National Institute of Standards & Technology

Certificate

Standard Reference Material® 4329a

Curium-243 Radioactivity Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive curium-243 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 4329a 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 **Curium-243** massic activity, at a **Reference Time of 1200 EST, 15 May 2019**, is:

$$\mathbf{(30.53 \pm 0.17)\ Bq \bullet g^{-1}}.$$

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/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 4329a** 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 or register online) 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 March 1985 in the Center for Radiation Research, Nuclear Radiation Division, Radioactivity Group, under the direction of D.D Hoppes, Group Leader. Re-measurement was done in May 2019 in the NIST Physical Measurement Laboratory, Radiation Physics Division, Radioactivity Group under the direction of B.E. Zimmerman, Group Leader. Overall technical direction and physical measurement leading to certification were provided by R. Collé and L. Laureano-Pérez of the NIST Radiation Physics Division, Radioactivity Group. Photon-emitting-impurity analyses were provided by L. Pibida, also of the Radioactivity Group.

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 4329a

Radionuclide	**Curium-243**
Reference time	**1200 EST, 15 May 2019**
Massic activity of the solution[(a)]	**30.53 Bq•g^{-1}**
Relative expanded uncertainty (*k* = 2) [(b)]	**0.56 %**

[(a)] This solution is a re-standardization and recertification of SRM 4329, which was originally standardized by defined solid angle alpha counting in 1984. The current liquid scintillation-based standardization differs from the decay corrected original standardization by +1.5 %. However, due to the large uncertainty in the ^{243}Cm half-life and the nearly 35 years decay correction, the $k = 2$ uncertainty in the massic activity of the solution based on the decay corrected original standardization is ±2.5 %. Assay of ^{243}Cm in this SRM by gamma-ray spectrometry agrees with the certified value by –0.90 %.
[(b)] The uncertainties on certified values are expanded uncertainties, $U = k \cdot u_c$. 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 4329a

Source description	Liquid in a flame-sealed 5 mL borosilicate-glass ampoule [1]
Solution composition	Nominal 1 mol•L^{-1} HNO_3
Solution mass	(5.156 ± 0.011) g[(a)]
Alpha-particle-emitting impurity activity ratios	^{243}Am / ^{243}Cm < 0.00003[(b)] ^{244}Cm / ^{243}Cm < 0.0005[(c)]
Photon-emitting impurities	None detected [(d)]
Half-lifes used [6]	^{243}Cm: (28.9 ± 0.4) a[(e)] ^{243}Am: (7367 ± 23) a ^{244}Cm: (18.11 ± 0.03) a
Calibration methods (and instruments)	The certified massic activity for ^{243}Cm was obtained by 4πα liquid scintillation (LS) counting using three different LS measurement systems (with widely varying operating characteristics). For the massic activity determination, two different LS cocktail compositions (with 4 counting sources for each) were measured 5 or 6 times on each of the three instruments. Confirmatory measurement of the ^{243}Cm massic activity was performed by gamma-ray spectrometry

[(a)] The stated uncertainty is two times the standard uncertainty [5].
[(b)] Based on gamma-ray spectrometric analyses at Oak Ridge National Laboratory in 1975.
[(c)] Based on mass spectrometric analyses at Oak Ridge National Laboratory in 1975. The sum of the activity ratios at the 2019 reference time for (^{242}Cm + ^{245}Cm + ^{246}Cm + ^{247}Cm + ^{248}Cm)/^{243}Cm < 5.4 x 10^{-7}
[(d)] The estimated limits of detection for photon-emitting impurities, expressed as massic photon emission rates (numbers of photons per second per gram), are:
1.1 s^{-1}•g^{-1} for energies between 30 keV and 40 keV,
0.3 s^{-1}•g^{-1} for energies between 45 keV and 105 keV,
0.2 s^{-1}•g^{-1} for energies between 110 keV and 125 keV,
0.1 s^{-1}•g^{-1} for energies between 130 keV and 220 keV,
0.2 s^{-1}•g^{-1} for energies between 225 keV and 230 keV,
0.09 s^{-1}•g^{-1} for energies between 235 keV and 270 keV,
0.2 s^{-1}•g^{-1} for energies between 275 keV and 280 keV,
0.08 s^{-1}•g^{-1} for energies between 285 keV and 1450 keV, and
0.08 s^{-1}•g^{-1} for energies between 1470 keV and 2000 keV, (skipped over 356 keV line)
provided that the photons are separated in energy by 4 keV or more from photons emitted in the decay of ^{243}Cm.
[(e)] The stated uncertainty is the standard uncertainty. See reference 6.

Table 2. Uncertainty Evaluation for the Massic Activity of SRM 4329a

	Uncertainty component	Assessment Type[a]	Relative standard uncertainty contribution on massic activity of ^{243}Cm (%)
1	LS measurement precision: Relative standard deviation of the mean on the great-grand mean for 6 LS measurement trials, considering all within-trial and between-trial components of variance. Each of the three grand mean values was based on either 5 or 6 replicate measurements on each of 4 LS counting sources (prepared with two different LS cocktail compositions) in three different LS counters. The typical within-trial relative standard deviation of the mean (considering the variations for the between 5 or 6 measurements and the between 4 sources) for each trial was 0.11 %. The between-trial relative standard deviation across the 6 trials was 0.068 %. The 136 individual data values fit a Normal distribution. The relative standard deviation of the mean on the set of 136 values was 0.019 %, with a 95 % confidence interval about the mean of ± 0.037 %.	A	0.082
2	Background; LS measurement variability and cocktail composition stability effects; assumed to be wholly embodied in component 1.	A	--
3	LS counters dependencies; wholly embodied in components 1 & 2	A	--
4	Live time determinations for LS counting time intervals	B	0.06
5	Aliquant mass determinations by gravimetric measurements for preparation of counting sources; includes mass measurement precision partially embodied in component 1.	B	0.02
6	LS detection inefficiency: includes wall effect; partially embodied in component 1.	B	0.01
7	^{243}Cm decay corrections for half-life uncertainty of 1.4 %	B	< 0.001
8	Alpha particle-emitting impurities	B	0.05
9	Photon-emitting impurities	B	0.25
Relative combined standard uncertainty			**0.28**
Relative expanded uncertainty (*k* = 2)			**0.56**

[a] Letter A denotes evaluation by statistical methods; letter B denotes evaluation by other methods.

INSTRUCTIONS FOR USE AND HANDLING

Storage: SRM 4329a 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 Jan 2020). Note: This SRM is contained in the standard NIST ampoule. This is **not** a pre-scored 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 https://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Jan 2020).

[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 https://www.bipm.org/utils/common/documents/jcgm/JCGM_200_2012.pdf (accessed Jan 2020).

[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 https://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Jan 2020).

[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/nist-technical-note-1297 (accessed Jan 2020).

[6] Chechev, V.P.; *LNE-LNHB/CEA Table of Radionuclides*, ^{243}Cm; (October 2010); available at http://www.lnhb.fr/nuclides/Cm-243_tables.pdf (accessed Jan 2020); see also Browne, E., Bé M.M., Helmer R.G; *LNE-LNHB/CEA Table of Radionuclides*, ^{243}Am; (February 2010); available at http://www.lnhb.fr/nuclides/Am-243_tables.pdf (accessed Jan 2020); see also Chechev, V.P.; *LNE-LNHB/CEA Table of Radionuclides*, ^{244}Cm; (May 2010); available at http://www.lnhb.fr/nuclides/Cm-244_tables.pdf (accessed Jan 2020).

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) 948-3730; e-mail srminfo@nist.gov; or via the Internet at https://www.nist.gov/srm.