U.S. Department of Commerce
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National Bureau of Standards
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National Bureau of Standards
Certificate
Standard Reference Material 4370

Radioactivity Standard

Europium-152

This Standard Reference Material consists of europium-152 in grams of carrier solution in a flame-sealed borosilicate-glass ampoule. The solution, which contains 269 micrograms of europium per gram of approximately 1 M hydrochloric acid, has a density of 1.016 g/mL at 19.5°C.

The radioactivity concentration of the europium-152 as of 1200 EST May 1, 1978, was

$$*7.196 \times 10^4\ s^{-1}g^{-1} \pm 1.4\%*.$$

Accurately weighed and dried aliquots of a master solution were measured, by photon counting, in the National Bureau of Standards 4π, 20.32-cm-diameter, NaI(Tl) well crystals. The solution from which this Standard Reference Material was prepared is a quantitative dilution of the master solution.

The uncertainty in the radioactivity concentration, 1.4 percent, is the linear sum of 0.11 percent, which is the limit of the random error of the sodium iodide measurements at the 99-percent confidence level ($4.604\ S_m$, where S_m is the standard error computed from five measurements) and 1.3 percent, which is the sum of the estimated upper limits of conceivable systematic errors.

The photon spectrum was examined with Ge(Li) and pure Ge spectrometers and the material was found to contain europium-154 and gadolinium-153 whose activities, as of the calibration date, were 0.4 percent and 0.15 percent, respectively, of the europium-152 activity. No other photon-emitting impurities were observed. The limit of the photon-emission rate at any given energy due to other impurities is estimated to be less than 0.1 percent of the emission rate of the 1408-keV gamma ray of europium-152, provided that the impurity photons are separated in energy by 5 keV or more from photons of equal or greater intensity emitted by europium-152, europium-154, or gadolinium-153.

(over)

The europium-152 activity, A, was obtained using the formula

$$A = T / [e_1 + f_2.e_2 + f_3.e_3],$$

where T is the total count rate, derived from an extrapolation to zero energy, f_2(= 0.004) and f_3(= 0.0015) are the ratios of the activities of europium-154 and gadolinium-153, respectively, to that of europium-152, and e_1(= 0.959), e_2(= 0.885) and e_3(= 0.874) are the total detection efficiencies for europium-152, europium-154 and gadolinium-153, respectively, calculated using the known decay schemes and the experimentally determined total efficiency curve for the 20.32-cm-diameter well crystals.

This Standard Reference Material was prepared in the Center for Radiation Research, Radioactivity Section, W. B. Mann, Chief.

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J. Paul Cali, Chief
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NOTES ON THE USE OF EUROPIUM-152 STANDARDS

The following data are provided for the convenience of users of ^{152}Eu sources. The gamma-ray probabilities given in Table I are the values resulting from an intercomparison organized by the International Committee for Radionuclide Metrology, as given in a report (PTB-Ra-7) issued by the Physikalisch-Technische Bundesanstalt, Braunschweig, West Germany.

CAUTION:

Many of the beta particles, x rays, and gamma rays from ^{152}Eu are emitted in coincidence. Therefore, summing corrections should be considered when these standards are used for establishing the efficiency of a detector as a function of energy [1,2]. If, under given measurement conditions, the total count rate observed is T, then the summing corrections for most gamma rays, expressed as fractions of the count rates that would be observed if there were no coincidences, are of the order of T/A, where A is the activity. With a point source directly on a Ge(Li) detector window, for example, the summing corrections for some lines can be as much as 25 percent. For a 70cm^3 Ge(Li) detector with a point source at 10cm, the summing corrections for most gamma rays are on the order of 1 percent.

TABLE I

Recommended values of gamma-ray probabilities and half-life for ^{152}Eu. The values marked with an asterisk are for gamma rays emitted from ^{154}Eu and correspond to a ^{154}Eu/^{152}Eu activity ratio of 0.004 (0.4%). The dagger signifies two lines separated by less than 1 keV. The uncertainties are given at the 68% confidence limit.

PHOTON ENERGY (keV)	*PHOTON PROBABILITY PER DECAY*	*UNCERTAINTY (%)*
121.8	0.2837	0.83
123.1	0.0017*	--
244.7	0.0751	0.71
247.9	0.0003*	--
344.3	0.2658	0.68
411.1	0.02234	0.57
444.0†	0.03121	0.56
778.9	0.1296	0.53
964.0†	0.1462	0.40
1085.8	0.1016	0.45
1112.1	0.1356	0.41
1408.0	0.2085	0.40

ISOTOPE	*HALF-LIFE (y)*
^{152}Eu	13.3 ± 0.1
^{154}Eu	8.6 ± 0.1
^{153}Gd	0.663 ± 0.003

SUMMING CORRECTIONS

If the efficiency of a Ge(Li) spectrometer is to be determined for a measurement geometry where the effective solid angle, as a fraction of 4π steradians, is on the order of 0.01 or greater, the effects of summation of coincident quanta should be considered [1,2]. The following formulae are satisfactory for summing corrections up to approximately ten percent[1]. For larger summing corrections second order effects must also be taken into account[2].

