Spallation reaction study for the long-lived fission product ^{107}Pd†

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In recent years, substantial research and development activity has been devoted to partitioning and transmutation technology for the reduction in high-level radioactive waste (HLW)[1] as well as for resource recycling from spent nuclear fuel. Fission products in HLW contain useful materials, and one promising metal is palladium. However, the palladium metal recovered from waste has a radioactive isotope, ^{107}Pd, which is a typical long-lived fission product (LLFP) with a half-life of 6.5×10^6 years[2]. In considering a possible mechanism for the reduction in the radioactivity of ^{107}Pd, we performed the studies for the proton- and deuteron-induced spallation reaction on ^{107}Pd at both 196 and 118 MeV/u using inverse kinematics technique.

A ^{238}U primary beam was accelerated to 345 MeV/u and impinged on a 1-mm thick beryllium target located at the entrance of the BigRIPS fragment separator[3]. Two settings were made in BigRIPS to make the ^{107}Pd beams with the energies of 196 and 118 MeV/u in front of the secondary targets, respectively. CH_2, CD_2[4] and ^{12}C targets were used to induce the secondary reactions. The thicknesses for CH_2 and CD_2 were 179.2 and 217.8 mg/cm^2, respectively. For the ^{12}C targets, the thicknesses were 317.2 and 226.0 mg/cm^2 for 196 and 118 MeV/u, respectively. In order to measure the background contribution, addtional data were taken by using the target holder with no target material inserted. Reaction residues were identified by the ZeroDegree spectrometer[3]. The large acceptance mode was used and five different $B\rho$ settings were applied in order to cover a broad range of fragments.

The isotopic distribution of cross sections for the different elements produced from ^{107}Pd on protons and deuterons at both 196 and 118 MeV/u were successfully obtained. It was found that the proton-induced cross sections at 196 MeV/u are similar to the deuteron-induced ones at 118 MeV/u for light products such as Ru, Tc and Mo, as shown in Fig. 1 d) - f). The production of these light products depends on the energy deposited. Because deuteron has two nucleons, the deuteron-induced reaction at 118 MeV/u dissipates an energy that is similar to that of the proton-induced reaction at 196 MeV/u in the evaporation process, resulting in a similar production. In addition, the results are discussed by comparing them with the SPACS parameterization and the PHITS calculation including both the intra-nuclear cascade and evaporation processes. Our data provide a design goal for the proton/deuteron flux for the transmutation of ^{107}Pd via spallation reactions.

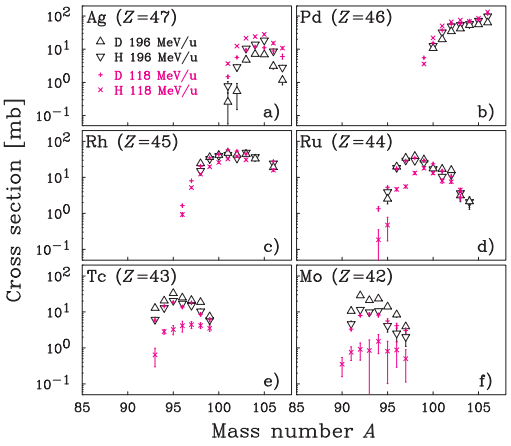

Fig. 1. Isotopic production cross sections for $42 \leq Z \leq 47$ elements produced by ^{107}Pd on protons and deuterons at different reaction energies.

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References

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