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Testing position dependence for activity measurement using 4πβ(LS)-γ coincidence counting

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1. Introduction

The High-flux Advanced Neutron Application Reactor (HANARO) at Korea Atomic Energy Research Institute (KAERI) has been used for producing radionuclides [1-3]. These radionuclides are supplied to various institutes, and are mainly used for medical purposes. The produced radionuclides are handled by workers in a hot-cell, a shielded nuclear radiation containment chamber, before supplied to the customers. The workspace of the hot-cell is limited, and there are some requirements for measuring the quality of the produced radionuclides in such narrow place. To fulfill these requirements, a mini-size activity measurement system was developed from 2021 to 2023 at KAERI [4].

The main technique for measuring activity is 4πβ-γ coincidence counting [5], and the radionuclide sample to be measured is prepared as an aqueous solution. And it's generally assumed that the sample is uniformly distributed within the β detecting material, in order to achieve 4πβ measurement and obtain correct activity of the sample. But this configuration can't be applied to solid-state samples, because those samples can't be distributed uniformly within the β detecting material. For this reason, when measuring the activity of a solid-state sample, it is suspected that the position of the sample will affect the result. In this work, the position dependence of activity measurement was tested using solid-state ^{60}Co radioactive source and the results are presented.

2. Methods and Results

2.1 Activity measurement system

The activity measurement system consists of the detection part and the DAQ system. Figure 1 is a photo of the activity measurement system at KAERI. In Fig.1, the dark box contains the detection part. The detection part consists of one β detector and two γ detectors. The detecting material of β detector is liquid scintillator (LS), and that of γ detector is NaI crystal scintillator. The radionuclide sample is contained in the β detector. The γ detectors surrounds β detector on both sides, to measure the escaped γs from the β detector. The details of the activity measurement system are described in [4].

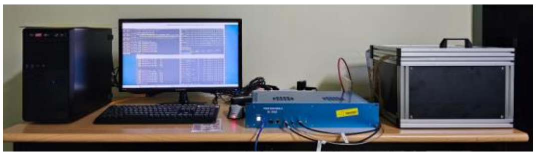

Fig. 1. The activity measurement system at KAERI.

2.2 ^{60}Co radioactive source and holders

For testing position dependence, a solid-state ^{60}Co radioactive source (Fig.2 left) is used. To prepare the source, neutron irradiation was carried out to ^{59}Co wire, at the neutron irradiation hole in HANARO. The diameter of the source is 2.5 mm, and the length is 5 mm.

Holders for different positioning of the source were made by 3-D printer. The holder in Fig.2 center is for testing the position dependence at the center and the edges of the β detector, and has 6 different positions. The holder in Fig.2 right is for testing position dependence at the center in detail, and has 11 different positions.

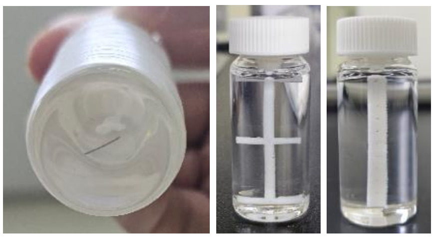

Fig. 2. ^{60}Co radioactive source in the β detector (left) and holders for testing position dependence (center and right).

2.3 Testing position dependence for activity measurement

The position dependence for activity measurement was tested using 2 different source holders, as shown in Fig.2 center and right. At first, the holder in Fig.2 center was used. There are 3 different vertical levels, bottom, middle, and top. Bottom is 0.4 cm above the lower surface of the β detector. Middle is 2.45 cm and top is 4.5 cm. Each level has two positions at the center and the edge, and the gap between the two is 0.65 cm. Figure 3 shows the measured activity values at the center and the edge of bottom level. Comparing the two results, the activity value at the center is higher than that at the edge. This tendency is also shown for top level (Fig.5). In contrast, the difference of the activity values is in the error size for middle level. Comparing the activity values for difference vertical levels (left plots of Fig.3-5), the value for middle level is the highest. The value for top level is lower than that for bottom level, and it can occur owing to the difference of the environment between the two levels.

The position dependence at the center positions were more tested in detail, using the holder with 11 different positions (Fig.2 right). The lowest position is 0.4 cm above the lower surface of the β detector, while the highest position is 4.5 cm above the surface. The interval among the positions is 0.41 cm. The activity values of the ^{60}Co wire source for 11 positions were measured, and the results are shown in Fig.5. The highest activity value was measured at 1.96 cm, the value at 0.4 cm was higher than that at 4.5 cm. The similar results were obtained with 2 different holders.

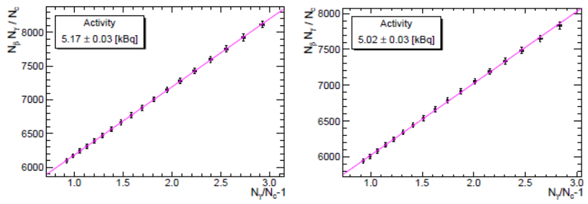

Fig. 3. Measured activity values for bottom level at the center (left) and the edge (right).

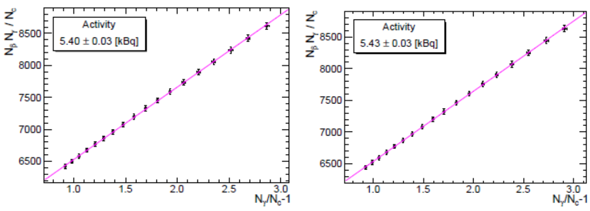

Fig. 4. Measured activity values for middle level at the center (left) and the edge (right).

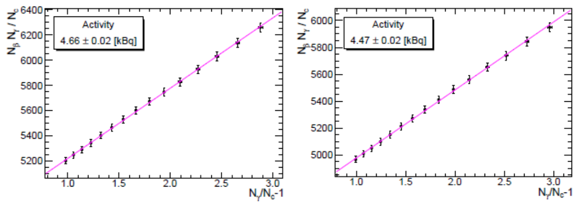

Fig. 4. Measured activity values for top level at the center (left) and the edge (right).

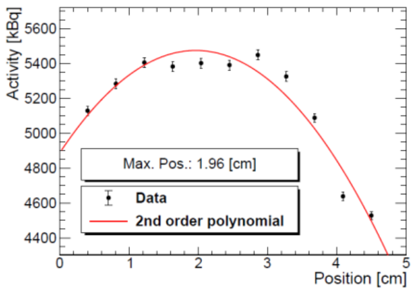

Fig. 5. Measured activity values for 11 different positions at the center.

3. Conclusions

The position dependence for activity measurement was tested with various positions using solid-state ^{60}Co radioactive source. The activity values were measured with different positions and the results showed that the measured activity is the highest at the center, and continuously decreases as the position goes to the edge. And from this work, the understanding of the position dependence for activity measurement is improved but the many things to be confirmed (the exact origin of the difference between bottom and top levels, the effect of geometric structure of the β detector, etc.) are still remained. To investigate these questions, the Monte Carlo simulation will be developed for the activity measurement system, and the further studies will be carried out.

Acknowledgements

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