Production cross sections of deuteron-induced reactions on natural palladium for Ag isotopes†

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Radioisotopes (RI) are available for medical therapy and diagnostics.[1] ^{103}Pd with a half-life of $T_{1/2}$ = 16.991 d decays (100% electron capture (EC)) into ^{103m}Rh, which successively decays (100% isomeric transition) into ^{103}Rh with a 39.5-keV γ-ray emission. ^{103}Pd is a medical radioisotope and is available for brachytherapy.[2] For the effective production of ^{103}Pd, a variety of reactions should be investigated for comparison, including reactions to produce ^{103}Ag ($T_{1/2}$ = 65.7 min), which is a parent of ^{103}Pd. One of the processes used for producing ^{103}Ag is deuteron-induced reactions on natural palladium, which has only been studied up to 20.3 MeV in previous studies.[3–5]

In addition to ^{103}Pd, the radionuclide ^{104g}Ag which has a short β^+ decay half-life ($T_{1/2}$ = 69.2 min) can be used for diagnostic imaging in positron emission tomography (PET). ^{111}Ag has significant potential as a therapeutic β^- radionuclide decaying (92% β^-, $E_{\beta\,\mathrm{max}}$) = 1037 keV) directly to the ground state of ^{111}Cd. The PET using ^{104}Ag has the possible combination of diagnostic studies to investigate the uptake of ^{111}Ag labelled compounds of the therapeutic radionuclide before treatment.[6] Ag, $^{104m,\,g}$Ag, and ^{111}Ag can be obtained by charged particle reactions on ^{nat}Pd. Therefore, we investigated the activation cross sections of deuteron-induced reactions on metallic foils of natural palladium (^{102}Pd 1.02%; ^{104}Pd 11.14%; ^{105}Pd 22.33%; ^{106}Pd 27.33%; ^{108}Pd 26.46%; ^{110}Pd 11.72%) in connection with the production of medically relevant radioisotopes.

The excitation functions of the ^{nat}Pd(d, x) reactions were measured by the stacked-foil method, activation method and high-resolution γ-ray spectroscopy. ^{nat}Pd foils (purity: 99.95%, Nilaco Corp., Japan) were stacked with ^{nat}Ti (purity: 99.6%, Nilaco Corp., Japan) and ^{nat}Zn foils (purity: 99.95%, Nilaco Corp., Japan) for monitoring the beam parameters and degrading the beam energy. The thicknesses of the Pd, Ti, and Zn foils were 8.15, 4.93, and 25.14 mg/cm^2, respectively.The irradiation was performed at the RIKEN AVF cyclotron. A 24-MeV deuteron beam with an average intensity of about 174 nA was irradiated on the target for 20 min. The incident beam energy was measured by the time-of-flight method using plastic scintillator monitors. The beam energy degraded in the stacked target was calculated using the polynomial approximation of stopping-power data.[7] The γ-ray spectra of the activated foils were measured using HPGe detectors. The nuclear decay data were taken from the online NuDat 2.6 database.[8]

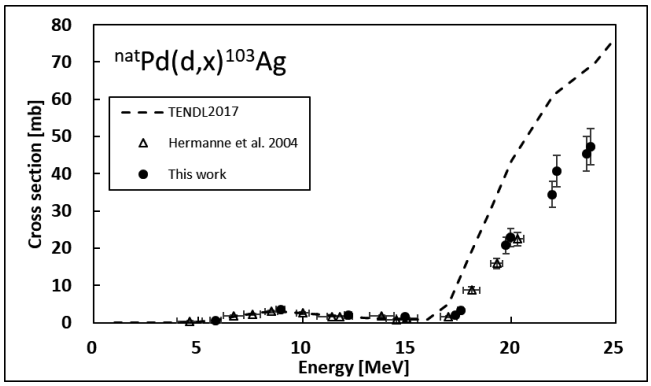

Fig. 1. Excitation function of the ^{nat}Pd(d, x)^{103}Ag reaction. The result is compared with a previous study[4] and TENDL-2017.[9]

We found that our result is in good agreement with the previous data obtained by Hermanne *et al.*[4] up to 20.3 MeV. On the other hand, the theoretical calculation reproduces well the experimental cross sections up to 15 MeV; however at higher energies, the calculation overestimates the experimental cross sections. We performed an experiment of the deuteron-induced reactions on natural palladium to produce Ag isotopes by using the stacked foil activation technique. The excitation functions of the ^{nat}Pd(d, x)^{103}Ag reaction from 20.3 MeV to 24 MeV, ^{nat}Pd(d, x)^{104g}Ag, and ^{nat}Pd(d, x)^{104m}Ag were measured for the first time. The production cross sections of ^{105}Ag, ^{106m}Ag, ^{110m}Ag, and ^{111}Ag are in good agreement with the previous experimental data. Above 20.3 MeV, all excitation functions in this work continued smoothly to the data in the previous study.

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