

### Development of Radioactive Calibration Sources of Gamma Ray Detector

, ,  
 220  
 ,  
 150  
 , ,  
 800  
<sup>60</sup>Co <sup>137</sup>Cs  
 가  
 가  
 661.662 keV, 1173.237 keV 1332.51 keV  
<sup>152</sup>Eu , <sup>60</sup>Co <sup>137</sup>Cs  
 .  
 , , ,  
 2001 3 1 0 <sup>60</sup>Co 1.0023 μCi,  
<sup>137</sup>Cs 1.0600 μCi 15 % .

### Abstract

In this study, we report on the development of the production technique of the calibration sources which are pertinent for both energy and detection efficiency calibration of gamma ray detector. For this objects, we made two calibration sources

with the radioisotope of  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  of which produced with HANARO reactor at KAERI. In order to certify the qualities of produced sources, the mass absorption coefficients, due to the thickness of source container, were systematically investigated for 661.662 keV, 1173.237 keV and 1332.51 keV photopeaks, respectively. Absolute detection efficiency curve for applied Ge detector is measured by using the standardized multi-gamma emitter  $^{152}\text{Eu}$ , covers overall the region of interest for this work. The activity of each produced source is determined by using the resulted detection efficiency curve and the uncertainty of each case is evaluated by root square sums of each uncertainty component arising from the quoted decay parameters such as transition probability, gamma-ray emission probability and conversion electron coefficient, arising from the used standard source and from the fraction of losses to throughout the container. Consequently, activity of  $^{60}\text{Co}$  is assigned, at the reference date of March 1, 2001, to be 1.0023  $\mu\text{Ci}$ , and activity of  $^{137}\text{Cs}$  to be 1.0600  $\mu\text{Ci}$  with the combined uncertainty of 1.5 % for both cases.

## I.

, ,  
 . X , .  
 / .  
 0 keV 2000 keV .  
 , , 가  
 . 가  $^{60}\text{Co}$ ,  $^{137}\text{Cs}$  ,  $^{88}\text{Y}$ ,  $^{54}\text{Mn}$ ,  $^{51}\text{Cr}$  [1,2]  
 가 1 2 .  
 . 10  
 % [3] 가 가  
 . .  
 [4,5] .

가 가 가 .  
 가 가  
<sup>60</sup>Co <sup>137</sup>Cs  
 가 .

661.662 keV, 1173.237 keV 1332.51 keV

<sup>152</sup>Eu Ge  
 , ,  
 가 , 2  
 , 3 4

II.

Ge  
 Ge vertical 가 3  
 keV - 10 MeV 60 cm<sup>3</sup> .  
 (FWHM) <sup>60</sup>Co 1332.51 keV 1.9 keV ,  
 (relative efficiency) 25 % . 3 keV  
 0.5 mm beryllium . Ge  
 10 cm .  
 X- 0.5 mm 1 mm  
 30 cm .

II-1.

가 가 .  
 가 .

