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Experimental Performance Evaluation of a Compton Suppression System by an Analysis of Geological Reference Materials

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1. Introduction

Compton scattering is one of major sources inducing a high background when a gamma-ray spectrum is acquired from a radioactive sample. The high background spectrum deteriorates the detection sensitivity for an analysis of the nuclide of interest. To improve the detection sensitivity by the reduction of the spectrum background, a Compton suppression system (CSS) applying an anti-coincidence mode was developed and has been used for a neutron activation analysis. A Compton suppression system (CSS) was implemented for an instrumental neutron activation analysis (INAA) at an NAA laboratory of the Korea Atomic Energy Research Institute (KAERI) in 2009. The CSS consists of a high-purity Ge (HPGe) detector and bismuth germinate (BGO) with electronic modules. An evaluation of the performance of the CSS was carried out based on the measurement of the gamma-ray emitting source and the detectable nuclides created thorough neutron activation of biological reference materials[1].

This study was executed to evaluate the performance of the CSS for geological standard reference materials (SRMs). Four geological SRMs produced by the National Institute of Standards and Technology (NIST) in the USA were selected and irradiated using an NAA#1 irradiation hole at HANARO. Gamma-ray spectra with normal mode and anti-coincidence mode were acquired at the same time, and advantage factors of CSS for each nuclide detected were calculated on the basis of the signal-to-noise ratio.

2. Experiments

Approximately 100 mg of SRM samples for short irradiation (~30 s) and 200 mg for long irradiation (~2 hrs) were put into polyethylene vials for neutron irradiation. The prepared samples were irradiated using a NAA#1 irradiation hole at the HANARO research reactor [2]. On the basis of a routine NAA, gamma-rays of the irradiated samples by normal and anti-coincidence modes were measured at distances of 5.5 cm, 9.5 cm and 13.5 cm using an HPGe detector for ~2000 s for short-lived nuclides, 4000 s for medium lived nuclides, and 40000 s for long-lived nuclides. Gamma-ray spectra with normal and anti-coincidence modes were acquired at the same time. Detectable target nuclides with their energy are indicated in Table 1. The net and background areas for interesting gamma-ray peaks of each nuclide in the measured spectrum were gained to evaluate the performance of CSS.

Table 1. Detectable target nuclides to be evaluated in this study

Division	Target nuclides (energy, keV)
Short irradiation	^{28}Al(1778), ^{139}Ba(165) , ^{80}Br(617), ^{49}Ca(3084), ^{38}Cl(1642), ^{66}Cu(1039), ^{165}Dy(165), ^{27}Mg(1014), ^{56}Mn(847), ^{42}K(1524), ^{24}Na(1368), ^{87m}Sr(387), ^{51}Ti(320), ^{52}V(1434)
Long irradiation (medium-lived nuclide)	^{76}As(559), ^{198}Au(411), ^{82}Br(554), ^{140}La(1596), ^{42}K(1524), ^{177}Lu(208), ^{24}Na(1368), ^{122}Sb(564), ^{153}Sm(103) , ^{175}Yb(396)
Long irradiation (long-lived nuclide)	^{110m}Ag(657), ^{131}Ba(496), ^{141}Ce(145), ^{60}Co(1173), ^{51}Cr(320), ^{134}Cs(795), ^{152}Eu(1408), ^{59}Fe(1099), ^{181}Hf(482), ^{203}Hg(279), ^{147}Nd(531), ^{86}Rb(1076), ^{124}Sb(1691), ^{46}Sc(889), ^{75}Se(264), ^{182}Ta(1221), ^{233}Pa(312), ^{169}Yb(198), ^{65}Zn(1115)

3. Results and Discussion

Thirteen short-lived, nine medium-lived and eighteen long-lived nuclides among the target nuclides in Table 1 were detected from four geological SRMs. The signa-to-noise ratio (S/N ratio) for each nuclide detected by both normal and anti-coincidence mode was calculated. The CSS performance was evaluated in terms of the advantage factor (AF). The AF can easily calculated by the following equation,

