PRODUCTION OF RARE ISOTOPES SUCH AS LI-7, B-11,AND F-19 BY HIGH ENERGY NEUTRINOS FROM SUPERNOVAE

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Abstract

The usual mechanism such as spallation invoked for the production of the isotopes of the very rare elements such as lithium and boron are not adequate to account for their enhancement seen in some Pop.I stars as well as in some giants. Moreover production of isotopes such as F-19 and very rare isotopes like Ta-161 and La-138 are not understood. Here we consider the possibility that the intense neutrino flux with energies of several Mev from supernovae can generate substantial amounts of the above isotopes and other related ones by interacting with nuclei such as carbon and neon.

<u>Introduction</u> Among the isotopes of the very rare elements Lithium, Beryllium and Boron only Li-7 is expected to be produced in big-bang nucleosynthesis with an abundance $\approx 10^{-9}$. However Li-7 as well as the isotopes of Be and B are rapidly astrated in stars as Lithium burning occurs at rather low central stellar temperatures and consequently at an early stage in stellar evolution [Clayton 1968]. So one would expect to see lower amounts of Li-7 than was made in the big-bang but actually its abundance is comparable to the big-bang value and is actually enhanced in many stars including C giants. Moreover one sees Li-6 with an abundance one magnitude lower in many stars and amounts comparable to the heavier isotope in flare stars and cosmic rays. Apart from the Fowler-Cameron process for Li-7, spallation reactions of cosmic rays and accelerated high energy particles with nuclei on stellar surfaces are considered to be the means of production of these isotopes in stars. However some giants show enhancements of Li-7 and Be isotopes. This necessitates consideration of other mechanisms. Moreover isotopes like F-19 (the only stable isotope of fluorine) are not generally included in usual models of stellar nucleosynthesis and element build up. Again one has the rather anomalous isotope ratios of Tantalum Ta-181/Ta-180 $\approx \approx 10^4$, and Lanthanum La-139/La-138 $\approx 10^3$, suggesting some non-equilibrium process.

<u>Supernova neutrino induced nucleosynthesis</u> The production of light elements from neutrinos emitted by collapsing stellar cores has been considered earlier [Domogatsky 1971].

For instance D and He^3 may be produced as $He^4 + \nu \rightarrow He^3 + n + \nu'$ and protons released by $He^3 + n \rightarrow H^3 + p$.

If the interacting shell containing the seed nuclei is too close to collapsing core, the isotopes produced would photodissociate soon after being produced as temperature scale as $(E_o/r)^{1/4}$, E_0 is the explosion energy and r the distance from core. The neutrino flux at the core boundary could be as large as ~ $10^{30} cm^{-2} s^{-1}$ with average energy ~ 10 Mev. Also includes the energetic μ and τ neutrinos which because of larger temperatures have greatly increased cross-section for exciting giant resonance transitions of spin dependent nuclear modes. The temperature falls off exponentially from centre with a time constant ~ $(\rho)^{-1/2}$~ 1s, where ρ is the density. So far away shells feel too little ν flux for nuclear conversions. C and Ne shells in type II supernovae at typical distances ~ 10^9cm from core are at the right distance for ν induced reactions. In carbon shell one can have

$$C^{12} + \nu \rightarrow B^{11} + p, \text{ or } C^{12} + \nu \rightarrow B^{10} + p + n, \; p + n \rightarrow D + \nu,$$

$$C^{12} + \nu \rightarrow C^{11} + \nu, \quad C^{11} + e^{+} \rightarrow B^{11} + \nu,$$

$$B^{10} + p \rightarrow Be^{7} + \alpha, \quad Be^{7} \rightarrow Li^{7} + e^{+} + \nu.$$

Some of Li^6 also from He^6 decay, He^6 from $Li^7 + \nu \rightarrow He^6 + p + \nu$. With the above neutrino flux interesting amounts of these isotopes could be produced ≈ 10^{-8}per carbon atom per second with the appropriate cross section [Weaver 1980]. ν interactions in the Ne shell can lead to F^{19}production as [Haxton 1988]: $Ne^{20} + \nu \rightarrow Ne^{20*} + \nu'$ (with ν_μ , ν_τ),cross section at T ≈ 10 Mev ≈ $10^{-41} cm^2$ per flavour of neutrino, $Ne^{20*} \rightarrow F^{19} + p$ or $Ne^{19} + n$ with Ne^{19}decaying to F^{19}. $F^{19}$is not overproduced as it also undergoes photodecay as $F^{19} + \gamma \rightarrow N^{15} + \alpha$; thus $N^{15}$is produced. Also interesting amounts of Al^{26} produced along with F^{19}. The rare isotopes Ta^{180}, La^{138} are produced from the parents Ta^{181}, La^{139} by neutrino induced reactions with a yield ≈ 10^{-4}. Other isotopes likely to be produced are Gd^{150}(from Eu^{151}), Pb^{202} (from Tl^{203}), I^{129} from Te^{130} and also $Mn^{53}$from Fe^{54}.

In short it is worthwhile to look into the question of all the possible neutrino induced nuclear isotope production in the supernovae environment a few seconds after the explosion. Many rare isotopes could be produced in this manner whose occurrence in observed abundances we would otherwise find difficult to explain

REFERENCES

Clayton D.D. 1968 "Stellar nucleosynthesis" Acad. N.Y.
Domogatsky D.et al 1977 preprint Inst.Appl.Math.No43

Haxton W. 1988 preprint Univ.of Washington
Sivaram C. 1977 I.I.A.report (unpubl.) USSR Acad.Moscow
Weaver T.and Woosely S. 1980 Ann.N.Y. Acad.of Science