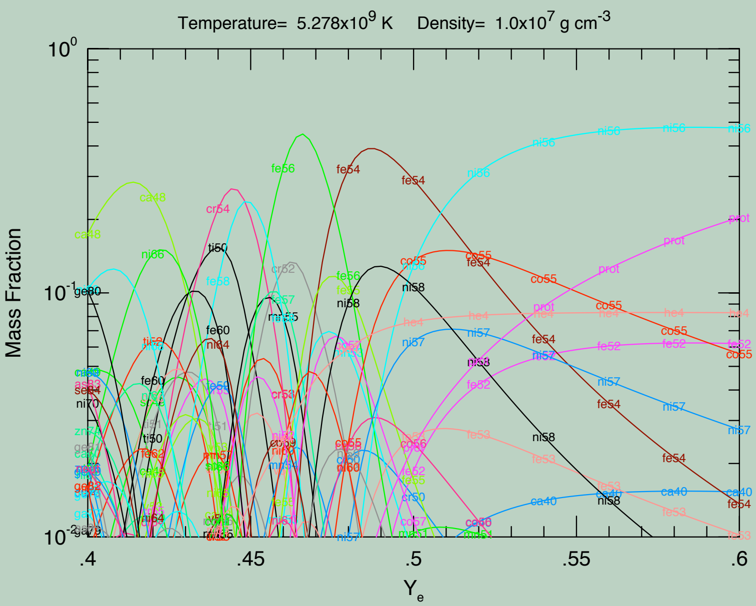
Proton-rich Nuclear Statistical Equilibrium



Mass fractions in nuclear statistical equilibrium for neutron-rich and proton-rich material at the specified thermodynamic conditions. Qualitatively different behavior occurs for neutron-rich material (region to the left of the symmetric matter point, $Y_e = 0.5$) than for proton-rich matter (region to the right of the symmetric matter point). Movies may be downloaded by clicking on this link.

Proton-rich material in a state of nuclear statistical equilibrium is of the least studied regimes of nucleosysnthesis. One reason for this is that after hydrogen burning,stellar evolution proceeds at conditions of equal numbers of neutrons and protons or at a slight degree of neutron richness. Proton-rich nucleosynthesis in stars tends to occur only when hydrogen-rich material that accretes onto a white dwarf or neutron star explodes, or when neutrino interactions in the winds from a proto–neutron star or a collapsar disk, can make the matter proton-rich prior to or during the nucleosynthesis.

This new project has two phases. The first phase seeks a comprehensive, quantitative understanding of the abundance levels of proton-rich material in nuclear statistical equilibrium. What are the mass fraction distributions, how do the distributions change when the thermodynamic conditions are varied, and are there exact analytical expressions that describe the main properties of the distributions? The figure shows an example of the mass fractions as a function the electron per baryon ratio (number of protons)/(number of nucleons) ratio for a specific temperature and density. The second phase of this new project seeks to better understand the resulting nucleosynthesis when this material cools along various thermodynamic trajectories. While the rapid-proton process has been well studied - it is generally known that freeze out along common trajectories leaves a final composition dominated by iron-group isotopes - more realistic trajectories may have much more complex behavior (e.g., Wallace & Woosley, 1982; Schatz et al 2001; Jordon & Meyer 2003).

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References

Jordan, G.C., & Meyer, B.S., ApJL 131,617, 2004

Schatz, H., et al, PRL, 86,3471, 2001

Wallace, R.K. & Woosley, S.E., ApJS, 45, 389, 1982

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