Constraining multi-neutron emission models with spectroscopy of neutron-rich Ga isotopes using BRIKEN array

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As we move further from the line of β-stability towards the neutron drip line, Qβ values become larger than the two-neutron separation energy (S2n), which allows multi-neutron emissions after β-decay. In the neutron-rich nuclei along the astrophysical r-process path, multi-neutron emissions are considered to be dominant decay modes.1) The numbers of neutrons emitted in the β-decays of exotic nuclei modify the decay path back to stability and affect the final abundance calculation. However, experimental data that enable the evaluation of multi-neutron emissions for the r-process nuclei are almost non-existent. Until quite recently, theoretical predictions of the neutron branching ratio (P0n) were based on a cut-off model that assumes only the higher-multiplicity neutron emission prevails in the energy regions open to multiple neutron-emission channels. In order to include the competition of one-neutron emission from the states above S2n, Kawano et al. developed a Hauser-Feshbach statistical model calculation.2)

We studied neutron-rich Ga isotopes by means of β-n-γ spectroscopy at RIBF using the high-efficiency neutron counter array BRIKEN,3-5) with two Ge clover detectors. The result that one-neutron emission is dominant for all the four Ga isotopes was interpreted as competition in one-neutron emission among two-neutron unbound states, and we demonstrated that the inclusion of the statistical model reproduces the branching ratio better than the cut-off model.6)

Recently, we analyzed γ-ray spectra of the decay of 84-87Ga. Figure 1 shows γ spectra gated by the neutron multiplicity of the BRIKEN array for the decay of 86Ga. γ rays from 84, 85, 86Ge are clearly identified in the 2n, 1n, and 0n gated spectra. The 2+ → 0+ γ ray from 84Ge in the two-neutron branches was observed at 624 keV. The intensity of the 624-keV γ ray per 100 two-neutron decays was 37(8)%. We performed our Hauser-Feshbach statistical model calculation by using the strength distribution and level densities from shell-model calculations. This model was used to validate the measurement of the neutron spectra in the decay of 83, 84Ga.7) The shell model produced less states below S2n than the number of the default levels generated by the statistical model using the Gilbert-Cameron formula. When known, the low-lying states in the decay daughters calculated by the shell model were replaced with experimental data. Compared with the feeding of the experimental 624-keV state in 84Ge, the statistical model predicted the γ intensity as 33%, which is in good agreement with the experimental value we measured. The statistical model also reproduced the γ branching ratio of other γ rays in the decay. The detailed β-n-γ analysis of other neutron-rich Ga isotopes is in progress.

References
1) P. Möller et al., At. Data Nucl. Data Tables 125, 1 (2019).

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