$^{60}\text{Co}$   $^{137}\text{Cs}$

1

26 mm, 24 mm, 5.5 mm

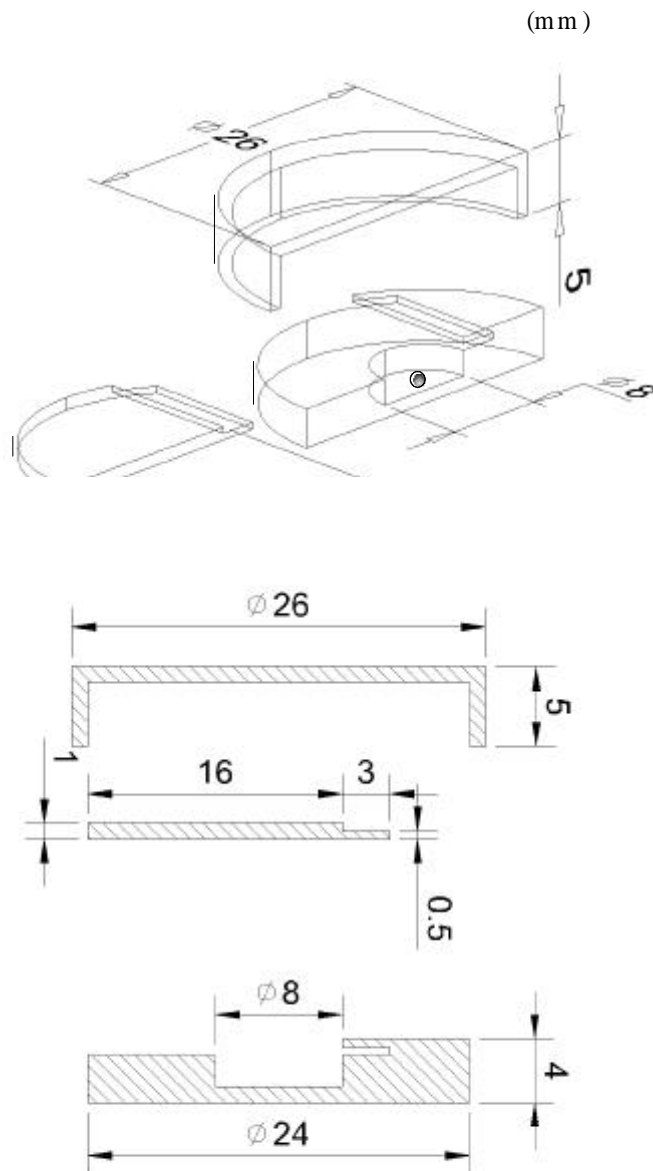
1 mm, 8 mm . 1

(a)

(b)

1 mm

가



(absorption coefficient)

