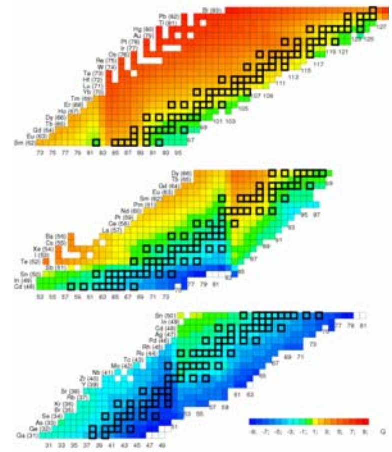
Reaction flow and flow hindrance in the p-process

Clover Detector (left) and Si detector (right) arrangements for p-process cross section studies by activation and elastic scattering measurements.

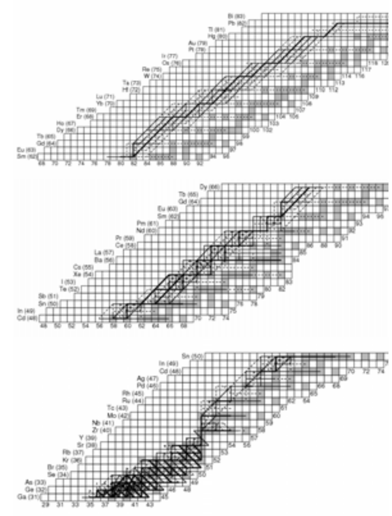
The p-nuclei are stable but very rare neutron deficient isotopes of the elements above Z=42. In our present interpretation they are produced by photodisintegration processes of heavy elements in high photon-flux environments. Such conditions are expected in the type II supernova shock front heating and compressing the outer layers of the star.

The p-process is one of the least studies nucleosynthesis processes. Systematic simulations of the reaction flow show that the p-process reaction flow is guided by the shell structure of the associated neutron deficient nuclei which determines their respective binding energies [1]. Alpha thresholds change dramatically for isotopes along the closed Z,N=50, 82 proton and neutron shells as demonstrated on the right hand panel. This translates directly into a change of photo dissociation flow pattern in a p-process burning environment. The p-process flow pattern shown at the lower panel clearly demonstrates the change in reaction flow pattern near the closed shells. The strong (γ,α) pattern dominates the flow in the inter-shell regions where isotopes are alpha unbound. It disappears closed to shells where the alpha binding energy is high.

Near the Z=50 shell alpha binding energies are close to zero and the level density is limited. This may affect the reliability of the underlying reaction rates which have been predicted on the basis of statistical model calculations. A program was initiated to study systematically alpha capture and alpha scattering reactions at Cd and Sn isotopes. The experiments were performed using the tandem accelerator at the nuclear science laboratory at Notre Dame. The figures above show the experimental set-up for the alpha capture and scattering measurements. The experimental cross sections show distinct differences to the theoretical predictions [2,3]. This indicates that the shell effects in the



Alpha thresholds in isotopes above Z=30 (Zn). The isotopes marked in yellow to red are alpha unbound and alpha decay easily at high gamma flux conditions by photodisintegration, the green to blue marked isotopes have increasingly higher binding energies and are more difficult to undergo photon induced alpha dissociation. Closed shells are characterized by drastic changes in alpha binding energy.



Reaction flow pattern of the p-process. The initial stable seed abundance distribution is converted by (γ,n) processes to a distribution of neutron deficient isotopes. This is followed by (γ,α) alpha dissociation of the heavy isotopes towards lower masses. Alpha dissociation is hindered at closed shells N=82, Z=50, and N=50. This flow hindrance is by-passed by alternative γ induced neutron or proton dissociation processes. Below N=50, the alpha binding energy is too high and alpha photo-dissociation disappears.

reaction flow might be even more pronounced than anticipated on the basis of the flow analysis.

Investigators:

Zs. Fulop[1], J. Görres[2], R. T. Gurray[3], Gy. Gyürky , F. Käppeler [4], N. Özkan , A. Palumbo[2], W. Rapp[2,5], H. Schatz[5], E. Somorjai[1], E. Stech[2], W. Tan[2], M. Wiescher[2]

[1] Atomki, Debrecen, Hungary
[2] U. Notre Dame
[3] Kocaeli U., Turkey
[4] FZ Karlsruhe, Germany
[5] NSCL, MSU

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Contact:

Michael Wiescher (University of Notre Dame) 574-631-6788
Michael.C.Wiescher.1@nd.edu