National Institute of Standards & Technology

Certificate

Standard Reference Material 4274

Holmium-166m Gamma-ray Emission Rate Standard

This Standard Reference Material (SRM) consists of a solution of a standardized and certified quantity of radioactive holmium-166m 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. The solution, whose composition is specified in Table 1, is contained in a flame-sealed, 5 mL, NIST, borosilicate-glass ampoule (see Note 1)*.

The certified values for the holmium-166m massic gamma-ray emission rates, at a Reference Time of 1200 EST, 15 February 2006, are given in Table 2.

Additional physical, chemical, and radiological properties for the SRM, as well as details on the standardization method, are given in Table 1. Uncertainty intervals for certified quantities are expanded ($k = 2$) uncertainties calculated according to the ISO and NIST Guidelines (see Note 2). Tables 3 and 4 contain a specification of the components that comprise the uncertainty analyses.

The certification of this SRM, within the measurement uncertainties specified, is valid for at least five (5) years after receipt. The solution matrix, in an unopened ampoule, is believed to be indefinitely homogeneous and stable, within its half-life-dependent, useful lifetime. NIST will monitor this material and will report any substantive changes in certification to the purchaser. Should any of the certified values change, purchasers of this SRM will be notified of the change by NIST.

This SRM may represent a radiological hazard and a chemical hazard. Consult the Material Safety Data Sheet (MSDS), enclosed with the SRM shipment, for details (see Note 1).

This Standard Reference Material was prepared in the Physics Laboratory, Ionizing Radiation Division, Radioactivity Group, Dr. M.P. Unterweger, Acting Group Leader. The overall technical direction and physical measurements leading to certification were provided by Drs. R. Collé and L. Laureano-Pérez of the Radioactivity Group, with production by Dr. L.L. Lucas, and with photonic emission rate measurements by Dr. L. Pibida. The support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the Standard Reference Materials Program.

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*Notes and references are in page 6

Table 1. Properties of SRM 4274

Certified values

Radionuclide	**Holmium-166m**
Reference time	**1200 EST, 15 February 2006**
Massic gamma-ray emission rates	**See Table 2**

Uncertified information

Source description	Liquid in flame-sealed NIST borosilicate ampoule (see Note 1)*
Solution composition	1.0 mol•L^{-1} HCl with 282 µg Ho^{+3} per gram of solution (as $HoCl_3$)
Solution density	(1.016 ± 0.002) g•mL^{-1} at 20.0 °C (see Note 3)
Solution mass	(5.057 ± 0.007) g (see Note 3)
Nominal massic activity	(19.3 ± 0.4) kBq•g (see Note 3)
Photon-emitting impurities	None detected (see Note 4)
Half lives used	Holmium -166m (1.2 ± 0.18) × 10^3 a (see Note 5)
Calibration method (and instruments)	Certified values for the gamma-ray emission rates were obtained from high resolution gamma-ray spectrometry using three different calibrated high-purity Ge detectors (NIST detectors "X", "B", and "T") in several geometries; Confirmatory measurements of the Ho-166m activity, to ensure consistency with the photonic rate measurements, were also made with the NIST pressurized "4π" γ ionization chamber "A" which was previously calibrated with a Ho-166m solution whose activity was determined by total efficiency counting using two NaI(Tl) crystals in 4π geometry .

*Notes and references are in page 6

Table 2. Certified values for the holmium-166m massic gamma-ray emission rates, in units of photons per second per gram of solution, for SRM 4274, at the reference time of 1200 EST 15 February 2006

Gamma-ray energy (keV)H	**Massic emission rate (s^{-1} g^{-1})**	**Relative expanded (k = 2) uncertainty (%)**
80.58	**2 390.**	**1.7**
184.41	**13 984.**	**2.4**
280.46	**5 794.**	**1.2**
300.74	**722.2**	**1.4**
365.77	**474.1**	**1.2**
410.96	**2194.**	**1.2**
451.54	**566.2**	**1.8**
529.82	**1 811.**	**1.3**
570.99	**1 048.**	**1.4**
670.53	**1 037.**	**1.3**
711.70	**10 527.**	**1.0**
752.28	**2 337.**	**1.0**
810.29	**11 078.**	**0.86**
830.57	**1 869.**	**1.1**
950.99	**531.1**	**0.81**
1120.34	**37.41**	**2.8**
1146.85	**38.24**	**3.8**
1241.52	**177.8**	**3.1**
1282.10	**37.91**	**4.2**
1400.79	**94.66**	**1.7**
1427.24	**96.36**	**1.8**

