National Institute of Standards & Technology

Certificate

Standard Reference Material® 4251d

Barium-133 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive Barium-133 in a suitably stable and homogeneous matrix. It is intended primarily for the calibration of instruments that are used to measure radioactivity and for the monitoring of radiochemical procedures. A unit of SRM 4251d consists of approximately 5 mL of a solution, whose composition is specified in Tables 1 and 2, contained in a flame-sealed borosilicate-glass ampoule [1].

The certified **Barium-133** massic activity, at a **Reference Time of 1200 EST, 13 July 2018**, is:

(382.56 ± 4.59) kBq•g^{-1}.

A NIST certified value, as used within the context of this certificate, is a value for which NIST has the highest confidence in its uncertainty assessment. It is a "measurement result" [2] obtained directly or indirectly from a "primary reference measurement procedure" [3]. The certified value is traceable to the derived SI unit, becquerel (Bq).

Additional physical, chemical, and radiological properties for this SRM, as well as details on the standardization method, are given in Tables 1 and 2. Uncertainties for the certified quantities are expanded ($k = 2$). The uncertainties are calculated according to the ISO/JCGM and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analysis.

Expiration of Certification: The certification of **SRM 4251d** is valid indefinitely, within the measurement uncertainty specified, provided that the SRM is handled and stored properly and that no evaporation or change in composition has occurred. The solution matrix, in an unopened ampoule, is homogeneous and stable within its half-life-dependent useful lifetime provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Use and Handling"). Periodic recertification of this SRM is not required. The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification before the expiration of this certificate, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

Radiological and chemical hazard: Consult the Safety Data Sheet (SDS), enclosed with the SRM shipment, for radiological and chemical hazard information.

This SRM was prepared the NIST Physical Measurement Laboratory, Radiation Physics Division, under the direction of B.E. Zimmerman, Acting Group Leader of the Radioactivity Group. Overall technical direction and physical measurement leading to certification were provided by R. Fitzgerald, R. Collé and L. Laureano-Pérez of the NIST Radiation Physics Division, Radioactivity Group. Photon-emitting-impurity analyses were provided by L. Pibida.

Support aspects involved in the issuance of this SRM were coordinated through the NIST Office of Reference Materials.

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Table 1. Certified Massic Activity of SRM 4251d

Radionuclide	**Barium-133**
Reference time	**1200 EST, 13 July 2018**
Massic activity of the solution	**382.56 kBq•g^{-1}**
Relative expanded uncertainty (k = 2)	**1.2 %** [(a)]

(a) The uncertainties on certified values are expanded uncertainties, $U = ku_c$. The quantity u_c is the combined standard uncertainty calculated according to the ISO and NIST Guides [4, 5]. The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4251d

Source description	Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1]
Solution composition	88 µg•g^{-1} Ba^{+2} in 0.98 mol•L^{-1} HCl
Solution density	(1.015 ± 0.002) g•mL^{-1} at 22.6 °C[(a)]
Solution mass	(5.063 ± 0.003) g[(a)]
Photon-emitting impurities	None detected [(b)]
Half-lifes used [6]	^{133}Ba: (10.539 ± 0.006) a [(c)]
Calibration methods (and instruments)	The certified massic activity for ^{133}Ba was obtained by 4π (e, X) - γ(NaI) live-timed anti-coincidence (LTAC) counting. Confirmatory measurements were performed by five other methods: (i) 4παβ liquid scintillation (LS) spectrometry (with ^{3}H standard efficiency tracing for β efficiencies) and two counters; (ii) 4παβ liquid scintillation (LS) spectrometry (with ^{55}Fe standard efficiency tracing for β efficiencies) and two counters (iii) an LS-based 4παβ triple-to-double coincidence ratio (TDCR) method; (iv) 4πγ ionization chamber measurements using NIST chamber "A"; and (v) HPGe γ-ray spectrometry.[(d)]

(a) The stated uncertainty is two times the standard uncertainty [5].
(b) The estimated limits of detection for photon-emitting impurities, expressed as massic photon emission rates (numbers of photons per second per gram), are:

