NUCLEOSYNTHESIS OF SHORT-LIVED RADIOACTIVITIES IN MASSIVE STARS. B. S. Meyer[1], Department of Physics and Astronomy, Clemson University, Clemson, SC 29634-0978, USA (mbradle@clemson.edu).

Introduction: A leading model for the source of many of the short-lived radioactivities in the early solar nebula is direct incorporation from a massive star [1]. A recent and promising incarnation of this model includes an "injection mass cut", which is a boundary between the stellar ejecta that become incorporated into the solar cloud and those ejecta that do not [2-4]. This model also includes a delay time between ejection from the star and incorporation into early solar system solid bodies.

While largely successful, this model requires further validation and comparison against data. Such evaluation becomes easier if we have a better sense of the nature of the synthesis of the various radioactivities in the star. That is the goal of this brief abstract.

In what follows, I present the results of a calculations run at Clemson University. With collaborators Lih-Sin The and Mounib El Eid, I have calculated the presupernova evolution of a 25 solar mass star. We then exploded the star and post-processes the accompanying nucleosynthesis [4]. The present abstract discusses briefly the synthesis of six isotopes (^{26}Al, ^{36}Cl, ^{41}Ca, ^{60}Fe, ^{107}Pd, and ^{182}Hf).

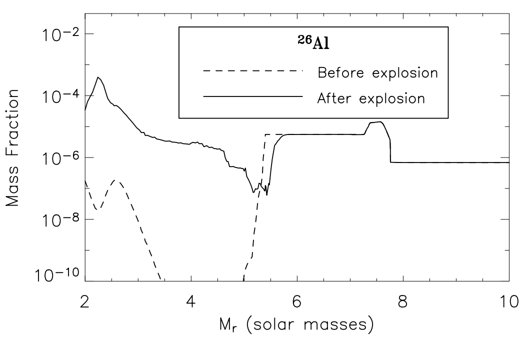

Fig. 1: Mass fractions of ^{26}Al in the initially 25 solar mass star just before and one year after the explosion of the star.

^{26}Al: Figure 1 shows the pre-supernova (just prior to explosion) and post-supernova mass fractions of ^{26}Al as a function interior mass coordinate in the star. The entire envelope (reaching out to the surface of the star at about 18 solar masses due to mass loss) contains ^{26}Al due to dredge up of the hydrogen burning shell. From Figure 1 it is clear that the supernova neutrinos and supernova shock passage are responsible for production of ^{26}Al inside about 5.5 solar masses (the inner edge of the helium shell in the presupernova star). Outside about 5.5 solar masses, however, the explosion does not alter the presupernova ^{26}Al abundance. Unless matter from deep inside the star is injected into the solar cloud, most injected ^{26}Al was produced in the presupenova evolution.

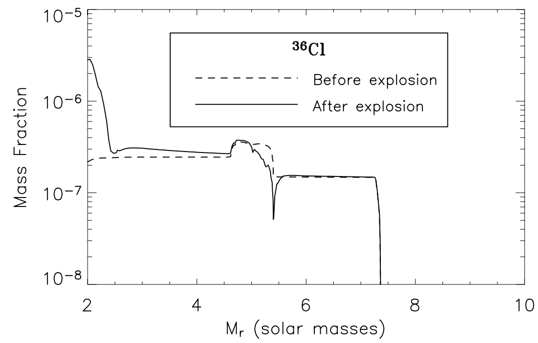

Fig. 2: Mass fractions of ^{36}Cl in the initially 25 solar mass star just before and one year after the explosion of the star.

^{36}Cl: Figure 2 shows the pre- and post-supernova mass fractions of ^{36}Cl. For this isotope, it is clear that the bulk of the ^{36}Cl ejected from the star is made in the pre-supernova evolution. This production is due to s-process synthesis in core and shell helium burning and shell carbon burning. Such synthesis is robust. Moreover, the lack of light particles in the carbon shell (from about 2.3 to 5.5 solar masses) means there is little alteration of the presupernova abundances by shock passage. Only in the inner layers of the star near 2 solar masses do explosive burning upon shock passage significantly enhance the presupernova ^{36}Cl.

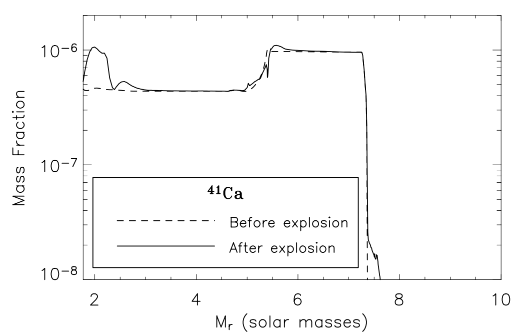

Fig. 3: Mass fractions of ^{41}Ca in the initially 25 solar mass star just before and one year after the explosion of the star.

