National Institute of Standards & Technology
Certificate

Standard Reference Material 4241C
Barium-133 Radioactivity Standard

This Standard Reference Material (SRM) consists of a dried deposit of radioactive barium-133 chloride and non-radioactive barium chloride on a filter-paper disk sealed between two layers of polyester tape that are supported on an aluminum annulus. The SRM is intended for the calibration of gamma-ray spectrometry systems.

Radiological Hazard

The SRM contains barium-133 with a total activity of less than 200 kBq. Barium-133 decays by electron capture and during the decay process X-rays and gamma rays with energies from 4 keV to 400 keV are emitted. Most of these photons escape from the SRM and can represent a radiation hazard. Approximate unshielded dose rates at several distances (as of the reference time) are given in note [a]*. Appropriate shielding and/or distance should be used to minimize personnel exposure. The SRM should be used only by persons qualified to handle radioactive material.

Chemical Hazard

The SRM contains less than 7 µg of barium chloride. The material does not represent a significant chemical hazard.

Storage and Handling

The SRM should be stored and used at a temperature between 5 and 40 °C. If the point source is properly handled and stored, it should remain stable until at least January 2009.

The SRM should always be clearly marked as containing radioactive material. If the SRM is transported it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The SRM is a dangerous good (hazardous material) because of the radioactivity.

Preparation

This Standard Reference Material was prepared in the Physics Laboratory, Ionizing Radiation Division, Radioactivity Group, L.R. Karam, Group Leader. The overall technical direction and physical measurements leading to certification were provided by L.L. Lucas of the Radioactivity Group and D.B. Golas, Nuclear Energy Institute Research Associate.

The support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the Standard Reference Materials Program by N.M. Trahey.

Gaithersburg, Maryland 20899
February 1999

Thomas E. Gills, Chief
Standard Reference Materials Program

PROPERTIES OF SRM 4241C
(Certified values are shown in bold type)

Source identification number	NIST SRM 4241C-
Physical Properties:	
Source description	Dried deposit of barium chloride on a filter-paper disk sealed between two layers of polyester tape that are supported on an aluminum annulus
Point-source specifications	Aluminum annulus O.D. 5.4 cm Aluminum annulus I.D. 3.8 cm Aluminum annulus thickness 0.05 cm Polyester tape thickness 0.006 cm Filter paper diameter 0.6 cm
Chemical Properties:	

Point-source composition	Chemical Formula	Mass (g)	
	$BaCl_2$	7×10^{-4}	
	$^{133}BaCl_2$	3×10^{-8}	

Radiological Properties:	
Radionuclide	**Barium-133**
Reference time	**1200 EST, 1 January 1999**
Activity	**kBq**
Relative expanded uncertainty (k=2)	**0.60%** [b]
Photon-emitting impurities	None detected [c]
Half lives used	Barium-133: (10.52 ± 0.13) a [d] Radium-226: (1600 ± 7) a [d]
Measuring instrument	Pressurized "4π"γ ionization chamber A calibrated using a barium-133 solution whose activity was determined by $4\pi(e+X)$-γ-anticoincidence counting