336 s^{-1}•g^{-1} for energies between 15 keV and 95 keV,
150 s^{-1}•g^{-1} for energies between 100 keV and 280 keV,
276 s^{-1}•g^{-1} for energies between 285 keV and 370 keV,
142 s^{-1}•g^{-1} for energies between 380 keV and 400 keV,
16 s^{-1}•g^{-1} for energies between 410 keV and 1430 keV,
24 s^{-1}•g^{-1} for energies between 1440 keV and 1480 keV, and
13 s^{-1}•g^{-1} for energies between 1490 keV and 2000 keV,

provided that the photons are separated in energy by 4 keV or more from photons emitted in the decay of ^{133}Ba.
(c) The stated uncertainty is the standard uncertainty. See reference [6].
(d) The expanded (k = 2) uncertainties for the five confirmatory methods were: (i) 2.4 %; (ii) 2.4 %; (iii) 1.2 %; (iv) 1.6 %; and (v) 1.7 %, respectively. All of the confirmatory measurements agreed with the certified value within their respective measurement uncertainties. The results for methods (iii) and (iv) agreed with the certified anti-coincidence value to better than 0.2 %.

Table 2. Uncertainty evaluation for the massic activity of SRM 4251d

Uncertainty component		Assessment Type[a]	Relative standard uncertainty contribution on massic activity of ^{133}Ba (%)
1	Measurement repeatability; standard deviation of the distribution for 6 samples, each measured once	A	0.35
2	Background; estimated by half the difference of using the middle background measurement rather than the background measurement closest in time to each sample measurement	A	0.06
3	Extrapolation fit; median uncertainty on least-squares intercept value for a single set of γ-ray gates	A	0.05
4	Analysis model, standard deviation between extrapolation intercept for two gate settings	A	0.46
5	Dead time; from previous systematic studies	B	0.1
6	Gravimetric (mass) measurements; includes uncertainty on average sample mass and dilution to SRM solution. From previous systematic studies.	B	0.05
7	^{133}Ba decay corrections; from DDEP half-life of ^{133}Ba of (10.539 ± 0.006) a	B	0.00004
8	Impurity limit, from limit (no impurities seen) from γ-ray spectrometry	A	0.04
Relative combined standard uncertainty			**0.60**
Relative expanded uncertainty (k = 2)			**1.2**

(a) = (A) denotes evaluation by statistical methods; (B) denotes evaluation by other methods.

INSTRUCTIONS FOR USE AND HANDLING

Storage: SRM 4251d should be stored and used at a temperature between 5 °C and 65 °C. The ampoule (or any subsequent container) should always be clearly marked as containing radioactive material.

Handling: If the ampoule is transported, it should be packed, marked, labeled, and shipped in accordance with the applicable national, international, and carrier regulations. The solution in the ampoule is a dangerous good (hazardous material) because of both the radioactivity and the strong acid. The ampoule should be opened only by persons qualified to handle both radioactive material and alkaline and/or acidic solutions. Appropriate shielding and/or distance should be used to minimize personnel exposure. Refer to the SDS for further information.

REFERENCES

[1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*; available at https://www.nist.gov/pml/radiation-physics/ampoule-specifications-and-opening-procedure (accessed Nov 2017). Note: This SRM is contained in a generic borosilicate-glass ampoule and not in the standard NIST ampoule.

[2] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)*; (2008 version with Minor Corrections), 3rd edition; Joint Committee for Guides in Metrology (JCGM): BIPM, Sevres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2017).

[3] JCGM 200:2012; *International Vocabulary of Metrology - Basic and General Concepts and Associated Terms (VIM)*; (2008 version with Minor Corrections), 3rd edition; JCGM: BIPM, Sevres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2017).

[4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement*; (GUM 1995 with Minor Corrections), JCGM: BIPM, Sevres Cedex, France (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2017).

[5] Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297, U.S. Government Printing Office: Washington, DC (1994); available at https://www.nist.gov/pml/productsservices/special-publications-tutorials (accessed Nov 2017).

[6] Chechev, V.P. and N.K. Kuzmenko ; *LNE-LNHB/CEA Table of Radionuclides*, ^{133}Ba; (October 2016); available at http://www.lnhb.fr/nuclides/Ba-133_tables.pdf (accessed Oct 2018).

Users of this SRM should ensure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: telephone (301) 975-2200; fax (301) 926-4751; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.