Neutrons in Astrophysics

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While the elements from carbon to iron were found to be produced by charged particle reactions during the evolutionary phases from stellar He to Si burning, all elements heavier than iron are essentially built up by neutron reactions in the slow (s) and rapid (r) neutron capture processes.

The s process, which takes place during He and C burning, is characterized by comparably low neutron densities, typically 1E7 ÷ 1E11 neutrons/ccm, so that neutron capture times are much slower than most beta-decay times. This implies that the reaction path of the s process follows the stability valley with the important consequence that the neutron capture cross sections averaged over the stellar spectrum are of pivotal importance for the resulting s abundances. The corresponding stellar temperatures range form kT = 5 keV to kT = 90 keV.

The necessary experiments determining the neutron-induced cross sections generally require pulsed neutron sources to apply the neutron time-of-flight technique. If the product of the neutron-induced reaction is unstable, the activation technique using a constant neutron flux can be applied to determine the necessary cross sections with very high sensitivity. In addition, samples of astrophysical interest have to be available, which is in particular for radioactive isotopes a challenge.

New intense neutron sources can contribute to both requirements. They can provide neutrons for irradiating stable material to produce radioactive isotopes or neutrons to actually determine astrophysically interesting reaction rates.