Radioactivity Measurement of Reactor-produced Radionuclide ^{177}Lu using 4πβ(LS)-γ Coincidence System

Jinyu Kim [a*], Bo-Young Han [a], Gwang-Min Sun [a], Taeyun Kim [a]
[a]*Korea Atomic Energy Research Institute, HANARO Utilization Division, 111, Daedeok-daero 989beon-gil, Yuseong-gu, Daejeon, Republic of Korea 34057*
[*]*Corresponding author: jinyukim@kaeri.re.kr*

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1. Introduction

Radionuclides are produced using research reactor HANARO, in Korea Atomic Energy Research Institute (KAERI). These reactor-produced radionuclides are mainly used for medical purposes, and have been supplied to various institutes. A radioactivity measurement system using 4πβ(LS)-γ was developed for the reactor-produced radionuclides. The system was tested using calibration source ^{60}Co , and its characteristics was figured out.

In this work, the results of β/γ spectra and radioactivity measurements for ^{177}Lu produced in research reactor HANARO are presented.

2. Overview of Radioactivity Measurement System

2.1 4πβ(LS)-γ coincidence counting

4πβ(LS)-γ coincidence counting is the technique for the radioactivity measurement of radionuclide. A radioactivity is obtained from the count rate of β and γ emitted from the radionuclide, and their coincidence rate. The relation among these values can be written as follows,

$$\frac{N_\beta N_\gamma}{N_c} = N\left[1 + C\left(\frac{N_\gamma}{N_c} - 1\right)\right] \qquad (1)$$

Where N_β and N_γ are count rate for β and γ, and N_c is coincidence rate between N_β and N_γ. N is radioactivity of radionuclide. In analysis, Eq. (1) is used as the fitting function for measured values, $N_\beta N_\gamma/N_c$. When N_γ/N_c reaches to 1, which means detection efficiency reaches to 1, N can be obtained. This method is called "efficiency-extrapolation". Accordingly, β and γ detectors are required for a radioactivity measurement system using 4πβγ coincidence counting.

2.2 Structure of Radioactivity Measurement System

Figure 1 is the picture of developed radioactivity measurement system. The system consists of one β detector and two γ detectors. β detector is placed at the center of the system, consists of a vial containing liquid scintillator (LS) and SiPM. Radionuclide is uniformly distributed in the LS as an aqueous solution. The energy of emitted β from the radionuclide is deposited in LS and changes to scintillation light. The other side, almost γ emitted from the radionuclide escapes from the LS without losing its energy. For the detection of emitted γ, two γ detectors using NaI crystals surround the vial on both sides. On all the three detectors, SiPMs are attached for the detection of scintillation light.

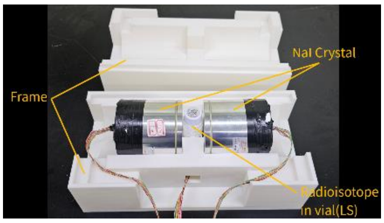


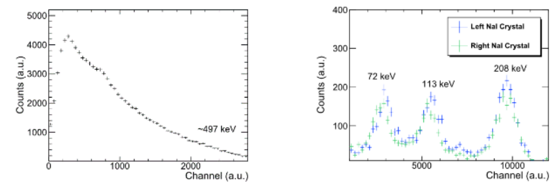
Fig. 1. Developed radioactivity measurement system

3. Measurements for ^{177}Lu

The β/γ spectra and radioactivity of radionuclide ^{177}Lu produced in the research reactor HANARO are measured using the radioactivity measurement system.

3.1 β/γ spectra measurements for ^{177}Lu

The spectra of emitted β/γ from ^{177}Lu are presented in Fig. 2. The dominant values of maximum and averaged energies of ^{177}Lu are 498 and 194 keV, respectively. [1] In measured γ spectrum, the peaks for 72, 113, and 208 keV are presented.



(a) β (b) γ

Fig. 1. Measured β/γ spectra for reactor-produced radionuclide ^{177}Lu

3.1 β/γ spectra measurements for ^{177}Lu

In the analysis, various values of (N_γ/N_c-1) and ($N_\beta N_\gamma/N_c$) are obtained by changing the range of β energy, with fixed γ energy range. And efficiency-extrapolation is carried out using those values. In Fig 3., the changes of minimum value, threshold, of the γ energy range are described. From the efficiency-extrapolation, radioactivity of ^{177}Lu is obtained, as shown in Fig. 4. Equation (1) is used as fitting function.

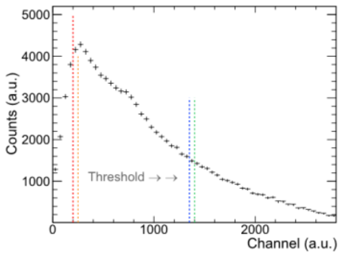


Fig. 3. Changes of threshold values for β energy

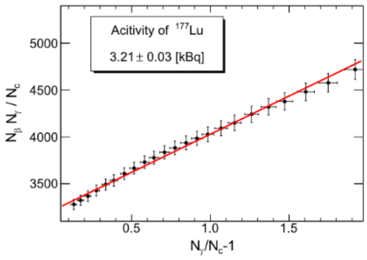


Fig. 4. Efficiency-extrapolation for ^{177}Lu

The radioactivity measurements for ^{177}Lu were carried out 4 times from May to June in 2023, and the feasibility of the measurements was tested using exponential decay function, as shown in Fig. 5.

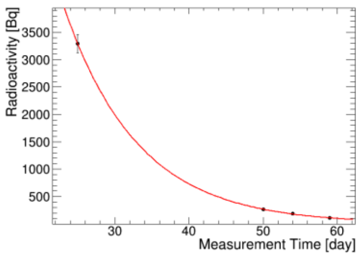


Fig. 5. Changes of radioactivity of ^{177}Lu over time

4. Status and Plan

The radioactivity measurement system was developed and its characteristics was figured out. The radioactivity measurements of reactor-produced radionuclide ^{177}Lu were also carried out. The systematic uncertainties of radioactivity measurement are being investigated, including background, gain changes of the signals from the detectors, etc. The radioactivity measurements for reactor-produced radionuclides are going to be carried out, and their results will be given along with the total errors.

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