Proton- and deuteron-induced reactions on $^{107}$Pd and $^{93}$Zr at 20–30 MeV/nucleon


The nuclear transmutation of long-lived fission products (LLFPs), which are produced in nuclear reactors, is one of the candidate techniques for the reduction and/or reuse of LLFPs. To design optimum pathways for the transmutation process, several nuclear reactions have been studied by using LLFPs as secondary beams. The studies indicate that proton- and/or deuteron-induced spallation reactions at intermediate energies (100–200 MeV/nucleon) are sufficiently effective for the LLFP transmutation.1–3 We note that protons/deuterons lose their energies in materials; therefore, measurements at lower reaction energies are definitely desired for the application of transmutation. In this study, the isotopic production cross sections of proton- and deuteron-induced reactions on $^{107}$Pd and $^{93}$Zr at 20–30 MeV/nucleon were measured under an inverse kinematics condition. The experiment was conducted at the OEDO4 beamline at RIBF. This was the first physics experiment using OEDO. Detailed descriptions of the setup and procedure can be found in Ref. 5.

Figure 1 shows the preliminary results for the isotopic production cross sections of the proton-induced reactions on $^{107}$Pd. Considering the energy loss of the beam in the target, the measured cross sections are the ones averaged over 25–30 MeV/nucleon. The sensitivity threshold of the measurement was 5 mb because of statistics. We determined the cross sections for five isotopes ($^{107}$-109Ag and $^{106,105}$Pd).

The results show significant production of Ag isotopes; about 70% of the total cross section is exhausted by Ag isotopes. This can be understood by the compound-nuclear process: $^{107}$Pd + p →$^{108}$Ag*. The Ag isotopes are probably produced by the evaporation of neutrons from the highly excited compound nucleus $^{108}$Ag*. Actually, the trend is completely different from the high-energy spallation reaction case,2 in which the contribution of Ag isotopes is less than 10%.

The curves in Fig. 1 show the excitation functions evaluated by TENDL-2017.6 The cross sections of Ag and Pd isotopes were reasonably reproduced by the evaluation. On the other hand, the cross sections of $^{103,104}$Rh were considerably overestimated; TENDL predicted significant values for $^{103,104}$Rh, but they were not detected in the experiment.

The present data, as well as higher-energy data, would provide an effective guideline for a possible solution of LLFP transmutation. The results will be finalized soon, and the preparation for publication is in progress. Regarding the $^{93}$Zr data, the analysis for particle identification is ongoing.

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References

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