NUCLEOSYNTHESIS OF SHORT-LIVED RADIOACTIVITIES IN MASSIVE STARS.  B. S. Meyer, 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}\text{Al},^{36}\text{Cl},^{41}\text{Ca},^{60}\text{Fe},^{107}\text{Pd},\text{ and }^{182}\text{Hf})

Outside about 5.5 solar masses, however, the explosion does not alter the presupernova \(^{26}\text{Al}\) abundance. Unless matter from deep inside the star is injected into the solar cloud, most injected \(^{26}\text{Al}\) was produced in the presupenova evolution.

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

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

\[\text{Fig. 3: Mass fractions of }^{41}\text{Ca in the initially 25 solar mass star just before and one year after the explosion of the star.}\]
41Ca: As Figure 3 shows, the 41Ca ejected from the star, like the 36Cl, mostly derives from the presupernova evolution. Also like the 36Cl, the 41Ca is mostly produced in s-process synthesis in core and shell helium burning and shell carbon burning.

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

60Fe: As seen in Figure 4, the 60Fe 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 59Fe and enhance the 60Fe over its lower, presupernova helium shell abundance. Presupernova 60Fe in the carbon shell is little affected by the supernova shock. Explosive burning around 2 solar masses makes some 60Fe in the supernova.

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

107Pd: Figure 5 shows that most of the 107Pd 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 182Hf in the initially 25 solar mass star just before and one year after the explosion of the star.

182Hf: Figure 6 shows that much of the 182Hf ejected from the star is produced during the explosion by the neutron burst in the helium shell. Some 182Hf (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 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 26Al, 36Cl, 41Ca, and 107Pd predominantly come from presupernova synthesis. The injected 60Fe and 182Hf are mostly made in the neutron burst during the explosion itself. This means that if indeed 36Cl and 107Pd 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 60Fe or 182Hf prove problematic for the injection model, then we must look to the details of the explosion for possible solutions.

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