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The fission fragments of neutron-rich nuclei by the Langevin method toward application to r-process calculations

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Nuclear fission plays an essential role in nucleosynthesis by the rapid-neutron-capture process (r-process), which is a cosmic origin of heavy elements beyond iron. For very neutron-rich environments in neutron star mergers, the strong r-process can be achieved, and the nucleosynthesis path goes into the trans-uranium region. In such conditions, fission is important to shape the r-process abundances due to fission recycling, which determined the termination of the r-process in the heavy nuclei region. Besides abundance prediction, fission is also a key role as the main heating source of kilonovae, which are electromagnetic transients of neutron star mergers. A sign of fission heating may have been observed in the light curve of the kilonova associated with the gravitational wave, GW170817. The precise understanding of fission becomes much crucial in the era of gravitational astronomy.

In this study, we calculate the fission-fragment mass distributions of very neutron-rich nuclei, which are important for the nucleosynthesis calculations of the r-process, but experimental nuclear data is not available. We adopt the Langevin method [1], widely adopted in the study of low-energy fission in the past few years. We found that the calculated mass distributions for uranium, of which Z distribution is calculated with UCD (unchanged charge distribution assumption), well reproduce experimental data in JENDL (^{232}U to ^{238}U) [2]. We also found that the fission distribution changes from the two peak feature (asymmetric fission) to the one-peak (symmetric fission) as the neutron number increases. The confirmation by future experiments would be desirable for these theoretical predictions to develop a complete theory set of fission distributions applicable to r-process nucleosynthesis simulations.

[1] S. Tanaka, Y. Aritomo, Y. Miyamoto, K. Hirose, and K. Nishio PRC 100, 064605 (2019).
[2] K. Shibata, O. Iwamoto et al.: "JENDL-4.0: A New Library for Nuclear Science and Engineering," J. Nucl. Sci. Technol. 48(1), 1-30 (2011).

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