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Analysis of Uranium Sample by γ-spectrometry

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1. Introduction

The γ-ray spectrum of depleted UO_2 powder sample was measured with a HPGe detector. The mass ratio of ^{235}U to ^{238}U can be obtained by measuring the γ-peaks from each radioisotope. But, because the γ-peaks from ^{238}U were not distinguishable from background on the spectrum, analysis was performed by using the fact that secular equilibrium between ^{238}U and ^{234m}Pa has been attained.

2. Mathematical Method

Secular equilibrium between ^{238}U, ^{234}Th and ^{234m}Pa is achieved because the half-life of ^{238}U is much longer than those of ^{234}Th and ^{234m}Pa [1] as shown in figure 1.

$$^{238}\mathrm{U} \xrightarrow[\alpha,4.5\times10^{9}\,y]{} {}^{234}\mathrm{Th} \xrightarrow[\beta^-,24.1d]{} {}^{234m}\mathrm{Pa} \xrightarrow[\beta^-,1.17\,\mathrm{min}]{} {}^{234}\mathrm{U}$$

Figure 1. Decay scheme of ^{238}U.

Hence it is possible to calculate the mass ratio of ^{235}U to ^{238}U (m_{235}/m_{238}) by using the 1001.0 keV and 185.7 keV γ-peaks from ^{234m}Pa and ^{235}U. In case of ^{234}Th, it is difficult to analyze because of the interference with other γ-peaks. The mass ratio can be calculated by equation (1),

$$\frac{m_{235}}{m_{238}} = \frac{A_{235}/SA_{235}}{A_{238}/SA_{238}} \quad (1)$$

where A and SA are activity and specific activity of each radioisotope. The activity was calculated from the peak count rate with considering the emission probability, detector efficiency and self-absorption correction factor. The emission probabilities used in the calculation were specified in Table of Isotopes [1] and the self-absorption correction factor, κ, was determined by Integrated Lambert-Beer law [2] defined in equation (2),

$$\kappa(E_\gamma) = \frac{\mu(E_\gamma)d}{1-\exp[\mu(E_\gamma)d]} \quad (2)$$

where $\mu(E_\gamma)$ and d are mass-absorption coefficient of photon of energy E_γ and sample thickness, respectively.

3. Experiment and Results

The mass and thickness of measured sample were 154±1 mg and 1.0±0.1 mm. A closed ended coaxial type HPGe detector was used in the measurement. The relative efficiency of the HPGe detector is 18% and the energy resolution is 1.8 keV at 1.33 MeV γ-peak from ^{60}Co. Source-to-detector distance was 5 cm and the efficiency curve was recalibrated. The measurement time was 39 hours.

Measured sample spectrum is shown in figure 2. 185.7 keV and 1001.0 keV γ-peaks are marked on the spectrum. The count rates of peaks are 0.239±0.004 and 0.053±0.001 cps, respectively. The derived activities and mass ratio are shown in table 1.

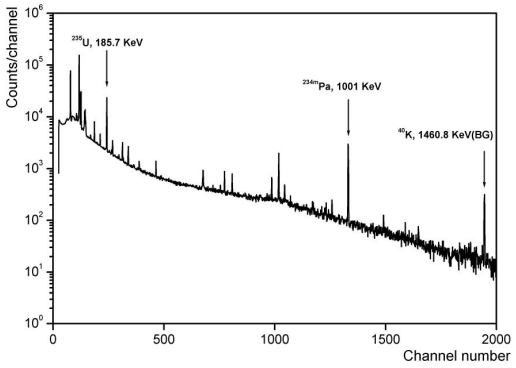

Figure 2. Measured spectrum of the UO_2 sample.

Table 1. Calculated activity and mass ratio.

Radio-isotope	Activity [Bq]	SA [Bq/g]	Mass ratio [%]
^{235}U	31.9±0.3	7.99×10^4	0.21±0.01
^{238}U	2319.5±27.6	1.24×10^4	

4. Conclusions

An analysis of UO_2 sample was performed with HPGe detector. The activities of ^{235}U and ^{238}U were measured considering the secular equilibrium condition and self-absorption correction. From the activities, mass ratio of ^{235}U to ^{238}U was derived and the result was 0.21±0.01%. It is reasonable compared with the normal mass ratio of the depleted uranium (0.2 ~ 0.4%).

REFERENCES

[1] R.B. Firestone, V.S. Shirley, Table of Isotopes, 8th ed., Wiley, New York, 1996.
[2] K. Siemon, R.A. Esterlund, J.V. Aarle, M. Knaack, W. Westmeier and P. Patzelt, A New Measurement of the Gamma-ray Intensities of ^{234m}Pa Accompanying the Decay of ^{238}U, Applied Radiation and Isotopes, Vol. 43, p. 873, 1992.