Neutron capture processes: r- and s-process

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Abstract
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Overview

Elements like Gold or Uranium have special properties and play an important role for humankind – either from a cultural or a technical point of view. But it is not a trivial question how they were created. The binding energy per nucleon of nuclei has a maxium around a mass number of 60. One special conditions for the creation of "trans-iron isotopes" with A>60. It is a major aspect of modern physics to analyse the circumstances of this phenomenon.
Two main processes are relevant for the creation of trans-iron isotopes: The r(apid)- and s(low)-process are two different neutron capture processes.

s-process

When the hydrogen in a low-mass star's core is depleted, it expands and enters the so-called "asymptotic giant branch" (AGB) phase. In the outer part of the AGB star, free neutrons are created. Nuclei capture the neutrons and decay via a beta decay before being able to capture another neutron, because the half life time is shorter then the capture process. This capture process creates many isotopes of the valley of stabilty until the end point A=210 is reached.

r-process

The s-process does not explain isotopes like Uranium or Thorium and does not fit with the oberserved mass spectra. This led to the idea of the r-process where the neutron capture is much faster than the decay. Therefore, neutron-rich isotopes are created – only limited by the neutron drip line. They are immediately decaying towards the valley of stability. In addition, fission processes become important around A=260.
It is not fully understood where the r-process occurs but nowadays the most promising scenarios are core-collapse supernovae and the mergers of two neutron stars or a neutron star and a black hole.

Summary

Current research is made in the fields of nuclear physics and astrophysics to understand these neutron capture processes – especially the r-process. These processes can explain the creation of trans-iron elements and therefore explain the creation of parts of ourselves.