National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material® 187f

Sodium Tetraborate Decahydrate (Borax)

pH Standard

This Standard Reference Material (SRM) is intended for use in preparing solutions for calibrating electrodes for pH measuring systems. SRM 187f Sodium Tetraborate Decahydrate ($Na_2B_4O_7{\cdot}10\ H_2O$) was prepared to ensure high purity and uniformity. However, this SRM is certified **ONLY** as a pH standard [pH(S)], not as a pure substance. A unit of SRM 187f consists of 30 g of sodium tetraborate decahydrate.

Certified Values: The certified pH(S) values provided in Table 1 correspond to $\lg(1/a_H)$, where a_H is the conventional activity of the hydrogen (hydronium) ion referred to the standard state (p = 1 atm = 1.013 25 × 10^5 Pa) on the scale of molality. The values were derived from potential measurements of cells without liquid junction by the primary measurement method [1,2]. A NIST certified value is a value for which NIST has the highest confidence in its accuracy in that all known or suspected sources of bias have been investigated or taken into account [3]. The certified pH(S) values and their expanded uncertainties, U, are stated in Table 1.

Reference Values: The uncertainty [1,4] of the Bates-Guggenheim convention [5] is excluded from the uncertainty calculation for the reference values provided in Table 2. Reference values are noncertified values that are the best estimate of the true value; however, the values do not meet the NIST criteria for certification and are provided with associated uncertainties that may not include all sources of uncertainty [3].

Traceability: The measurand is the pH of the specified buffer solution. The certified values in Table 1 are metrologically traceable to the International System of Units (SI) of amount-of-substance and mass and to the convention [5] used to define ionic activity, including its uncertainty [1,4]. The reference values in Table 2 are traceable to the SI units for amount-of-substance and mass and to this defining convention [5], taken as an exact value with no uncertainty (the uncertainty of the Bates-Guggenheim convention is excluded from the uncertainty calculation).

Expiration of Certification: The certification of **SRM 187f** is valid, within the measurement uncertainty specified, until **31 August 2021**, provided the SRM is handled and stored in accordance with the instructions given in this certificate (see "Instructions for Handling, Storage and Use"). 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 before the expiration of this certificate, NIST will notify the purchaser. Registration (see attached sheet or register online) will facilitate notification.

Experimental work leading to the certification of this material was performed by R.A. Easley and J.F. Waters of the NIST Chemical Sciences Division.

Statistical consultation was provided by W.F. Guthrie of the NIST Statistical Engineering Division.

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

Carlos A. Gonzalez, Chief
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Gaithersburg, MD 20899
Certificate Issue Date: 29 August 2017

Steven J. Choquette, Director
Office of Reference Materials

INSTRUCTIONS FOR HANDLING, STORAGE AND USE

Storage: SRM 187f is stable when stored in its original container, with the cap tightly closed, in a dry environment, and under normal laboratory temperatures.

Drying Instructions: Use as received. SRM 187f must not be dried in an oven. Do not store in a desiccator before use.

Source Water for Solution Preparation: The water used in the preparation of the SRM 187f buffer solution should be protected from atmospheric carbon dioxide. This water must be prepared either by (1) boiling of distilled water (conductivity < 2 μS/cm) for 10 min and guarding it with a soda-lime tube while cooling or (2) dispensing water directly from a deionization-based point-of-use system into the vessel used to prepare the buffer solutions (resistivity > 17 MΩ·cm, conductivity < 0.06 μS/cm). The prepared solution should be protected against evaporation and contamination.

Preparation of the 0.01 mol/kg Solution: Quantities denoted by m' and associated numerical factors in this paragraph include the effect of air buoyancy, i.e., they correspond to the balance indication in units of mass obtained in the laboratory (the *balance reading*). Weigh by difference approximately 3.7 g of SRM 187f, m'_{187f}, to an accuracy of 1 mg, into a clean, dry 1 L polyethylene bottle. Add a weighed quantity of CO_2-free water, equal to 261.841 multiplied by m'_{187f}, to an accuracy of 0.1 g. Shake until the solid has totally dissolved. Gravimetric preparation in this manner eliminates the need to weigh exactly predetermined masses of solid samples. Proportionately smaller quantities of each SRM may be used in this preparation, provided that m'_{187f} exceeds 0.42 g.

Stability of the Prepared Solution: The solution should be discarded after one month, or sooner if sediment appears or if it has been exposed repeatedly to air containing carbon dioxide. To avoid contamination of the buffer solution with atmospheric carbon dioxide, keep the bottle capped except when removing a portion of the solution.

SOURCE, PREPARATION AND ANALYSIS[(1)]

Source of Material: The sodium tetraborate decahydrate ($Na_2B_4O_7{\cdot}10\ H_2O$) was obtained from a commercial company. This material conforms to the specifications of the American Chemical Society for primary standard chemicals [6].

Certified Values: The pH(S) and the expanded uncertainty, U, of this solution as a function of temperature are given in Table 1. The expanded uncertainty in the certified value, U, is calculated as $U = ku_c(y)$, where $u_c(y)$ is the "combined standard uncertainty" calculated according to the ISO/JCGM Guide [7]. The value of $u_c(y)$ represents the combined effect of the following uncertainty components: extrapolation to obtain the acidity function, $p(a_H\gamma_{Cl})°$; standard electrode potentials, $E°$; material heterogeneity[(2)]; molality of HCl, b_{HCl}, used for determining $E°$; measured cell potentials; correction to the standard pressure for H_2 gas; mean activity coefficient of HCl at b_{HCl}; gas constant; temperature; Faraday constant; the molality of NaCl; and the uncertainty of the conventional calculation of log γ_{Cl} (Bates-Guggenheim convention [5]). Current expert opinion [1,4] has assessed the uncertainty attributable to the Bates-Guggenheim convention as 0.010 pH (95 % confidence interval). The value of $u_c(y)$ has been multiplied by a coverage factor, k, obtained by the Student's t-distribution for effective degrees of freedom at the given temperature and a 95 % confidence level. A solution of molality 0.01 mol/kg is recommended for the calibration of pH measuring systems. **NOTE**: These certified values apply ONLY to a 0.01 mol/kg solution prepared from SRM 187f. Minor variations of pH(S) values may be expected to occur between SRM lots.