1 mm

661.662 keV, 1173.237 keV

1332.51 keV

II-2

$^{137}\text{Cs}$   $^{60}\text{Co}$

CsCl<sub>2</sub>, CoNO<sub>3</sub>

100 μCi

20 μCi

99.999 %

10 ml

1 μCi

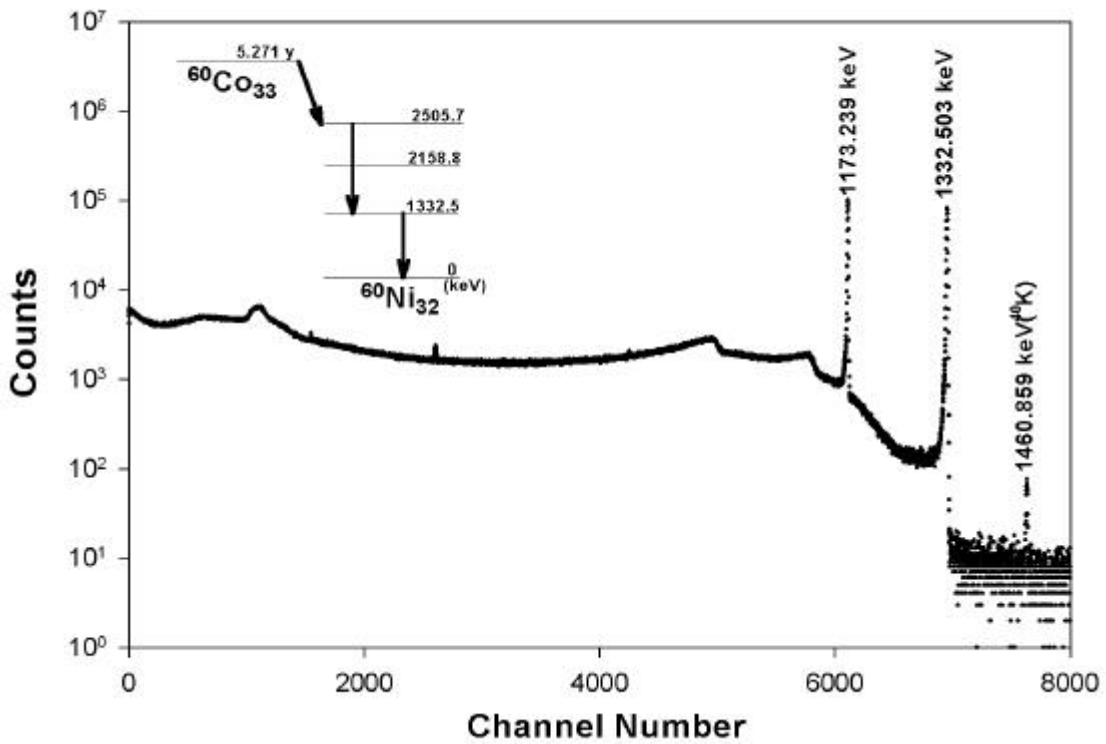
10 ml - 20 ml

$^{60}\text{Co}$

$^{137}\text{Cs}$

1 μCi

가



2.

$^{60}\text{Co}$

$^{60}\text{Co}$

II-3

$^{137}\text{Cs}$ ,  $^{60}\text{Co}$

.가

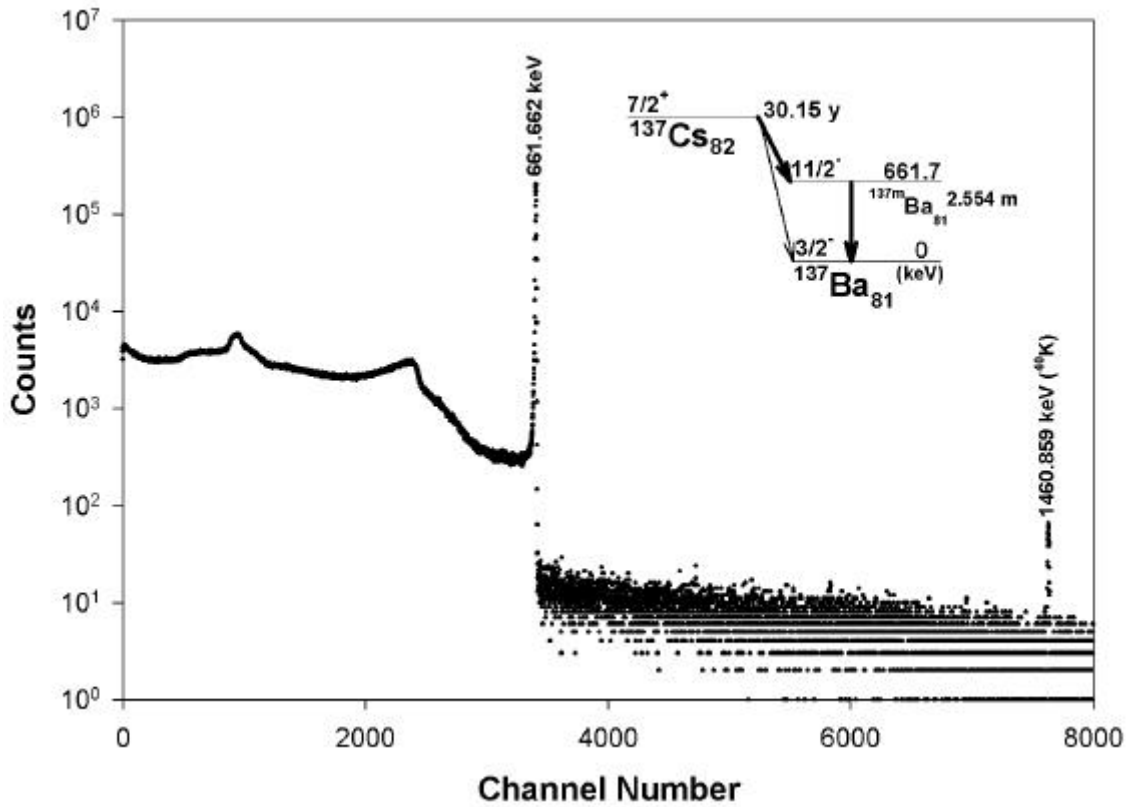
Ge

1 %

(absolute detection efficiency curve)

