Production cross sections of ^{111}Ag in deuteron-induced nuclear reactions on natural palladium

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Several radionuclides such as ^{90}Y and ^{131}I are currently used for nuclear medicine therapy of tumors. These radionuclides are produced using nuclear reactors. In Japan, all therapeutic radionuclides are now imported from other countries. Therefore, domestic production using accelerators is desirable for a stable supply of therapeutic radionuclides.

Silver-111 (^{111}Ag) is a β^- emitter, which can be applied to the therapy of tumors. It has a half-life of 7.45 d and can be produced in ^{110}Pd(d, x)^{111}Ag reactions using accelerators. This radionuclide also emits γ rays with energies of 342 and 245 keV, which can be used for imaging by single photon emission computed tomography (SPECT). These nuclear properties of ^{111}Ag are expected to be suitable for theranostics (therapeutics + diagnosis). However, ^{111}Ag has been rarely applied to the nuclear medicine field. In this study, production cross sections for ^{nat}Pd(d, x)^{111}Ag reactions are investigated for future nuclear medical application of ^{111}Ag.

The cross sections of ^{nat}Pd(d, x)^{111}Ag reactions were measured by the stacked-foil method. Metallic foils of natural isotopic Pd (purity: 99.95% and thickness: 0.0125 mm, Nilaco Corp., Japan) were used as the target. Metallic foils of ^{nat}Ta (purity: 99.95% and thickness: 0.10 mm, Nilaco Corp., Japan) and ^{nat}Ni (purity: 99.95% and thickness: 0.001 mm, Nilaco Corp., Japan) were also used as a beam energy degrader and beam intensity monitor with the ^{nat}Ni(d, x)^{61}Cu reactions, respectively. Twenty five Pd and 10 Ni foils were stacked together with 2 Ta foils which were placed on the top of the stack. The irradiation of the stack with the 24 MeV deuteron beam was conducted using the RIKEN K70 AVF Cyclotron. The stack covered the beam energy range of 4–17 MeV for the measurement of cross sections of ^{nat}Pd(d, x)^{111}Ag reactions. The average beam intensity was approximately 180 nA and the irradiation time was 2 h. After the irradiation of the stack, each foil was subjected to γ-ray spectrometry using a HPGe detector. The 245-keV γ peak of ^{111}Ag was used to calculate the cross sections.

Because ^{110m}Ag would be produced simultaneously with ^{111}Ag and remain in the body for a long time owing to its very long half-life (249.79 d) during radiotherapy, the cross sections of ^{nat}Pd(d, x)^{110m}Ag reactions were also investigated. The preliminary results of the cross sections of the ^{nat}Pd(d, x)^{111}Ag and ^{nat}Pd(d, x)^{110m}Ag reactions are shown in Fig. 1. ^{111}Ag is produced not only in the direct nuclear reaction but also from the decay of by-products ^{111m}Ag ($T_{1/2}$ = 64.8 s) and ^{111m}Pd ($T_{1/2}$ = 5.5 h). Therefore, cumulative cross sections for ^{111}Ag are shown in Fig. 1. The energy at the peak of the excitation function of ^{nat}Pd(d, x)^{111}Ag reactions was approximately 9 MeV with a cross section of approximately 40 mb, which is consistent with the previous results.[1–3] The excitation function of ^{nat}Pd(d, x)^{110m}Ag reactions has a maximum of approximately 40 mb at around 14 MeV and almost half amplitude of that of the ^{nat}Pd(d, x)^{111}Ag reactions at around 9 MeV. Although ^{110m}Ag is simultaneously produced with ^{111}Ag, the radioactivity of ^{110m}Ag produced with 9-MeV deuteron beam would be approximately 1% of the ^{111}Ag activity owing to the difference in cross sections and half-lives between ^{111}Ag and ^{110m}Ag.

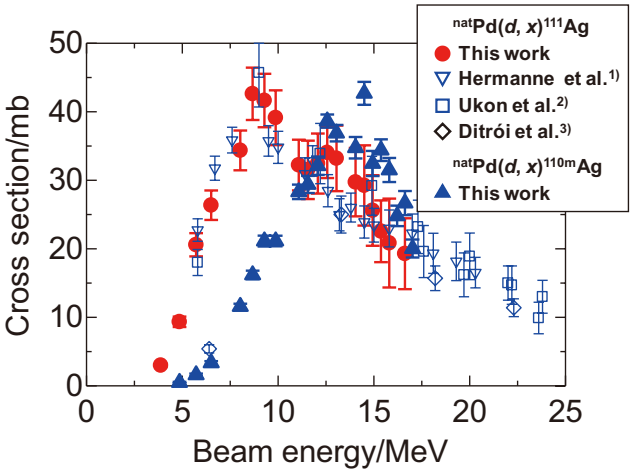

Fig. 1. Excitation functions of ^{nat}Pd(d, x)^{111}Ag and ^{nat}Pd(d, x)^{110m}Ag reactions.

As the next step for the medical application of ^{111}Ag, chemical purification of ^{111}Ag from a Pd target will be performed by ion exchange chromatography.

References

1) A. Hermanne *et al.*, Nucl. Instrum. Methods Phys. Res. B **217**, 193 (2004).
2) N. Ukon *et al.*, Nucl. Instrum. Methods Phys. Res. B **426**, 13 (2018).
3) F. Ditrói *et al.*, Nucl. Instrum. Methods Phys. Res. B **270**, 61 (2012).

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