National Institute of Standards & Technology

Certificate

Standard Reference Material® 4339b

Radium-228 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive radium-228 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 4339b 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 **radium-228** massic activity value, at a **Reference Time of 1200 EST, 07 October 2010**, is:

$$\mathbf{(195 \pm 14)\ Bq{\bullet}g^{-1}}$$

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 and NIST Guides [4,5]. Table 3 contains a specification of the components that comprise the uncertainty analyses.

Expiration of Certification: The certification of **SRM 4339b** 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 Handling and Storage”). Periodic recertification of this SRM is not required. The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of SRM Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification, 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 in the Physical Measurement Laboratory, Radiation and Biomolecular Physics Division, Radioactivity Group, M.P. Unterweger, Group Leader. The overall technical direction and physical measurement leading to certification and photon-emitting impurity analyses were provided by L. Pibida of the NIST Radioactivity Group, with production assistance by J. LaRosa, R. Collé, and L. Laureano-Pérez. Alpha-emitting impurity analyses were provided by J. LaRosa.

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 4339b

Radionuclide	**Radium-228[a]**
Reference time	**1200 EST, 07 October 2010**
Massic activity of the solution	**195 Bq•g^{-1}**
Relative expanded uncertainty (k = 2)	**7.2 %[b]**

[a] The final ^{228}Ra purification from the ^{232}Th mother solution was performed on 02 September 2010 0920 EST.
[b] 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 what is assumed to be an approximate 95 % level of confidence.

Table 2. Uncertified Information of SRM 4339b

Source description	Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1]
Solution composition	1.3 mol•L^{-1} HNO_3 with 19.8 µg•g^{-1} Ba^{+2}
Solution density	(1.034 ± 0.002) g•mL^{-1} at 20.8 °C[a]
Solution mass	(5.180 ± 0.003) g[a]
Photon-emitting impurities	^{226}Ra: < 0.5 Bq•g^{-1}[b]
Alpha-emitting impurities	^{232}Th: < 0.08 Bq•g^{-1}[c]
Half-lives used	^{228}Ra: (5.75 ± 0.04) a[d] [6] ^{228}Ac: (6.15 ± 0.02) h [7] ^{226}Ra: (1600 ± 7) a [8] ^{232}Th: (14.02 ± 0.06) x 10^9 a [9]
Calibration methods (and instruments)	The certified massic activity for ^{228}Ra was obtained by high-resolution gamma-ray spectrometry of three master solution ampoules (eleven separate determinations), as measured on three to five different spectrometers and geometries on each ampoule, and used assumed nuclear data for probabilities per decay for 16 gamma-ray transitions. Confirmatory measurements were performed by $2\pi\alpha$ spectrometry of ingrown ^{228}Th with a planar, ion-implanted Si detector.

[a] The stated uncertainty is two times the standard uncertainty. See reference 5.
[b] Based on gamma-ray spectrometry of forced-fitted peak at 186.2 keV and assuming a probability per decay of 0.0355 [6].
[c] The maximum ^{232}Th activity concentration in ^{228}Ra.
[d] The stated uncertainty is the standard uncertainty. See reference 5.

Table 3. Uncertainty Evaluation for the Massic Activity of SRM 4339b

	Uncertainty component	Assessment Type[a]	Relative standard uncertainty contribution on massic activity of ^{228}Ra (%)
1	Gamma-ray spectrometry precision; relative standard deviation of the grand mean on the average massic gamma-ray emission rates for 16 measured ^{228}Ac gamma-ray transitions. Each mean in the grand mean is based on 11 determinations with three sources in three to five different detectors. The uncertainty in the determination of the massic gamma-ray emission rate for any one transition in a given determination ranged from typically 0.5 % to 1.5 %. The relative standard deviation of the mean for the average of the 16 lines, for any one determination, was typically 1 %; whereas the relative standard deviation of the grand mean for the average of the 16 lines across all 11 determinations is 0.34 %[b]. Data passes normality test.	A	0.84
2	Uncertainty due to assumed gamma-ray probabilities per decay for the measured ^{228}Ac transitions [7]. The uncertainty on each transition has a shared (correlated) component of 2.5 % (see comments in [7]).	B	3.5
3	Detection efficiencies not embodied within component 1	B	0.4
4	Mass determinations for dilution factors and counting source preparations	B	0.1
5	Decay corrections for ^{228}Ra half-life uncertainty of 0.7 % [6]	B	0.003
6	Effect of ^{228}Ra and ^{228}Ac half-life uncertainties on secular equilibrium ratio	B	0.02
Relative combined standard uncertainty			**3.6**
Relative expanded uncertainty (k = 2)			**7.2**

[a] Letter A denotes evaluation by statistical methods; B denotes evaluation by other methods.
[b] Average massic gamma-ray emission rates of 11 geometries (R_γ) for 16 measured ^{228}Ac gamma-ray transitions with their respective energy (E_γ); assumed gamma-ray probabilities per decay (I_γ) and standard deviation of the mean (S_m).

E_γ (keV)	Assumed I_γ (%) [1]	Mean R_γ (s^{-1}•g^{-1})[i]	S_m (%)[ii]
129.065	2.50	1347	0.38
153.967	0.754	421.6	0.40
209.249	3.97	2264	0.55
270.245	3.55	2014	0.33
328.004	3.04	1822	0.43
338.32	11.4	6712	0.43
409.46	2.02	1185	0.29
463.002	4.45	2645	0.33
755.313	1.03	593.3	0.46
772.291	1.52	899.2	0.53
794.942	4.31	2588	0.35
835.704	1.7	995.3	0.42
911.196	26.2	15609	0.29
964.786	4.99	3007	0.35
968.96	15.9	9582	0.30
1588.2	3.06	1889	0.28

(i) Grand mean for n = 11 determinations with three sources in three to five different detectors.
(ii) Relative standard deviation of the grand mean on R_γ for n = 11.

INSTRUCTIONS FOR HANDLING AND STORAGE

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 SDS for further information.

Storage: SRM 4339b 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.

REFERENCES

[1] NIST Physical Measurement Laboratory; *Storage and Handling of Radioactive Standard Reference Materials, Ampoule Specifications and Opening Procedure*, available at http://www.nist.gov/pml/div682/grp04/srm.cfm (accessed Nov 2012). 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: BIPM, Sevres Cedex, France; p. 19 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[3] 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: BIPM, Sevres Cedex, France; p. 18 (2012); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Nov 2012).

[4] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement;* (ISO GUM 1995 with Minor Corrections), Joint Committee for Guides in Metrology: BIPM, Sevres Cedex, France (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Nov 2012).

[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 http://physics.nist.gov/Pubs/ (accessed Nov 2012).

[6] Luca, A.; June 2009, ^{228}Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-228_tables.pdf (accessed Nov 2012).

[7] Pearce, A.; January 2010, ^{228}Ac. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ac-228_tables.pdf (accessed Nov 2012).

[8] Christé, V. and M.M. Bé; December 2006, ^{226}Ra. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Ra-226_tables.pdf (accessed Nov 2012).

[9] Arinc, A.; September 2008, ^{232}Th. LNE-LNHB/CEA Table of Radionuclides, available at http://www.nucleide.org/DDEP_WG/Nuclides/Th-232_tables.pdf (accessed Nov 2012).

Users of this SRM should ensure that the Certificate in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 948-3730; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.