New technique for measuring excitation function of fusion-evaporation reaction using a multi reflection time-of-flight mass spectrograph

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A multi reflection time-of-flight mass spectrograph (MRTOF-MS)[1)] is a high-precision mass measurement devices. Recently, we performed direct mass measurements of superheavy nuclides in the SHE-Mass facility[2)] and discovered a new uranium isotope in the KEK Isotope Separation System.[3)] An MRTOF is not only a high-precision mass measurement device, but also a high-efficacy equipment that can simultaneously identify a wide mass range of nuclides. We have utilized this ability of an MRTOF-MS to conduct demonstration experiments to simultaneously measure the yields of several nuclides produced by fusion-evaporation reactions.

The experimental setup of the SHE-Mass facility is described elsewhere.[2)] A ^{51}V beam was accelerated to 6.0 MeV/nucleon by the RIKEN ring cyclotron (RRC). To change the beam energy at the center of the target, a rotatable Al degrader was installed upstream of the target (Fig 1. (a)), which allowed choosing the beam energy from 220.7 MeV to 268.1 MeV. A beam was irradiated on a 350 μg/cm^2-thick ^{139}La target with a 0.8 μm Al backing.

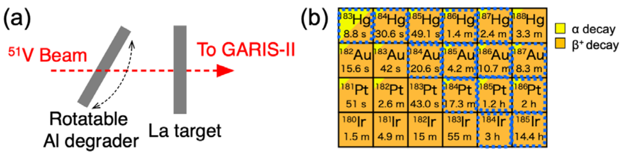

Fig. 1. (a) Schematic of target section. Energy of ^{51}V beam degraded by rotatable Al degrader that rotates from 0° to 60°. The beam and reaction products that pass through the target enter a gas-filled recoil ion separator GARIS-II. (b) Nuclear chart of measured region with decay modes and half lives of nuclides. Blue dashed line shows nuclides observed in experiment.

The yield curves of the fusion-evaporation reaction in the ^{51}V + ^{139}La system obtained experimentally are shown in Fig. 2. The counts at each data point are normalized by counting the Rutherford scattering of the ^{51}V beam from the target. Eleven nuclides are observed from $A = 184$ to $A = 187$. Each isotope is identified from the MRTOF-MS spectra. The nuclides produced by the xn, pxn, and αxn evaporation channels are identified, and their respective yields are changed according to the incident beam energy. Most of the nuclides observed in this experiment are β-decaying nuclides or have an α-branching ratio of less than a few percent. For nuclides with such a decay mode, quantitatively evaluating the production yield by traditional decay measurements is difficult. Direct ion counting method using a high-precision high-accuracy MRTOF-MS is promising and can be a new experimental technique for future nuclear reaction research. This study investigated the excitation function of a fusion-evaporation reaction using an MRTOF-MS. This new technique when combined with decay correlation techniques, such as the α/β-TOF detector,[4,5)] will allow isomers to be separated, and its further development can be expected. Further analysis is ongoing to determine the absolute cross-section from the yield curves.

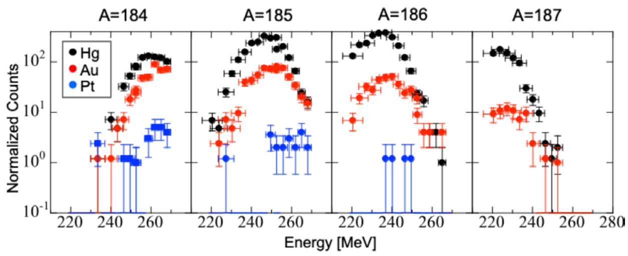

Fig. 2. Preliminary yield curves from the fusion reaction of ^{51}V + ^{139}La system. Colors represent different elements produced by the different evaporation channels.

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