Production of ^{173}Lu and ^{184}Re for gamma-ray standard

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In gamma-ray spectrometry, the detection efficiency curve with respect to the photoelectric peak is highly significant for the quantification of radioactivity. In general, the logarithm of the detection efficiency of a high-purity germanium semiconductor detector depends linearly on the logarithm of the energy for gamma-ray energies above 200 keV. However, at energies of approximately 100 keV, the dependence is not linear. There are not many standard sources that emit γ-rays in this energy range, the most typical being ^{109}Cd ($T_{1/2}$ = 462 d, E_γ = 88 keV), ^{57}Co ($T_{1/2}$ = 272 d, E_γ = 122, 136 keV), and ^{139}Ce ($T_{1/2}$ = 138 d, E_γ = 166 keV). These are nuclides that emit one or two γ-rays, and different sources are required for measurements in the higher energy region. ^{133}Ba and ^{152}Eu, which emit gamma rays over a wide energy range, have only a few peaks near 100 keV and are insufficient for detection efficiency curves to be drawn with high accuracy. Therefore, we selected ^{173}Lu and ^{184}Re as candidate standard sources that emit multiple γ-rays at approximately 100 keV and have peaks at relatively high energies. Table 1 lists the γ-rays mainly emitted by ^{173}Lu and ^{184m}Re. ^{184g}Re is in radioative equilibrium with ^{184m}Re and emits γ-rays of almost the same energy. In this study, these nuclides were produced in the ^{nat}Yb$(d,x)^{173}$Lu and ^{nat}Ta$(\alpha,x)^{184}$Re reactions and their excitation functions were measured.

Table 1. List of gamma rays of ^{173}Lu and ^{184}Re.[1,2)]

Nuclide	Half-life	E_γ / keV	I_γ / %
^{173}Lu	1.37 y	78.63	11.9
		100.72	5.24
		171.39	2.90
		179.36	1.38
		272.10	21.2
^{184m}Re	169 d	104.74	13.6
		111.22	5.8
		161.27	6.56
		215.33	2.81
		216.55	9.5
		252.84	10.8

The production cross sections of ^{173}Lu and ^{184}Re were measured by means of a stacked-foil technique. Each of the $^{nat}Yb_2O_3$ pellets and ^{nat}Ta metal foils were individually covered with 10-μm-thick Al foil. The thickness of one Yb_2O_3 pellet was approximately 65 mg cm^{-2}, and the Ta foil was approximately 15 mg cm^{-2} thick. These were stacked alternately with 4-μm-thick ^{nat}Cu foil as a target. The Cu foils were used for monitoring the beam current and as an energy degrader. The Yb target was irradiated with 24-MeV deuterons supplied by the RIKEN AVF cyclotron, and the Ta target was irradiated with 29-MeV alpha particles. The average beam current for deuterons was 240 particle nA and that for alpha particles was approximately 120 particle nA. Following irradiation, the nuclei were identified and quantified through γ-ray spectrometry using a Ge detector.

Figure 1 presents the γ-ray spectra of the ytterbium and tantalum targets just after end of bombardment (EOB) and 1–2 months later, respectively. Because the irradiation energy was not optimized to produce only ^{173}Lu and ^{184}Re, the γ-ray peaks of several non-purpose nuclides (mainly Lu and Re isotopes) were observed just after EOB. However, after 1–2 months, long-lived ^{173}Lu and ^{184}Re were observed. Preliminary analysis indicates that the radioactivity of these nuclides is close to that expected from the cross sections by TENDL.[3)] Once most of the short-lived nuclides have decayed, we plan to obtain accurate excitation functions and examine whether they can be used as standard sources.

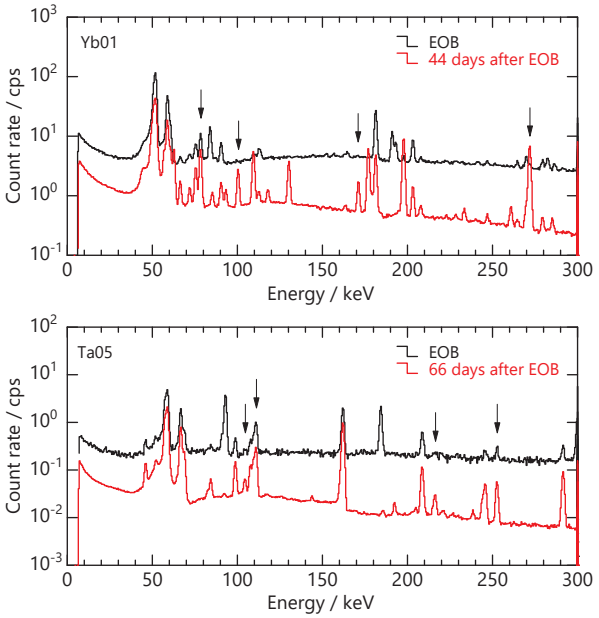

Fig. 1. γ-ray spectrum of the ytterbium and the tantalum targets. The arrows indicate the peaks of ^{173}Lu (upper part) and ^{184}Re (lower part).

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References

1) V. S. Shirley, Nucl. Data Sheets **54**, 589 (1988).
2) C. M. Baglin, Nucl. Data Sheets **111**, 275 (2010).
3) A. J. Koning *et al.*, Nucl. Data Sheets **155**, 1 (2019).

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