EVALUATION OF THE UNCERTAINTY OF THE ACTIVITY [b]*

Input Quantity x_i, the source of uncertainty (and individual uncertainty components where appropriate)	Method Used To Evaluate $u(x_i)$, the standard uncertainty of x_i (A) denotes evaluation by statistical methods (B) denotes evaluation by other methods	Relative Uncertainty Of Input Quantity, $u(x_i)/x_i$, (%) [e]	Relative Sensitivity Factor, $\|\partial y/\partial x_i\| \cdot (x_i/y)$ [f]	Relative Uncertainty Of Output Quantity, $u_i(y)/y$, (%) [g]
PIC A net response per gram of master solution, measured relative to RRS10 [h]	Standard deviation of the mean for 500 repeated measurements (A)	0.003	1.0	0.003
PIC A background response, measured relative to RRS10	Standard deviation of the mean for >250 repeated measurements (A)	0.25	0.002 [i]	0.0005
PIC A net response for RRS200, measured relative to RRS10	Standard deviation of the mean for >100 repeated measurements (A)	0.06	1.0	0.06
PIC A net response per Bq of barium-133 in solution, measured relative to RRS200.	Standard deviation of the mean for 240 repeated measurements (A)	0.02	1.0	0.02
Gravimetric measurements	Estimated (B)	0.10	1.0	0.10
Half life of barium-133 Half life of radium-226	Standard uncertainty of the half life (A)	1.24 [j] 0.44 [j]	0.008 [k] 0.007 [k]	0.009 0.003
Activity used to calibrate PIC A net response per Bq of barium-133 in solution	Standard uncertainty of the activity determined by $4\pi(e+X)$-γ-anticoincidence counting (B)	0.22	1.0	0.22
Live-time [m]	Estimated (B)	0.10	1.0	0.10
PIC A charge collection	Estimated (B)	0.05	1.0	0.05
Source Positioning	Estimated (B)	0.05	1.0	0.05
Photon-emitting impurities	Limit of detection (B) [n]	100.	0.001	0.10

Relative Combined Standard Uncertainty of the Output Quantity, $u_c(y)/y$, (%)	0.30
Coverage Factor, k	<u>x 2</u>
Relative Expanded Uncertainty of the Output Quantity, U/y, (%)	0.60

[a]   The Sievert is the SI unit for dose equivalent. See reference [1]. One µSv is equal to 0.1 mrem.

Distance from Source (cm):	1	30	100
Approximate Dose Rate (µSv/h):	30	0.3	<0.1

[b]   The reported value, y, of activity at the reference time was not measured directly but was derived from measurements and calculations of other quantities. This can be expressed as $y = f(x_1, x_2, x_3, \ldots x_n)$, where f is a mathematical function derived from the assumed model of the measurement process.

The value, x_i, used for each input quantity i has a **standard uncertainty**, $u(x_i)$, that generates a corresponding uncertainty in y, $u_i(y) = |\partial y/\partial x_i| \cdot u(x_i)$, called a **component of combined standard uncertainty** of y.

The **combined standard uncertainty** of y, $u_c(y)$, is the positive square root of the sum of the squares of the components of combined standard uncertainty.

The combined standard uncertainty is multiplied by a **coverage factor** of $k = 2$ to obtain U, the **expanded uncertainty** of y.

Since it can be assumed that the possible estimated values of the massic activity are approximately normally distributed with approximate standard deviation $u_c(y)$, the unknown value of the massic activity is believed to lie in the interval $y \pm U$ with a level of confidence of approximately 95 percent.

For further information on the expression of uncertainties, see references [2] and [3].

[c]   Estimated limits of detection for photon-emitting impurities are:
0.003 $\gamma \cdot s^{-1} \cdot Bq^{-1}$ for energies between 15 keV and   77 keV,
0.0006 $\gamma \cdot s^{-1} \cdot Bq^{-1}$ for energies between 85 keV and 272 keV,
0.0012 $\gamma \cdot s^{-1} \cdot Bq^{-1}$ for energies between 280 keV and 352 keV,
0.0006 $\gamma \cdot s^{-1} \cdot Bq^{-1}$ for energies between 360 keV and 379 keV, and
0.00002 $\gamma \cdot s^{-1} \cdot Bq^{-1}$ for energies between 387 keV and 3300 keV, provided that the photons are separated in energy by 4 keV or more from photons emitted in the decay of barium-133.

[d]   The stated uncertainty is the standard uncertainty. See reference [5].

[e]   Relative standard uncertainty of the input quantity x_i.

[f]   The relative change in the output quantity y divided by the relative change in the input quantity x_i. If $|\partial y/\partial x_i| \cdot (x_i/y) = 1.0$, then a 1% change in x_i results in a 1% change in y. If $|\partial y/\partial x_i| \cdot (x_i/y) = 0.05$, then a 1% change in x_i results in a 0.05% change in y.