$$AF = (S/N)_{\text{anti-coincidence}}/(S/N)_{\text{normal}}$$

The results are shown in Table 2. As for the short-lived nuclides, Sr-87m, I-128 and Cl-38 nuclides were detected only from SRM 1632C-bituminous coal. AF values from 95keV of Dy-165 to 3084keV of Ca-49 were evaluated and the range of mean AF value for each nuclide is from 1.06 (1642 keV of Cl-38) to 2.95 (1014 keV of Mg-27). In terms of medium-lived nuclides, the AF values from 103keV of Sm-153 to 1596keV of La-140 were evaluated and the range of mean AF value for each nuclides is from 1.28 (1596 keV of La-140) to 2.63 (564 keV of Sb-122). Because As-76 (559keV) and Sb-122 (564keV) have higher AF values than other nuclides, detection sensitivity for NAA can be highly improved. As a result of long-lived nuclides, Se-75 and Ag-110m nuclides were detected from SRM 1632C-bituminous coal and SRM 2711-montana soil, respectively. The AF values for each nuclide from 145keV of Ce-141 to 1690keV of Sb-124 were evaluated and the range of mean AF value is from 1.40 (1221 keV of Ta-182) to 3.30 (531 keV of Nd-147).

Table 2. Advantage factors for detected nuclides by CSS

Nuclides	Energy (keV)	Range	Mean	No. of detection
Dy-165	95	1.06 ~ 1.30	1.20	4
Ba-139	165	1.66 ~ 2.53	2.22	4
Ti-51	320	1.31 ~ 2.59	2.02	4
Sr-87m	387	N.A	1.82	1
I-128	442	N.A	1.97	1
Mg-27	1014	1.94 ~ 3.98	2.95	3
Na-24	1368	1.54 ~ 2.15	1.82	4
V-52	1434	2.42 ~ 3.39	2.90	4
K-42	1524	1.69 ~ 3.39	2.52	4
Cl-38	1642	N.A	1.06	1
Al-28	1779	1.71 ~ 2.99	2.21	4
Mn-56	1810	1.80 ~ 2.50	2.12	4
Ca-49	3084	0.46 ~ 3.58	1.69	3
Sm-153	103	1.16 ~ 1.47	1.32	4
Lu-177	208	1.62 ~ 1.86	1.73	4
Yb-175	396	1.96 ~ 2.07	1.99	4
Au-198	411	1.87 ~ 2.17	2.02	2
Br-82	554	1.65 ~ 2.18	1.94	4
As-76	559	2.17 ~ 2.87	2.54	4
Sb-122	564	2.24 ~ 3.05	2.63	4
Na-24	1368	1.33 ~ 1.69	1.55	3
La-140	1596	0.91 ~ 1.52	1.28	4
Ce-141	145	1.73 ~ 2.15	1.98	4
Yb-169	198	1.64 ~ 1.71	1.67	4
Se-75	264	N.A	1.48	1
Hg-203	279	1.61 ~ 1.93	1.82	3
Pa-233	312	1.83 ~ 2.34	2.18	4
Cr-51	320	1.96 ~ 2.32	2.14	4
Hf-181	482	1.87 ~ 3.18	2.41	4
Ba-131	496	2.38 ~ 2.74	2.53	4
Nd-147	531	2.82 ~ 3.95	3.30	4
Ag-110	657	N.A	1.70	1
Cs-134	796	2.00 ~ 2.25	2.13	4
Sc-46	889	1.73 ~ 1.85	1.79	4
Rb-86	1076	1.51 ~ 1.82	1.67	4
Fe-59	1099	1.62 ~ 1.72	1.65	4
Co-60	1173	1.31 ~ 1.64	1.50	4
Ta-182	1221	1.07 ~ 1.72	1.40	4
Eu-152	1408	2.15 ~ 2.45	2.26	4
Sb-124	1690	1.94 ~ 3.35	2.41	4

4. Conclusions

The performance of CSS was evaluated by nuclides detected from geological SRMs. The mean AF values for the short, medium and long-lived nuclides evaluated in this work are 2.04, 1.89, and 2.00, respectively.

REFERENCES

[1] J. H, Moon, G. M. Sun, S. H. Kim, Y. S. Chung, "Performance Test of Compton Suppression System by Measurement of Multi-nuclide Standard Source and an Analysis of Biological Reference" Transactions of the Korean Nuclear Society Spring Meeting, Gyeongju, Korea, Oct. 27-28, 2011.
[2] J. H, Moon, S. H. Kim, Y. S. Chung, Y. J. Kim, "Application of the k0-NAA method at the HANARO research reactor" J. Radioanal. Nucl. Chem., Vol. 271(2), p. 289-295, 2007.