or whether it can be condensed during the diamond growth.



Mass fractions at end of H burning in $30M_\odot$ star

The new feature is the hydrodynamic instabilities that occur early after the core bounce and thermonuclear explosion. These cause both inward and outward plumes of matter [7]. Some explosive oxygen, containing also Xe-L, bursts through the He shell where the diamonds will later nucleate, for example. The disruption of layered radial flow introduces the possibility of mild shocks later as one fluid element overtakes another. It is then that the Xe-L and the Xe-H can be implanted. This implantation is at much lower speeds than one normally thinks of in relation to lunar studies. Indeed, a solar-wind-speed Xe atom would either crash through a 25Å diamond or disrupt it or both--but not be captured by it. The desired speeds will allow penetration of the surface barrier of the diamond without later leaving another surface. This problem seems to merit study. In much the same spirit the ^{13}C-rich carbon in the hydrogen plasma may facilitate further diamond growth for several years. Without the disruption of the radial flow the collisions would soon cease owing to the t^{-3} decline of particle density. A proper description of the growth of the diamonds will exceed our grasp for some time but will, in the end if this description is correct, offer unparallelled insights into the fluid mechanics and chemical reactions within the expanding supernova interior.

References: [1] Clayton, D.D. 1981 *Proc. Lunar Planet Sci* **12B**, 1781;
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