[g]   Relative component of combined standard uncertainty of output quantity y, rounded to two significant figures or less. The relative component of combined standard uncertainty of y is given by $u_i(y)/y = |\partial y/\partial x_i| \cdot u(x_i)/y = |\partial y/\partial x_i| \cdot (x_i/y) \cdot u(x_i)/x_i$. The numerical values of $u(x_i)/x_i$, $|\partial y/\partial x_i| \cdot (x_i/y)$, and $u_i(y)/y$, all dimensionless quantities, are listed in columns 3, 4, and 5, respectively. Thus, the value in column 5 is equal to the value in column 4 multiplied by the value in column 3. The input quantities are independent, or very nearly so. Hence the covariances are zero or negligible.

[h]   The response of pressurized ionization chamber A (PIC A) is determined from measurement of the time required to collect a given amount of charge on a stable fixed capacitor. All of the response measurements in the NIST pressurized ionization chambers are made relative to the response of one or more artifact standards. These artifact standards consist of microgram quantities of aged radium-226 in small welded stainless-steel capsules. These capsules are encapsulated in plastic rods whose dimensions are similar to those of the standard NIST ampoule. The artifact standards are called **Radium Reference Sources** and are designated as RRSx, where x is the nominal mass (in micrograms) of radium-226 in the capsule.

[i] $|\partial y/\partial x_i| \cdot (x/y)$ = (average background response)/(average net sample response)

[j]   The relative standard uncertainty of $\lambda \cdot t$ is determined by the relative standard uncertainty of λ (i.e., of the half life). The relative standard uncertainty of t is negligible.

[k] $|\partial y/\partial x_i| \cdot (x/y) = |\lambda \cdot t|$

[m]   The live time is determined by counting the pulses from a gated oscillator.

[n]   The standard uncertainty for each undetected impurity that might reasonably be expected to be present is estimated to be equal to the estimated limit of detection for that impurity, i.e. $u(x_i)/x_i = 100\%$. $|\partial y/\partial x_i| \cdot (x/y) = \{(\text{response per Bq of impurity})/(\text{response per Bq of Ba-133})\} \cdot \{(\text{Bq of impurity})/(\text{Bq of Ba-133})\}$. Thus $u_i(y)/y$ is the relative change in y if the impurity were present with a massic activity equal to the estimated limit of detection.

REFERENCES

[1]   International Organization for Standardization (ISO), *ISO Standards Handbook - Quantities and Units*, 1993. Available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036, U.S.A. 1-212-642-4900.

[2]   International Organization for Standardization (ISO), *Guide to the Expression of Uncertainty in Measurement*, 1993. Available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036, U.S.A. 1-212-642-4900. (Listed under ISO miscellaneous publications as "ISO Guide to the Expression 1993".)

[3]   B. N. Taylor and C. E. Kuyatt, *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*, NIST Technical Note 1297, 1994. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20407, U.S.A.

[4]   National Council on Radiation Protection and Measurements Report No. 58, *A Handbook of Radioactivity Measurements Procedures*, Second Edition, 1985. Available from the National Council on Radiation Protection and Measurements, 7910 Woodmont Avenue, Bethesda, MD 20814 U.S.A.

[5]   Evaluated Nuclear Structure Data File (ENSDF), January 1999.

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ADDENDUM

Corrections to Certificate dated February 1999

On page 1 of 6, line 2: delete "on a filter paper disk"

On page 3 of 6, Source description: delete "on a filter paper disk"

On page 3 of 6, Point-source specifications: delete "Filter paper diameter 0.6 cm"

Note: The source was inadvertently described incorrectly on the Certificate. The dried deposit of barium chloride is <u>not</u> on a filter paper disk. The source was prepared by depositing a standardized solution of barium chloride directly on the 0.006 cm thick polyester tape, drying the solution, and covering the deposit with another layer of the same tape. The deposit contains less than 7 µg of barium chloride and is centered in the annular ring to within 2 mm. Based on recent Fuji plate imaging, the diameter of the deposit is approximately 3.5 ± 0.5 mm.

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