0 keV 2000 keV

1-2 %



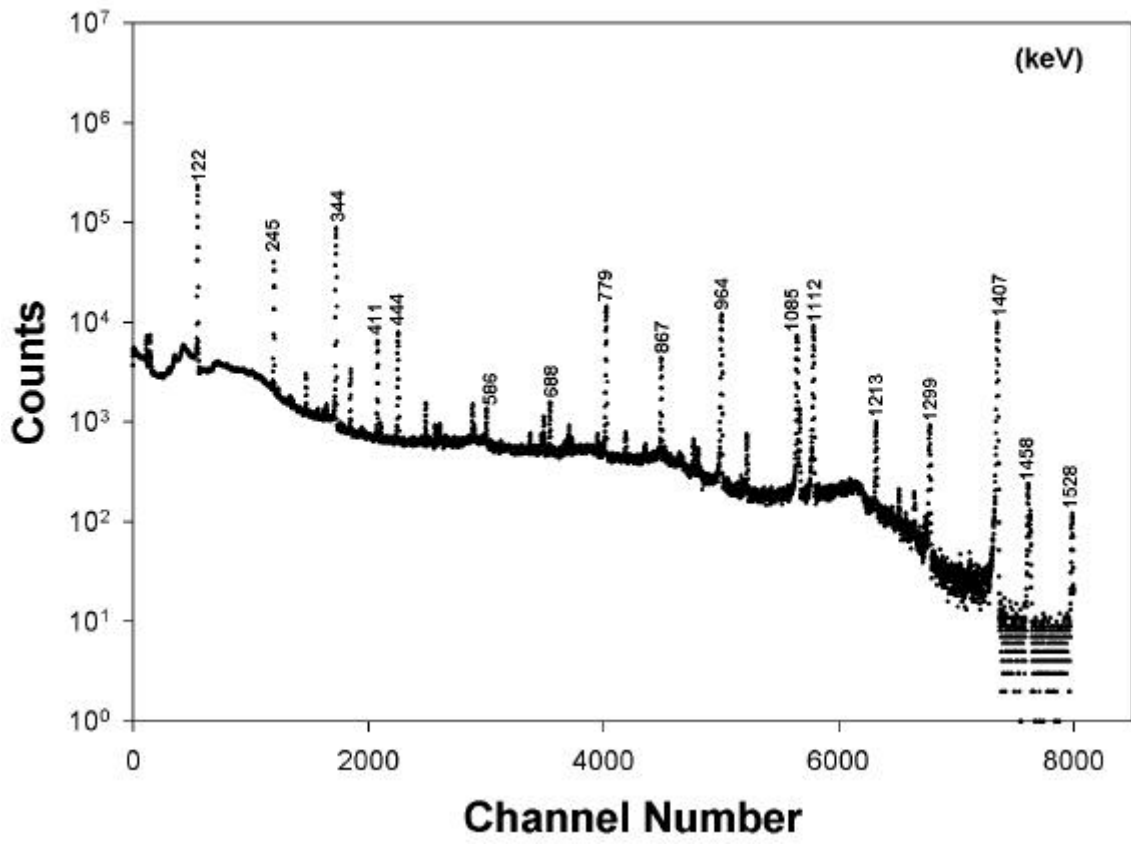
3.

$^{137}\text{Cs}$

$^{137}\text{Cs}$

$^{152}\text{Eu}$        $^{137}\text{Cs}$        $^{60}\text{Co}$   
 Ge      100 keV      1500 keV

가



4.

$^{152}\text{Eu}$

$^{137}\text{Cs}$        $^{60}\text{Co}$

가 600 keV

가

Ge

$^{152}\text{Eu}$

가

$2 \times 10^5$  s

4

$^{152}\text{Eu}$

### III.

#### III- 1.

				1
		1 mm		
			1 mm	10
5	5(a)	$^{137}\text{Cs}$	661.662 keV	
	5 (b)	(c) $^{60}\text{Co}$	1173.237 keV	1332.51 keV
			661.662 keV	
			$\mu = (0.009794 \pm 0.000572)/\text{mm}$	$\mu = (0.009568 \pm 0.000637)/\text{mm}$
			1332.51 keV	$\mu = (0.009489 \pm 0.000374)/\text{mm}$

$$N = N_o e^{-\mu x} \quad (1)$$

$$\ln(N) = \ln(N_o) - \mu x \quad (2)$$

$N_o$  (  $x = 0$  ) ,  $\mu$  x

$N$  가 x

(2)

$\mu$  가 가 .

