How many neutrons are emitted after the beta decays of *r*-process nuclei?

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Beta-delayed neutron emission is found in neutron-rich nuclei, where the decay energy window is high enough to populate states above the neutron separation energy in the daughter nucleus. In the neutron-rich nuclei far from stability along the r-process path, Q-values are often larger than neutron separation energies (S_{1n}, S_{2n}, S_{3n}, etc.). However, it is not apparent how many neutrons will be emitted from such states. It is assumed that the neutron emission process is sequential, and in that case, the first neutron may carry most of the excitation energy of the state above multi-neutron separation energy.

Understanding of the neutron emission process is essential because delayed-neutron emission shapes the final abundance pattern of the r-process due to the modification of the isotopic population of the beta-decay path back to stability and by contributing significantly to the neutron flux after freeze-out. However, experimental data of multi-neutron emission properties for the r-process nuclei are almost non-existent. One-neutron and two-neutron branching ratios (P_{1n} and P_{2n}) have been measured in the decay of neutron-rich Ga isotopes A = 84 to 87 at the RI-beam Factory (RIBF) at the RIKEN Nishina

Center using a high-efficiency array of ^{3}He-based neutron counters (BRIKEN) [1-3]. Two-neutron emission was observed in the decay of $^{84, 85, 87}$Ga for the first time, and the observation of the large P_{1n} values compared to the P_{2n} values in the Ga isotopes is interpreted as a signature of one neutron emission from the two-neutron unbound excited states in Ge daughters. The experimental P_{xn} values agree better with theoretical calculations when Hauser Feshbach statistical model included. (See Ref. [4] for detail.)

The previous study of neutron emission probabilities showed that a mechanism for competition between one and multiple neutron emission branches must be included in theoretical calculations. Although the statistical model (i.e., emissions from the "compound" nucleus) reproduced the P_{xn} values of the Ga isotopes, further study is necessary to understand the beta-delayed neutron emission process fully. Detailed neutron and gamma-ray spectroscopy of the decay of the same Ga isotopes have been carried out at RIBF with the Versatile Array of Neutron Detectors at Low Energy (VANDLE) [5,6], two ORNL clover Ge detectors, and 12 HAGRiD [7] $LaBr_3$ detectors. Our current understanding of multi-neutron emission processes will be discussed based on the results from the two complemental measurements.

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