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Neutrino Driven Nucleosynthesis in the Early Galaxy

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We discuss a neutrino driven neutron capture mechanism that occurs in the He shell of an early core-collapse supernova. We calculate the nucleosynthesis, both before and after the passage of shock, in recent pre-supernova models of $11 - 15 M_{\odot}$ stars with an initial metallicity of $[Z] < -3$. We find that for an inverted neutrino mass hierarchy with a hard neutrino spectra, neutrino interactions with He via $^{4}\mathrm{He}(\bar{\nu}_e, e^{+}n)^{3}\mathrm{H}$ produces free neutrons on a timescale of $\sim 5 - 6$ s, which are captured by Fe seeds present in the He shell to produce isotopes with $A > 200$. This process occurs on a timescale of $\sim 100 - 300$ s at a temperature of $\sim 10^{8}$ K which is much longer and colder compared to the conventional hot rapid neutron capture process. The process is uniquely sensitive to the neutron capture cross-sections since $(n, \gamma) \leftrightarrow (\gamma, n)$ equilibrium is not established. We find that variation of neutron capture rates can have a dramatic effect on both the timescale and the final abundance pattern. We also explore the sensitivity of the mechanism on the neutrino emission parameters and oscillations, as well as on explosion energy and progenitor metallicity. We discuss the implications of this process with respect to the observed abundance of neutron capture elements in metal-poor stars.