H See Reference 3*

*Notes and references are in page 6

Table 3. Uncertainty evaluation for the massic emission rates for SRM 4274
(for gamma rays of energy **less than** 1000 keV),
giving range of values for the individual gamma rays for each uncertainty component

Uncertainty component		Assessment Type †	Range of values for the relative standard uncertainty contribution on the massic emission rate for the individual gamma rays (%)
1	Replicate measurement precision, standard deviation, for measurements in 10 independently calibrated geometries with two sources on three detectors (“T”, “B”, and “X).	A	0.07 to 0.61
2	“counting statistics” and photopeak fitting	B	0.01 to 0.20
3	Limit for photon-emitting impurities	B	0.06
4	Background; wholly embodied in items 1 & 2	--	--
5	Detection efficiency	B	0.23 to 1.15
6	Source-geometry positioning	B	0.21 to 0.56
7	Decay corrections for holmium-166m	B	$< 2 \times 10^{-5}$
8	Gravimetric (mass) measurements	B	0.05
Relative combined standard uncertainty§			**0.41 to 1.4**
Relative expanded uncertainty (*k* = 2) §			**0.81 to 2.4**

† = (A) denotes evaluation by statistical methods; (B) denotes evaluation by other methods.
§ = Range of values for the individual gamma rays (See Table 2)

Table 4. Uncertainty evaluation for the massic emission rates for SRM 4274
(for gamma rays of energy **greater than** 1000 keV),
giving range of values for the individual gamma rays for each uncertainty component

Uncertainty component		Assessment Type †	Range of values for the relative standard uncertainty contribution on the massic emission rate for the individual gamma rays (%)
1	Replicate measurement precision, standard deviation, for measurements in 4 independently calibrated geometries with two sources on two detectors ("T" and "X).	A	0.46 to 1.5
2	"counting statistics" and photopeak fitting	B	0.51 to 1.1
3	Background; wholly embodied in items 1 & 2	--	--
4	Limit for photon-emitting impurities	B	0.06
5	Detection efficiency	B	0.15 to 0.32
6	Source-geometry positioning	B	0.26 to 0.96
7	Decay corrections for holmium-166m	B	$< 3 \times 10^{-5}$
8	Gravimetric (mass) measurements	B	0.05
Relative combined standard uncertainty§			**0.87 to 2.1**
Relative expanded uncertainty (*k* = 2) §			**1.7 to 4.2**

† = (A) denotes evaluation by statistical methods; (B) denotes evaluation by other methods.
§ = Range of values for the individual gamma rays (See Table 2)

NOTES

Note 1. Refer to http://physics.nist.gov/Divisions/Div846/srm.html for the standardized ampoule dimensions and for assistance and instructions on how to properly open an ampoule. Information on additional storage and handling requirements is also included in the website.

Note 2. 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 (see references [1] and [2]). The combined standard uncertainty is multiplied by a coverage factor of $k = 2$ and was chosen to obtain an approximate 95 % level of confidence.

Note 3. The stated uncertainty is two times the standard uncertainty.

Note 4. The estimated lower limits of detection for photon-emitting impurities, expressed as massic photon emission rates, on 15 Feb. 2006, were:

- 11 s^{-1} g^{-1} for 20 keV < E < 40 keV
- 8.0 s^{-1} g^{-1} for 60 keV < E < 70 keV
- 5.8 s^{-1} g^{-1} for 90 keV < E < 160 keV
- 11 s^{-1} g^{-1} for 180 keV < E < 200 keV
- 8.7 s^{-1} g^{-1} for 210 keV < E < 650 keV
- 3.6 s^{-1} g^{-1} for 850 keV < E < 1450 keV
- 0.6 s^{-1} g^{-1} for 1500 keV < E < 1800 keV

Note 5. The stated uncertainty is the standard uncertainty. See reference [3].

REFERENCES

[1] International Organization for Standardization (ISO), *Guide to the Expression of Uncertainty in Measurement*, 1993 (corrected and reprinted, 1995). Available from Global Engineering Documents, 12 Inverness Way East, Englewood, CO 80112, U.S.A. Telephone 1-800-854-7179.

[2] 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.

[3] The *Table of Radionuclides, Vol. 2 – A=151 to 242*, M.M. Bé, et al., Bureau International des Poids et Measures, Pavillon de Breteuil F-92312 Sèvres Cedex FRANCE (2004).