National Institute of Standards & Technology

Certificate

Standard Reference Material 4203D
Cobalt-60 Radioactivity Standard

This Standard Reference Material (SRM) consists of a dried deposit of cobalt 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 cobalt-60 with a total activity of approximately 40 kBq. Cobalt-60 decays by beta-particle emission. Some of the beta particles escape from the SRM. During the decay process X-rays and gamma rays with energies from 8 to 2500 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 40 μg of cobalt 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 2005.

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, J.M.R. Hutchinson, 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
June 1995 (Text only revised November 1997)

Thomas E. Gills, Chief
Standard Reference Materials Program

*Notes and references are on pages 5 and 6.

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PROPERTIES OF SRM 4203D
(Certified values are shown in bold type)

Source identification number	NIST SRM 4203D-number~
Physical Properties:	
Source description	Dried deposit of cobalt 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: $CoCl_2$ — Mass (g): 4×10^{-5} Chemical Formula: $^{60}CoCl_2$ — Mass (g): 3×10^{-9}
Radiological Properties:	
Radionuclide	**Cobalt-60**
Reference time	**1200 EST, 1 January 1995**
Activity	**activity~ kBq·g^{-1}**
Relative expanded uncertainty (*k*=2)	**0.56%** [b]
Photon-emitting impurities	None detected [c]
Half lives used	Cobalt-60: (5.2714 ± 0.0005) a [d] Radium-226: (1600 ± 7) a [d]
Measuring instrument	Pressurized "4π"γ ionization chamber A calibrated using a cobalt-60 solution whose activity was determined by 4πß-γ-coincidence and anticoincidence counting

*Notes and references are on pages 5 and 6.

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, $\lvert \partial y/\partial x_i \rvert \cdot (x_i/y)$ [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 350 repeated measurements (A)	0.02	1.0	0.02
PIC A background response, measured relative to RRS10	Standard deviation of the mean for >250 repeated measurements (A)	0.25	0.001 [i]	0.0003
PIC A net response for RRS100, 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 cobalt-60 in solution, measured relative to RRS100.	Standard deviation of the mean for 720 repeated measurements (A)	0.02	1.0	0.02
Gravimetric measurements	Estimated (B)	0.10	1.0	0.10
Half life of cobalt-60 Half life of radium-226	Standard uncertainty of the half life (A)	0.01 [j] 0.44 [j]	0.03 [k] 0.006 [k]	0.0003 0.003
Activity used to calibrate PIC A net response per Bq of cobalt-60 in solution	Standard uncertainty of the activity determined by 4πß-γ-coincidence and anticoincidence (B)	0.20	1.0	0.20
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, $u_c(y)/y$, (%)				0.28
Coverage Factor, k				x 2
Relative Expanded Uncertainty of the Output Quantity, U/y, (%)				0.56

*Notes and references are on pages 5 and 6.

NOTES

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

Distance from Ampoule (cm):	1	30	100
Approximate Dose Rate (μSv/h):	50	0.5	<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, $u_i(y) \equiv |\partial y/\partial x_i| \cdot u(x_i)$, 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:
0.001 $\gamma \cdot s^{-1} \cdot Bq^{-1}$ for energies between 90 and 1169 keV,
0.0003 $\gamma \cdot s^{-1} \cdot Bq^{-1}$ for energies between 1177 and 1328 keV, and
0.0001 $\gamma \cdot s^{-1} \cdot Bq^{-1}$ for energies between 1336 and 1900 keV, provided that the photons are separated in energy by 4 keV or more from photons emitted in the decay of cobalt-60.

[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 $u_i(y)/y \equiv |\partial y/\partial x_i| \cdot u(x_i)/y = |\partial y/\partial x_i| \cdot (x_i/y) \cdot u(x_i)/x_i$. 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] $|\partial y/\partial x_i| \cdot (x_i/y)$ = (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] $|\partial y/\partial x_i| \cdot (x_i/y) = |\lambda \cdot t|$

[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%. $|\partial y/\partial x_i| \cdot (x_i/y)$ = {(response per Bq of impurity)/(response per Bq of Co-60)}•{(Bq of impurity)/(Bq of Co-60)}. 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 1995.