(1) Certain commercial equipment, instruments, or materials are identified in this certificate to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

(2) The uncertainty for material heterogeneity includes analysis of the relevant uncertainty arising from the uncertainty in SRM 187e, which was used in the collection of the data for assessing material heterogeneity. The uncertainty from the use of SRM 187e was determined to add only negligible uncertainty to the assessed material heterogeneity value.

Table 1. Certified pH(S) Values and Expanded Uncertainties (95 % Confidence)

Temperature (°C)	pH(S)	Combined Standard Uncertainty, u_c(y)	Coverage Factor, k	Expanded Uncertainty, U
5	9.401	0.0052	1.96	0.010
10	9.342	0.0051	1.96	0.010
15	9.288	0.0051	1.96	0.010
20	9.239	0.0051	1.96	0.010
25	9.195	0.0051	1.96	0.010
30	9.155	0.0054	1.96	0.010
35	9.120	0.0053	1.96	0.010
37	9.107	0.0052	1.96	0.010
40	9.088	0.0052	1.96	0.010
45	9.059	0.0052	1.96	0.010
50	9.034	0.0052	1.96	0.010

Reference Values: To attain traceability to the NIST reference pH(S) values for SRM 187f when traceability to the SI units is not necessary, the uncertainty of the Bates-Guggenheim convention is excluded from the uncertainty calculation. The respective pH(S) values in Table 2 are identical to those in Table 1 but are listed to the number of decimal places reported for the expanded uncertainty, U_R:

$$U_R = k_R u_c(\text{measurement}),$$

where k_R is the coverage factor for U_R. The quantities U_R and u_c(measurement) each include all components associated with the measurement method and assessment of material heterogeneity, but **DO NOT** include the uncertainty [1] of the Bates-Guggenheim Convention.

Table 2. Reference pH(S) Values and Expanded Reference Uncertainties (95 % Confidence)

Temperature (°C)	pH(S)	Combined Standard Uncertainty, u_c(measurement)	Reference Coverage Factor, k_R	Expanded Uncertainty, U_R
5	9.4013	0.0013	2.08	0.0028
10	9.3417	0.0012	2.09	0.0024
15	9.2878	0.0010	2.04	0.0021
20	9.2390	0.0010	2.02	0.0019
25	9.1951	0.0010	2.03	0.0020
30	9.1554	0.0019	2.01	0.0038
35	9.1198	0.0017	1.98	0.0033
37	9.1066	0.0016	1.97	0.0031
40	9.0879	0.0015	1.96	0.0029
45	9.0593	0.0015	1.96	0.0029
50	9.0338	0.0014	1.96	0.0028

REFERENCES

[1] Buck, R.P.; et. al.; *Measurement of pH. Definition, Standards, and Procedures*; (IUPAC Recommendation 2002), Pure Appl. Chem, Vol. 74, pp. 2169–2200 (2002); available at http://www.iupac.org/publications/pac/2002/pdf/7411x2169.pdf (accessed Aug 2017).

[2] Wu, Y.C.; Koch, W.F.; Marinenko, G.; *A Report on the National Bureau of Standards pH Standards*; J. Res. Natl. Bur. Stand.; Vol. 89, pp. 395–400 (1984); available at http://nvlpubs.nist.gov/nistpubs/jres/089/jresv89n5p395_A1b.pdf (accessed Aug 2017).

[3] May, W.; Parris, R.; Beck II, C.; Fassett, J.; Greenberg, R.; Guenther, F.; Kramer, G.; Wise, S.; Gills, T.; Colbert, J.; Gettings, R.; MacDonald, B.; *Definition of Terms and Modes Used at NIST for Value-Assignment of Reference Materials for Chemical Measurements*; NIST Special Publication 260-136; U.S. Government Printing Office: Washington, DC (20); available at http://www.nist.gov/srm/upload/SP260-136.PDF (accessed Aug 2017).

[4] Baucke, F.G.; *New IUPAC Recommendations on the Measurement of pH – Background and Essentials*; Anal. Bioanal. Chem., Vol. 374, p. 772 (2002).

[5] Bates, R.G.; Guggenheim, E.A.; *A Report on the Standardization of pH and Related Terminology*; Pure Appl. Chem., Vol. 1, pp. 163–168 (1960).

[6] American Chemical Society; *Reagent Chemicals*; 8th ed.; Washington, DC (1993).

[7] JCGM 100:2008; *Guide to the Expression of Uncertainty in Measurement*; (GUM 1995 with Minor Corrections), International Bureau of Weights and Measures, Joint Committee for Guides in Metrology, Sèvres Cedex, France (2008); available at http://www.bipm.org/utils/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Aug 2017); see also 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/sites/default/files/documents/2017/05/09/tn1297s.pdf (accessed Aug 2017).

Users of this SRM should ensure that the Certificate of Analysis 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 http://www.nist.gov/srm.