Yield development of KEK isotope separation system

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We have been developing KEK isotope separation system (KISS)[1] for lifetime measurements of neutron-rich nuclei around $N = 126$, relevant to r-process nucleosynthesis.[2] The multinucleon transfer (MNT) reaction between the ^{136}Xe beam and ^{198}Pt target was used at KISS, and it is one of the promising candidates to efficiently produce those neutron-rich nuclei.[3] The target was located in a gas cell, and the reaction products were stopped and neutralized in the argon gas filled in the gas cell. They were transported to the exit of the gas cell by laminar gas flow, where they were irradiated by the lasers to be ionized for a specific element by laser resonance ionization technique. Those extracted ions were mass-separated and transported to the measurement area for β-decay spectroscopy.

So far, we have successfully extracted radioactive isotopes (RIs) of ^{199}Pt and ^{196,197,198}Ir.[4] The accessible isotopes were limited to the vicinity of the ^{198}Pt target because of the low extraction efficiency ($\sim 1\times10^{-4}$) and limited beam intensity ($\sim$20 pnA) to prevent heat damage at the target. The low extraction efficiency might be due to the re-neutralization of the laser-ionized isotopes caused by the radiation from the dense plasma in the argon gas, which is induced by the primary beam.[5] We have developed a doughnut-shaped gas cell and a rotating target to accept a more intense beam without injecting it into the gas cell.

In parallel, we have started to investigate other possible reaction pairs to achieve more efficient production of the desired isotopes. GRAZING calculations[6] indicate larger cross sections using the ^{238}U beam as compared with the ^{136}Xe beam. The first attempt to extract RIs produced in the MNT reactions between the ^{238}U beam and the ^{198}Pt target at KISS is reported here.

The well-studied fixed-target gas cell was used in this measurement for comparison with ^{136}Xe beam data. A ^{198}Pt target with a thickness of 11 mg/cm^2 in the gas cell was bombarded by the ^{238}U beam accelerated up to 10.75 MeV/nucleon by RRC. The beam energy on the target was tuned by energy degraders to approximately 8.5 MeV/nucleon, which is the optimal value from the GRAZING calculations. Three plastic scintillator telescopes were used to detect β-rays by measuring the extracted RIs, which were implanted into aluminized Mylar tape at the detection area to identify them by measuring their lifetimes.

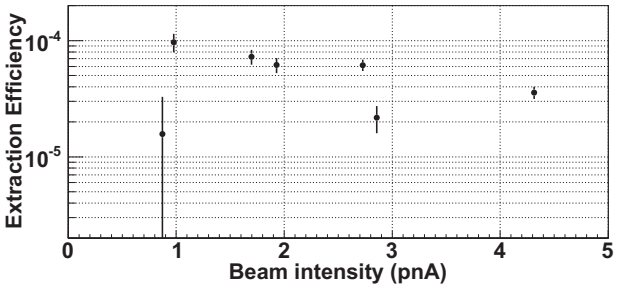

Fig. 1. Beam intensity dependence of extraction efficiency measured for ^{199}Pt.

Only one species of isotopes, ^{199}Pt, was identified in this measurement because of the low extraction efficiency and limited beam intensity. To investigate the intensity limitation, the beam intensity dependence of the extraction efficiency was measured. Figure 1 shows the result. The extraction efficiency was defined as the ratio the between number of extracted ions in the measurements and the number of ions ejected from the target in the calculations. The extraction efficiency was 1×10^{-4} at a beam intensity of approximately 1 pnA, and it decreased as the beam intensity increased. The absolute extraction efficiency and its beam-intensity dependence are similar to those in the case with the ^{136}Xe beam. Because the beam intensity was limited up to 5 pnA by the heat damage of the energy degrader foils and the target foil, the extraction efficiency was not available for higher beam intensity. In the next experiment, we will measure the extraction rates at higher intensities using rotating degraders and target with the doughnut-shaped gas cell for ^{199}Pt and other RIs.

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