(1)

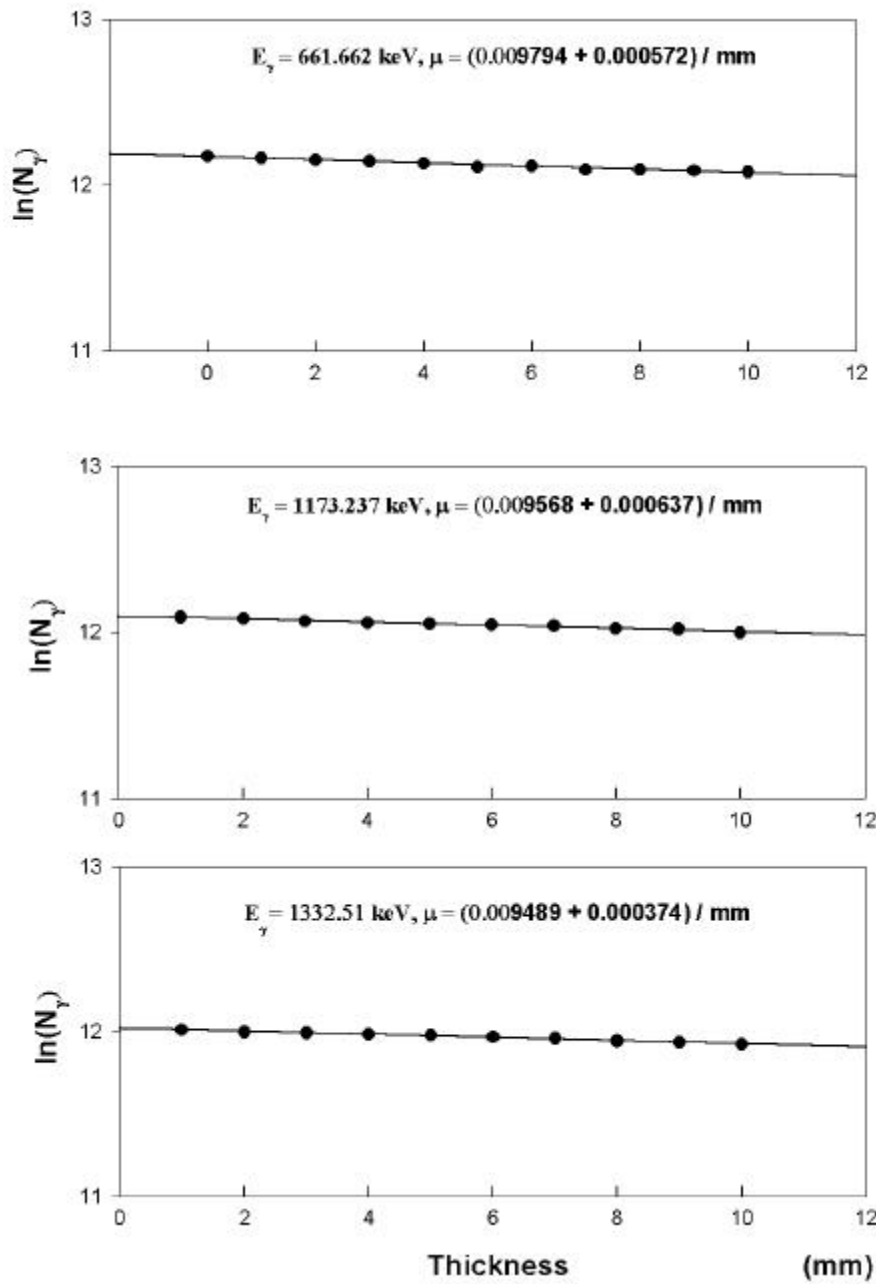
$$E_{\gamma} = 661.662 \text{ keV}, \quad \frac{N}{N_o} = 0.99025$$