If two quanta, 1 and 2, are emitted in coincidence, then the relative summation loss from peak 1 is given by[1]

$$v(1) = \frac{w_{\gamma c}(1,2) \cdot \varepsilon_t(2)}{w_\gamma(1)} \leq \varepsilon_t(2),$$

where $w_{\gamma c}(1,2)$ is the probability of simultaneous emission of both quanta, $w_\gamma(1)$ is the probability of emission of quantum 1, and $\varepsilon_t(2)$ is the total detection efficiency for quantum 2. The measured count rate N(1) is to be divided by [1-v(1)]. A corresponding correction is also to be made for all other quanta that are emitted in coincidence with quantum 1. Note that $\varepsilon_t(2)$ is the probability that quantum 2 causes a pulse of any magnitude in the detector, rather than just the probability of a count in the full-energy peak. [The latter efficiency is denoted by $\varepsilon(2)$.] For a large-volume detector in the energy region above 100 keV, the value of ε_t varies slowly with energy and therefore need only be determined at a few points. The quotients $w_{\gamma c}(1,2)/w_\gamma(1)$ are obtained from the decay scheme are presented in Table II for the major gamma rays from ^{152}Eu. It was assumed that angular correlations and triple coincidences can be neglected.

Similarly, for a transition 3 in parallel with a cascade 1-2, the count rate in the full-energy peak of 3 increases due to summation. The relative increase is given by[1]

$$z(3) = \frac{w_{\gamma c}(1,2) \cdot \varepsilon\ (1) \cdot \varepsilon(2)}{w_\gamma(3) \cdot \varepsilon(3)},$$

and the measured count rate N(3) is to be divided by [1+z(3)]. Here it is ε, rather than ε_t, that is important. The quotients $w_{\gamma c}(1,2)/w_\gamma(3)$ are presented in Table III for the major gamma rays from ^{152}Eu.

TABLE II.[a]

Probability of simultaneous emission of quanta 1 and 2 from ^{152}Eu, relative to the probability of emission of quantum 1. E_1 and E_2 are the photon energies. A single correction term is given for the coincidence of quantum 1 with the sum of all the x-ray emission (E_2 = 40 keV) following electron capture and internal conversion. A weighted mean value of the correction term was calculated for the two lines with E_1 = 444 keV.

E_1 (keV)	E_2 (keV)	$\frac{w_{\gamma c}(1,2)}{w_{\gamma}(1)}$	E_1 (keV)	E_2 (keV)	$\frac{w_{\gamma c}(1,2)}{w_{\gamma}(1)}$
122	40	0.79	411	344	0.96
	245	0.13		368	0.50
	444	0.035	444	40	0.97
	689	0.014		122	0.30
	867	0.080		245	0.11
	964	0.24		964	0.52
	1005	0.013		1086	0.36
	1112	0.23	779	344	0.96
	1213	0.027	964	40	1.00
	1408	0.35		122	0.47
	1458	0.008		444	0.12
245	40	1.00	1086	40	0.78
	122	0.47		444	0.12
	444	0.054	1112	40	1.00
	867	0.57		122	0.47
	1005	0.10	1408	40	1.00
	1213	0.19		122	0.47
344	368	0.044			
	411	0.085			
	779	0.48			
	1090	0.06			
	1299	0.06			

a. From reference 1.

TABLE III.[b]

Probability of simultaneous emission of quanta 1 and 2 from ^{152}Eu, relative to the probability of emission of quantum 3 with an energy $E_3 = E_1 + E_2$.

E_3 (keV)	E_1 (keV.)	E_2 (keV)	$\frac{W_{\gamma c}(1,2)}{W_\gamma(3)}$
779	368	411	0.07
1086	964	122	0.68
1112	867	245	0.28
1408	444	964	0.08

b. From reference 1.

REFERENCES

1. K. Debertin et. al., PTB Communication 85 (1975) 187. (Physikalisch-Technische Bundesanstalt, 33 Braunschweig, Bundasallee 100, Germany).
2. G. J. McCallum and G. E. Coote, Nucl. Inst. Meth. 130 (1975) 189.