Activation cross sections of deuteron-induced reactions on natural palladium for ^{103}Ag production

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^{103}Pd with a half life of 16.991 days decays (100% electron capture (EC)) to ^{103m}Rh (100% isomeric transition to ^{103}Rh with 39.5-keV γ-ray emission) is a medical radioisotope (RI) for brachytherapy. For the effective production of ^{103}Pd, a variety of reactions should be investigated. They also include reactions to produce ^{103}Ag ($T_{1/2}$ = 65.7 min), a parent of ^{103}Pd. A process to produce ^{103}Ag is a deuteron-induced reaction on natural palladium, which has only been studied up to 20.3 MeV.[1)] Therefore, we measured the activation cross sections of the ^{nat}Pd(d,x)^{103}Ag reaction using a 24-MeV deuteron beam.

The excitation function of the ^{nat}Pd(d,x)^{103}Ag reaction was 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 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 174.74 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.[2)] The γ-ray spectra of the activated foils were measured by HPGe detectors. Nuclear decay data are summarized in Table 1 and are taken from the online NuDat 2.6 database.[3)]

From the net peak area of the 118.75-keV γ-ray, the activation cross sections for the ^{nat}Pd(d,x)^{103}Ag reaction were deduced using the standard activation formula

$$\sigma = \frac{T_\gamma \lambda}{\varepsilon_d \varepsilon_\gamma \varepsilon_t N_t N_b (1 - e^{-\lambda t_b}) e^{-\lambda t_c} (1 - e^{-\lambda t_m})}$$

where N_t denotes the surface density of target atoms: N_b the number of bombarding particles per unit time: T_γ the number of counts in photo-peak: ε_d the detector efficiency: ε_γ the gamma ray abundances: ε_t the measurement dead time, which is the ratio of live time to real time: λ the decay constant: t_b the bombarding time: t_c the cooling time: and t_m acquisition time.

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Table 1. Decay data of ^{103}Ag.

Nuclide	$T_{1/2}$	E_γ (keV)	I_γ (%)
^{103}Ag	65.7 min	118.74	31.2
		148.2	28.3
		266.86	13.3
		531.92	8.8
		1273.83	9.4

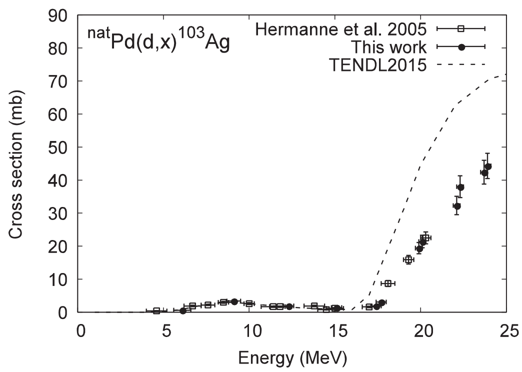

Fig.1. Excitation function of the ^{nat}Pd(d,x)^{103}Ag reactions. The result is compared with a previous study[1)] and TENDL-2015.[4)]

We found that our result is in good agreement with previous data obtained by Hermanne et al.[1)] up to 20.3 MeV.

On the other hand, the theoretical calculation reproduces well the experimental cross sections up to 15 MeV, while at higher energies, the calculation overestimates the cross section. This is probably because the theoretical calculation overestimates cross section of the ^{104}Pd (d,3n)^{103}Ag reaction.

In conclusion, we performed an experiment of deuteron-induced reactions on natural palladium to produce ^{103}Ag. The excitation function of the ^{nat}Pd(d,x)^{103}Ag reaction was measured for the first time from 22 MeV to 24 MeV.

References
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4) A. J. Koning et al.: TENDL-2015: TALYS-based evaluated nuclear data library.