(γ,n) and (γ,2n) cross sections in Coulomb breakup reactions of ^{79}Se,^{80}Se at 200 MeV/nucleon

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High-level radioactive wast, generated at nuclear power plants contain long lived fission products (LLFPs). Dumping LLFPs is still difficult because of their long lifetime. One way to reduce or reuse the LLFPs is the transmutation of the LLFPs into a short-lived or stable nucleus using nuclear reactions. For this transmutation, basic nuclear reaction data on LLFPs are important. Therefore, we performed nuclear reaction experiments using the LLFPs produced as secondary beams. In this report, we focus on the (γ,n) and (n,γ) reactions for the LLFPs and ^{79,80}Se. The ^{79}Se nucleus is an LLFP with a lifetime of 0.3M years. The (n,γ) reaction of LLFPs is important for transmutation ; however, experiments on the (n,γ) reaction have several difficulties. Therefore, we have measured the (γ,n) reaction as an alternative way to deduce the (n,γ) reaction cross section by introducing the Coulomb breakup reactions of ^{79,80}Se in inverse kinematics.

The experiment was performed using the SAMURAI spectrometer[1)] at the RIKEN Nishina Center. Secondary beams of ^{79,80}Se with an energy of 200 MeV/nucleon were produced by the in-flight fission of a ^{238}U primary beam with 345 MeV/nucleon on a ^{9}Be production target. Particle identification of the secondary beams was performed using BigRIPS. The momentum slit at the F1 focus was set to 0.1%, and the ΔE-TOF method using F7 and F13 plastic scintillators and the ionization chamber (ICB) at F13 was enough to identify secondary beams without Brho reconstruction. Figure 1 shows the particle identification of the secondary beams for the ^{79}Se setting. The secondary beam intensities are 2,700 and 2,500 cps at F13, beam energies were 216 and 218 MeV/nucleon, and beam purities were 54 % and 49 % for ^{79}Se and ^{80}Se, respectively. Beam directions and positions were measured by BDC (MWDC), which was placed upstream of the secondary target. Secondary targets of Pb and C with thickness of 0.54 g/cm^2 and 0.26 g/cm^2, respectively, were placed at the F13 focus and surrounded by DALI2 to detect de-excitation γ rays for reaction identification. Neutrons decaying from the excited states were detected by NeuLAND[2)] and NEBULA.[3)] Charged fragments produced in the breakup reactions were analyzed by the SAMURAI spectrometer. FDC1 (MWDC) was placed at the entrance of the SAMURAI magnet to measure the scattering angle of charged particles. At the exit of the magnet, FDC2 (MWDC) was installed to measure the bending angles and trajectories of the charged fragments. A plastic hodoscope was placed behind the FDC2 to measure ΔE and timing information. The hodoscope consists of seven slats of plastic scintillators with a thicknesses of 5 mm.

An analysis for charged particles is now ongoing. Identification of the atomic number was performed using the plastic hodoscope. By correcting the x- and y-position dependence of the light output in the scintillator, 4σ separation for atomic number has been achieved. To obtain mass-to-charge ratio, magnetic rigidities will be deduced by tracking information from the FDC1 and FDC2. Further analysis is in progress to deduce the inclusive and exclusive cross sections of the Coulomb breakup reactions.

This research was funded by ImPACT Program of Council for Science, Technology and Innovation (Cabinet Office, Government of Japan).

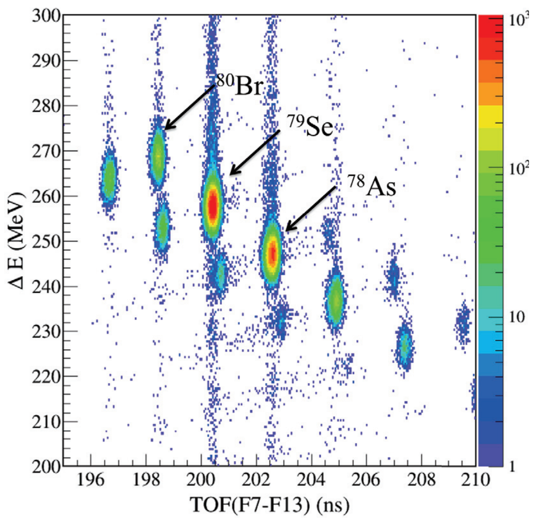

Fig. 1. Particle idetification of the secondary beam (for the ^{79}Se setup)

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References
1) T. Kobayashi et al. , Nucl. Instrum. Methods Phys. Res. Sect. B317, 294 (2013).
2) https://www.gsi.de/work/fairgsi/rareisotopebeams/r3b/neuland.htm
3) T. Nakamura et al. , Nucl. Instrum. Methods Phys. Res. Sect. B376, 156 (2016)