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Energy and Efficiency Calibrations of High Purity Germanium Detector Using k0-IAEA Program for k0 Standardization in INAA

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1. Introduction

The relative standardization method in instrumental neutron activation analysis (INAA) requires the simultaneous irradiation of elemental standards with samples and measurement of the standards and samples under the same conditions. Although the relative method can give the most accurate results, it has several serious disadvantages such as the preparation of standards, having enough space for standards in irradiation container, having time for measurement of standards, ensuring same geometry for sample and standard, and loss of information when the elemental standard is not irradiated [1]. To overcome these disadvantages, the k0 standardization method was finally developed and distributed to various laboratories in the late 1970s [2]. Since then, the freeware k0-IAEA Program has been launched by the International Atomic Energy Agency (IAEA), and it has been used to implement k0 standardization method in neutron activation analysis (NAA) laboratories owing to its proven accuracy [3].

The implementation of k0-IAEA program requires a calibration of detector before characterizing the irradiation facility. An efficiency calibration is an important step to achieve accurate results because it establishes the relationship between the peak energy and the probability of the detector recording a count in the full energy peak. The k0-IAEA program has the capability for the determination of peak position in a spectrum, performs energy calibration and plots energy calibration curves and determination of peak width (FWHM) and efficiency calibration curve. This study therefore focuses on the energy and efficiency calibrations using the k0-IAEA program for the high purity germanium (HPGe) detector at the NAA laboratory in the Korea Atomic Energy Research Institute (KAERI).

2. Methods and Results

2.1 Basic execution of k0-IAEA program

Detector calibrations were performed according to the k0-IAEA program manual for version 4.00 [4]. In the k0-IAEA program, detailed experimental information can be written on and read from the permanent and series database. The permanent and series database can be edited with the edit/database command. The execution of the k0-IAEA program can be divided into five steps. The first step is to edit the permanent database by entering the detector, certificates of the reference materials including the certified activities of the calibration sources, the irradiation facilities, sample capsule and material composition. The second step is to calibrate the detector. The third step is to calibrate the efficiency of detector. The fourth step is to characterize the irradiation facilities and the fifth step is to analyze samples and report them. The second through fifth steps all involve series of samples and associated spectra, and thus the creation of a series database is needed every time.

All measurement of the gamma spectra were conducted using high-purity coaxial germanium detector mode number 35195 (ORTEC), which has a relative efficiency of 30 % and a resolution of 1.95 keV (FWHM) for the 1.33 MeV gamma line of Co-60. The dimension of detector, crystal diameter of 57 mm, crystal length of 79.6 mm, end cap to crystal of 3 mm, aluminum absorbing layer of 1.27 mm, inactive germanium layer of 0.7 mm, the top cover diameter of 66.94 mm, core diameter of 9 mm and core height of 66 mm were all entered into the permanent database of the k0-IAEA program together with certified activities of Cs-137 and multi-nuclide standard calibration sources.

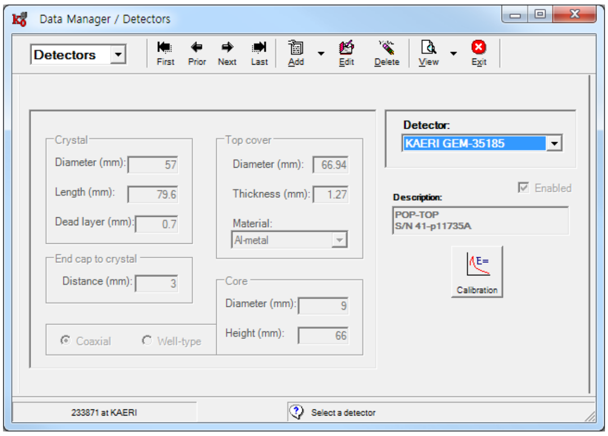

Fig. 1. Edition of the permanent database.

2.2 Energy calibration

The multi-nuclide standard source was measured at an 82 mm source-detector distance for 70000 seconds, and a series database was created with measured gamma energy spectrum. The spectrum analysis command was selected and a peak search was performed with known peak energies. The energy calibration curve and deviations between the fitted values and measured values are shown in fig. 2.

