The r-Process: Constraints on Nuclear Properties and Astrophysical Sites

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The rapid neutron capture process encounters unstable nuclei far from beta stability. Therefore its observable features, like the abundances, witness not only (1) the conditions in the appropriate astrophysical environment, but also (2) (still uncertain) nuclear structure features.

The remaining lack of a full understanding of its astrophysical origin requires to make still use of parametrized calculations which all relate to the neutron separation energy of the r-process path at the moment of neutron freeze-out. This is in classical studies given by the combination of neutron densities and temperatures. In more realistic but still parametrized calculations it relates to the combination of environment entropies S, proton/nucleon ratios Y_e, and expansion timescales τ which provide neutron densities and temperatures as a function of time. It turns out that at least for abundances of nuclei with $A>130$ both approaches give equivalent results. Therefore it is possible to address questions whether specific abundance features require a specific behavior of nuclear properties (e.g. shell quenching far from stability).

Some abundance features can provide clear constraints on the type of astrophysical environment (e.g. high or low entropy environments, neutron supplies which permit fission cycling). This can then be related to astrophysical origins like supernovae or cold decompression of neutron star matter. The comparison to astrophysical observations of low metallicity stars can provide additional information. Individual abundance observations give clues to the properties of each production event, while the scatter of r-process/Fe-abundances relates to the ratio of occurance frequencies with respect to supernovae.

We will address the present situation with regard to (1) nuclear physics issues, (2) astrophysical production sites, and (3) their role in galactic evolution.