$$E_{\gamma} = 1173.237 \text{ keV}, \quad \frac{N}{N_o} = 0.99048$$

$$E_{\gamma} = 1332.51 \text{ keV}, \quad \frac{N}{N_o} = 0.99056$$

1 %





5.  $661.662 \text{ keV},$   
 $1173.237 \text{ keV}$      $1332.51 \text{ keV}$  .

600 keV

가 1 mm

1 %

가

.

III-2.

가

가

.

.

.

.

0.42 %

<sup>152</sup>Eu

<sup>152</sup>Eu

100 - 1500 keV

가

가

가

.

.

<sup>60</sup>Co, <sup>137</sup>Cs

600 keV

[6]

<sup>152</sup>Eu

.

가

(Transition Probability),

(Gamma Emission Probability),

(Conversion Electron

Coefficient)

1

. 2 x 10<sup>5</sup>

1

6

6

1

.

.

200 keV

1

2

.

,

$$\log(\epsilon_\gamma) = A + B \log(E_\gamma) + C \log(E_\gamma)^2$$

가 200 keV

p-type Ge

knee point 가

.

6

121 keV

170 keV

가

200

keV

가 200 keV

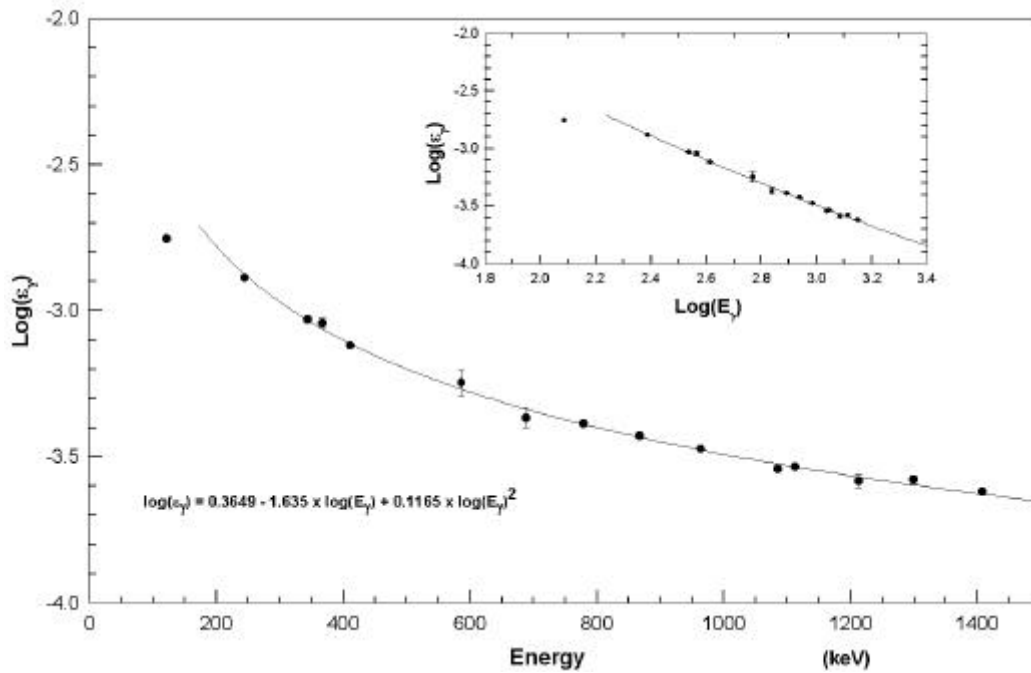
가

.