^{41}Ca: As Figure 3 shows, the ^{41}Ca ejected from the star, like the ^{36}Cl, mostly derives from the presupernova evolution. Also like the ^{36}Cl, the ^{41}Ca is mostly produced in s-process synthesis in core and shell helium burning and shell carbon burning.

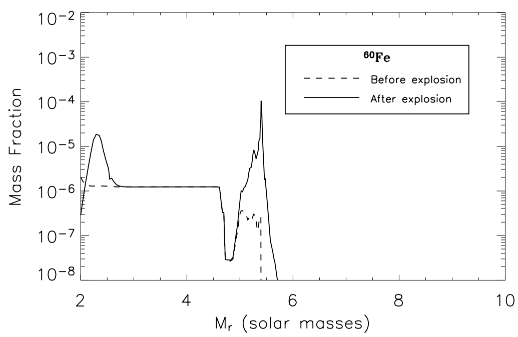

Fig. 4: Mass fractions of ^{60}Fe in the initially 25 solar mass star just before and one year after the explosion of the star.

^{60}Fe: As seen in Figure 4, the ^{60}Fe in the outer part of the ejecta (from ~5 to ~6 solar masses) is predominantly made in the explosion. This is due to the neutron burst that occurs during shock passage of the helium shell. This neutron burst releases enough neutrons to drive material past unstable ^{59}Fe and enhance the ^{60}Fe over its lower, presupernova helium shell abundance. Presupernova ^{60}Fe in the carbon shell is little affected by the supernova shock. Explosive burning around 2 solar masses makes some ^{60}Fe in the supernova.

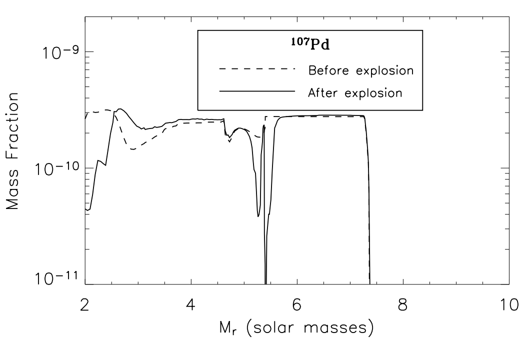

Fig. 5: Mass fractions of ^{107}Pd in the initially 25 solar mass star just before and one year after the explosion of the star.

^{107}Pd: Figure 5 shows that most of the ^{107}Pd ejected from the star is from presupernova s-processing. Some supernova processing occurs in the inner parts of the carbon and helium shells.

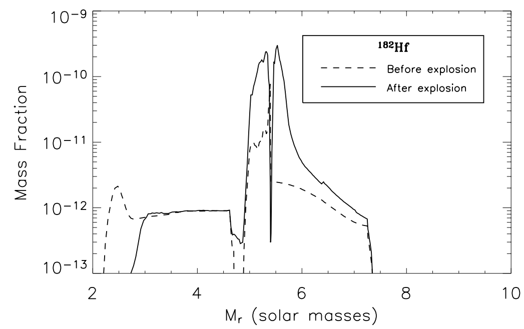

Fig. 6: Mass fractions of ^{182}Hf in the initially 25 solar mass star just before and one year after the explosion of the star.

^{182}Hf: Figure 6 shows that much of the ^{182}Hf ejected from the star is produced during the explosion by the neutron burst in the helium shell. Some ^{182}Hf (and 107Pd) may also be produced in the r-process, but if this happens, it does so deep in the star near the nascent neutron star surface at M_r approximately 1.5 solar masses.

Discussion: In the model in which the matter injected into the proto-solar nebula comes from the outer layers of the star, e.g., [4], we can see that the ^{26}Al, ^{36}Cl, ^{41}Ca, and ^{107}Pd predominantly come from presupernova synthesis. The injected ^{60}Fe and ^{182}Hf are mostly made in the neutron burst during the explosion itself. This means that if indeed ^{36}Cl and ^{107}Pd are somewhat too abundant, as perhaps suggested by our previous work [4], we should look to the details of the presupernova model for the possible problems. The treatment of mixing or some key reaction during helium shell burning would be likely culprits. If the yields of ^{60}Fe or ^{182}Hf prove problematic for the injection model, then we must look to the details of the explosion for possible solutions.

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References: [1] Cameron A. G. W. and Truran J. W. (1977) *Icarus 30,* 447-461. [2] Cameron A. G. W.. et al. (1995) *Astrophys. J. Lett., 447,* 53-57. [3] Meyer B. S. and Clayton D. D. (2000) *Space Sci. Rev., 92,* 133-152. [4] Meyer B. S. et al. (2004) *LPS XXXV,* Abstract #1908.