Production of neutron deficient Rf isotopes in ^{208}Pb + ^{48,50}Ti reactions

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Asymmetric nuclear fission in which mass of fissioning nucleus splits asymmetrically is obtained in low-energy induced fission and spontaneous fission (SF) of actinides. This type of fission is considered to be strongly influenced by shell effect of fission fragments, but it has not been explained quantitatively. Rutherfordium has many isotopes decaying by SF. Systematic research of fission properties, i.e., mass and total kinetic energy (TKE) distributions of fission fragments, can provide various information to clarify the asymmetric fission mechanism. In this work, as a preparatory experiment to measure fission properties of neutron deficient Rf isotopes (especially ^{253,254}Rf) conditions of production of these nuclides were optimized.

Experiments were performed at RIKEN Linear Accelerator facility (RILAC) using the gas-filled recoil ion separator (GARIS). Beam energies of ^{50}Ti in laboratory system were 242 and 249 MeV as acceleration energy, and that of ^{48}Ti was 242 MeV. Typical beam intensity of ^{50}Ti was about 140 pnA, and ^{48}Ti was about 190 pnA. Sixteen targets were prepared with vacuum evaporation of 98.4 %-enriched ^{208}Pb onto 60 μg cm^{-2} C-backing. Target thicknesses were 170–370 μg cm^{-2}. The targets were mounted on a rotating wheel with 30 cm in diameter. For cooling the targets, the wheel was rotated at 2000 rpm. Alminum degraders of 0, 0.8, 2.0, and 3.0 μm thicknesses were placed for every four targets. In order to measure an excitation function without changing accelaration energy, a target ID system was used.[2] This system allows to associate an event detected at a focal plane with a target where a reaction occured. Evaporation residues (ERs) recoilling out the target were separated from the beam and by-products using GARIS. Optimum mangetic regirity of GARIS was 2.048 T m. ERs passed through time-of-flight detectors, and were implanted into a position sensitive detector (PSD) at the focal plane of GARIS.

At first, ^{208}Pb was bomberded with ^{50}Ti to produce ^{256}Rf mainly. The number of SF events of ^{256}Rf were 132. By normalizing the obtained production cross section with the previous value,[3] transmission efficiency of GARIS was about 50 %. Since TKE distribution of ^{256}Rf was reported,[1] these data can be used to calibrate energies of fission fragments.

Next, ^{253,254}Rf were produced through ^{208}Pb + ^{48}Ti reaction. Figure 1 shows the decay time of SF events tagged by different thick targets, which are labeled by the occupied angle in the target wheel. The events with long decay time in region (c) and (d) may be ^{253}Rf and ^{255}Rf, respectively. Thirteen events with short decay time were identified as ^{254}Rf. The excitation function constructed from observed events in Fig. 1 is shown in Fig. 2. This is in good agreement with reported excitation function of ^{208}Pb(^{48}Ti, 2n)^{254}Rf.[3] Furthermore, the obtained half life was $20.9^{+8.0}_{-4.5}$ μs, which was consistent with $29.6^{+0.7}_{-0.6}$ μs of reference value.[3] Now, detailed analysis of TKE distribution of ^{254}Rf is carried out.

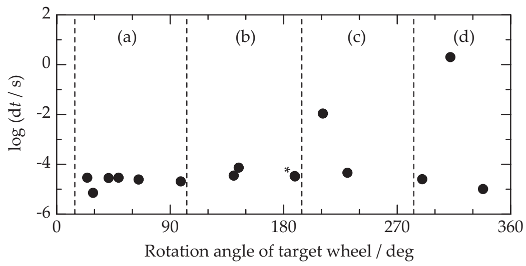

Fig. 1. Decay time of SF events in ^{208}Pb + ^{48}Ti reaction at E_{lab} = 242 MeV. The abscissa shows a rotation angle from a specific position. Regions of (a) to (d) correspond to the excitation energies, (a) E^* = 22.2 MeV, (b) 26.3 MeV, (c) 29.5 MeV, and (d) 17.8 MeV. *Two symbols almost overlapped.

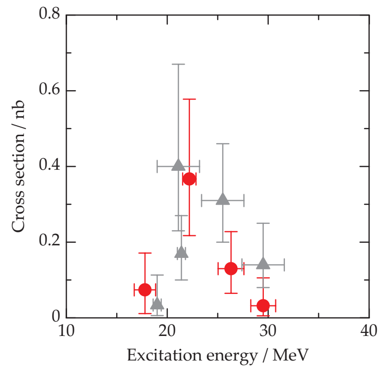

Fig. 2. Excitation functions of ^{254}Rf production in ^{208}Pb + ^{48}Ti reaction. Circles and triangles show results of this work and reference,[3] respectively.

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