. [ ]

$E_\gamma$ (keV)	$Q_\gamma$	$P_\gamma$	$\alpha_t$
121.7824 ± 0.006	61.5 ± 0.6	28.4065 ± 0.00277	1.065
244.692 ± 0.0006	8.35 ± 0.06	7.5361 ± 0.00054	0.108
344.275 ± 0.003	27.5 ± 0.3	26.4423 ± 0.00288	0.04
367.789 ± 0.00017	1.5 ± 0.6	28.4065 ± 0.00277	1.065
411.115 ± 0.0003	2.3 ± 0.03	2.2461 ± 0.00025	1.065
586.294 ± 0.006	0.468 ± 0.01	0.4575 ± 0.000096	0.023
688.678 ± 0.0007	0.88 ± 0.07	0.8462 ± 0.0007	1.065
778.903 ± 0.00004	12.98 ± 0.004	12.9560 ± 0.00004	0.00185
810.459 ± 0.0003	0.317 ± 0.03	0.317 ± 0.0003	0
867.388 ± 0.00006	4.24 ± 0.006	4.24 ± 0.00006	0
919.401 ± 0.00088	0.435 ± 0.088	0.4347 ± 0.00088	1.065
964.131 ± 0.00006	14.637 ± 0.006	14.2976 ± 0.00006	0.023
1085.914 ± 0.00008	10.11 ± 0.008	10.0887 ± 0.00008	1.065
1112.116 ± 0.0006	13.59 ± 0.06	13.5629 ± 0.0006	0.002
1212.95 ± 0.0001	1.424 ± 0.01	1.4230 ± 0.0001	0.00073
1299.124 ± 0.0001	1.63 ± 0.01	1.63 ± 0.0001	0
1408.011 ± 0.0012	20.81 ± 0.12	20.7984 ± 0.0012	1.065

$Q_\gamma$ : Absolute Intensity.  $P_\gamma$ : Gamma-Ray Emission Probability  $\alpha_t$ : Conversion Electron Coefficient.



6.

Ge

Log - Log

661.662 keV, 1173.237 keV 1332.51 keV  
<sup>137</sup>Cs <sup>60</sup>Co  
 2 3 6 1 2

2 . <sup>137</sup>Cs <sup>60</sup>Co

$E_\gamma$	$Q_\gamma$	$P_\gamma$	$\alpha_t$
1173.239 ± 0.004	99.91 ± 0.6	99.8933 ± 0.02	0.000167
1332.503 ± 0.005	99.9989 ± 0.0006	99.9862 ± 0.0006	0.000127
661.662 ± 0.003	94.6 ± 0.3	85.2483 ± 0.02997	0.1097

3 . 6 1 2

Nuclides	$E_\gamma$	Order of Fitting	Activity (μCi)
<sup>137</sup> Cs	661.662 keV	1 st.	1.044
		2 nd.	1.060
<sup>60</sup> Co	1173.237 keV	1 st.	1.011
		2 nd.	1.003
<sup>60</sup> Co	1332.501 keV	1 st.	1.021
		2 nd.	1.002

III-3.

Ge

(Combined Uncertainty)

[7]

15 %

4

4.

	(a)	(b)	(c)	(d)
(%)	1	0.1	1	0.42
(%)	$(a^2+b^2+c^2+d^2)^{1/2} \approx 1.5$			

III-4.

. 6 1 2  
 1.5 %  
 ( 4 ) 가 가  $\chi^2$   
 2  $\chi^2 = 0.996$  1 0.001 2  
 .  $^{60}\text{Co}$  1173.237 keV  
 1332.51 keV .  
 . 3 2  
 1.003  $\mu\text{Ci}$  1.002  $\mu\text{Ci}$  1173.237 keV 1332.51  
 keV 가 1332.51 keV  
 $^{60}\text{Co}$  .  
 2001 3 1 0  $^{60}\text{Co}$  1.0023  $\mu\text{Ci}$ ,  $^{137}\text{Cs}$  1.0600  
 $\mu\text{Ci}$  1.5 % .

IV.

$^{137}\text{Cs}$  가  $^{60}\text{Co}$   
 .  
 1173.237 keV 1332.51 keV 661.662 keV,  
 .  
 Ge .