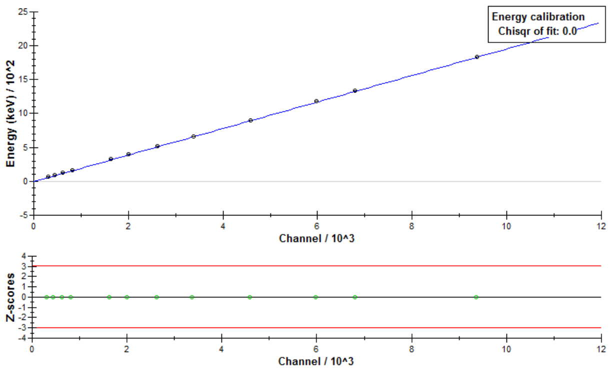

Fig. 2. Energy calibration curve of multi-nuclide source.

The fitted value is satisfactory if the deviation falls between -3 and 3. Fig. 2 shows a satisfactory overall fit to the measured values**.** The results was stored in the permanent database. A background spectrum analysis was only performed after the energy calibration was completed.

2.3 Efficiency calibration

The Cs-137 standard source was measured at an 82 mm source-detector distance for 70000 seconds. Then, Cs-137 spectrum was employed to determine the peak-to-total curve. Knowing the peak-to-total ratio, the efficiency curve was fitted using once again multi-nuclide standard source spectrum. The efficiency and peak-to-total curves and deviations between the fitted values and measured values at the reference position are shown in fig. 3 and 4.

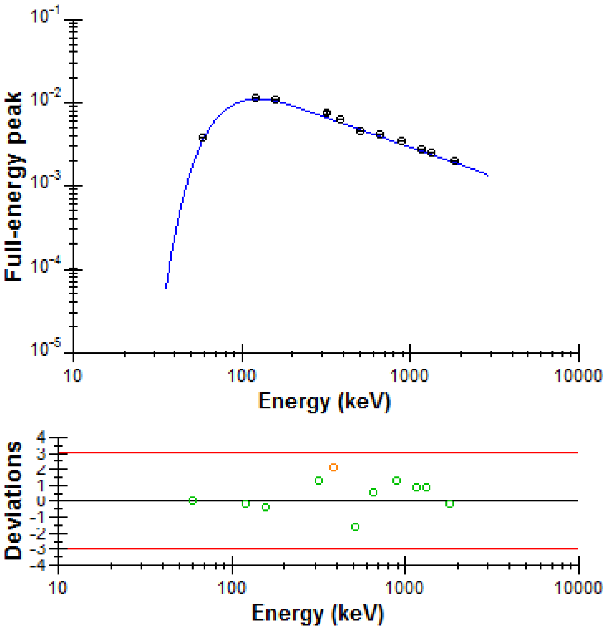

Fig. 3. Efficiency calibration curve and deviations between the measured and fitted values obtained from k0-IAEA program.

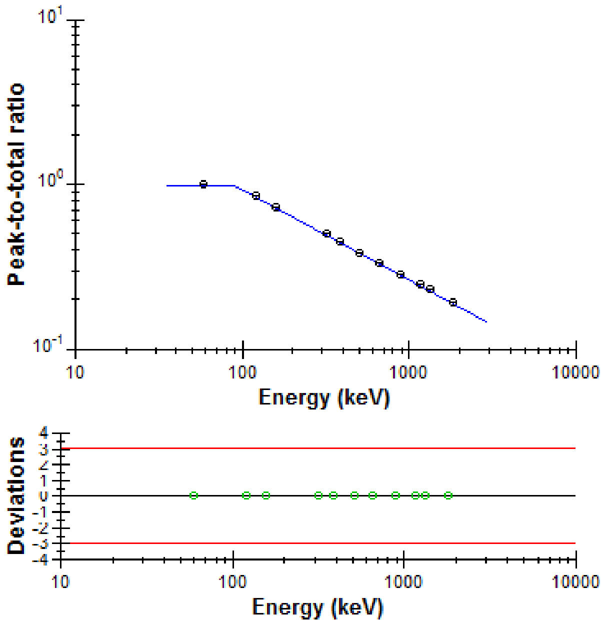

Fig. 4. Peak to total curve and deviations between the measured and fitted values obtained from k0-IAEA program.

The k0-IAEA calculates the deviation as the difference between measured and fitted values divided by its uncertainty. Fig. 3 and 4 show a satisfactory overall fit to the measured values. The entire results were stored in the permanent database.

3. Conclusions

The efficiency and peak-to-total curves for the HPGe detector at the reference position were obtained, and the deviations between the fitted values and measured values were satisfactory. The HPGe detector was successfully calibrated by the k0-IAEA program, and this results will be used for the implementation of k0 standardization method at the NAA laboratory in KAERI.

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