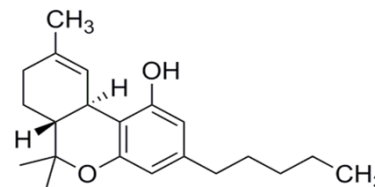


Certified Reference Material - Certificate of Analysis

(-)- Δ^9 -THC, Primary Measurement Standard

(6aR, 10aR)-6a, 7, 8, 10a-tetrahydro-6, 6, 9-trimethyl-3-pentyl-6H-dibenzo[b, d]pyran-1-ol

Product No.: T-005-1ML
Lot No.: FE04222001
Description of CRM: (-)- Δ^9 -THC in Methanol (Solution)
Expiration Date: May 2025 See Section "Stability Assessment".
Storage: Store unopened in freezer (-10 °C to -25 °C).
Shipping: Ambient. See Section "Stability Assessment".
Chemical formula: C₂₁H₃₀O₂
CAS No.: 1972-08-3
Regulatory: USDEA Exempt | Canadian TK # 61-1540



Analyte	Certified Concentration \pm associated uncertainty U, $u=k \cdot u$ (k=2)
(-)- Δ^9 -THC	1.000 \pm 0.018 mg/mL

Metrological traceability: Traceable to the SI and higher order standards from NIST through an unbroken chain of comparisons. See "Details on metrological traceability" on page 2.

Measurement method: The certified value is calculated from high precision weighing of thoroughly characterized starting material. See "Details about certification process" on page 2.

Intended use: This Certified Reference Material is suitable for the in vitro identification, calibration, and quantification of the analyte(s) in analytical and R&D applications. Not suitable for human or animal consumption.

Minimum sample size: 1 μ L for quantitative applications

Instructions for handling and correct use: Concentration is corrected for chromatographic purity, residual water, residual solvents, and residual inorganics. No adjustment required before use. Users should quantitatively transfer desired volume using established good laboratory practices to spike into matrix or to dilute to the desired concentration. Each ampoule is intended for one-time use.

Health and safety information: Danger. Please refer to the Safety Data Sheet for detailed information about the nature of any hazard and appropriate precautions to be taken.

Accreditation: Cerilliant Corp. is accredited by the US accreditation authority ANAB as registered reference material producer AR-1353 in accordance with ISO 17034 and registered testing laboratory AT-1352 according to ISO/IEC 17025.



Darron Ellsworth, Quality Assurance Manager

December 29, 2020

Issue Date

Cerilliant Corporation, 811 Paloma Drive, Suite A Round Rock,
 TX 78665, USA, Tel: 800-848-7837 / 512-238-9974; www.cerilliant.com
 Sigma-Aldrich Production GmbH is a subsidiary of Merck KGaA, Darmstadt, Germany.



Packaging:

2 mL amber USP Type 1 glass ampoule containing not less than 1 mL of certified solution. Ampoules are overfilled to ensure a minimum of 1 mL volume can be transferred when using a 1mL Class A volumetric pipette.

Details on starting materials:

Each raw material utilized has been identified and thoroughly characterized through the use of multiple analytical techniques and is assigned a Mass Balance Purity Factor. Spectral data is provided on subsequent pages of this CoA.

Certificate of Origin:

Cerilliant Corporation certifies no material of animal origin (BSE/TSE) was used in the preparation of this product. This material was manufactured in the USA.

Associated uncertainty:

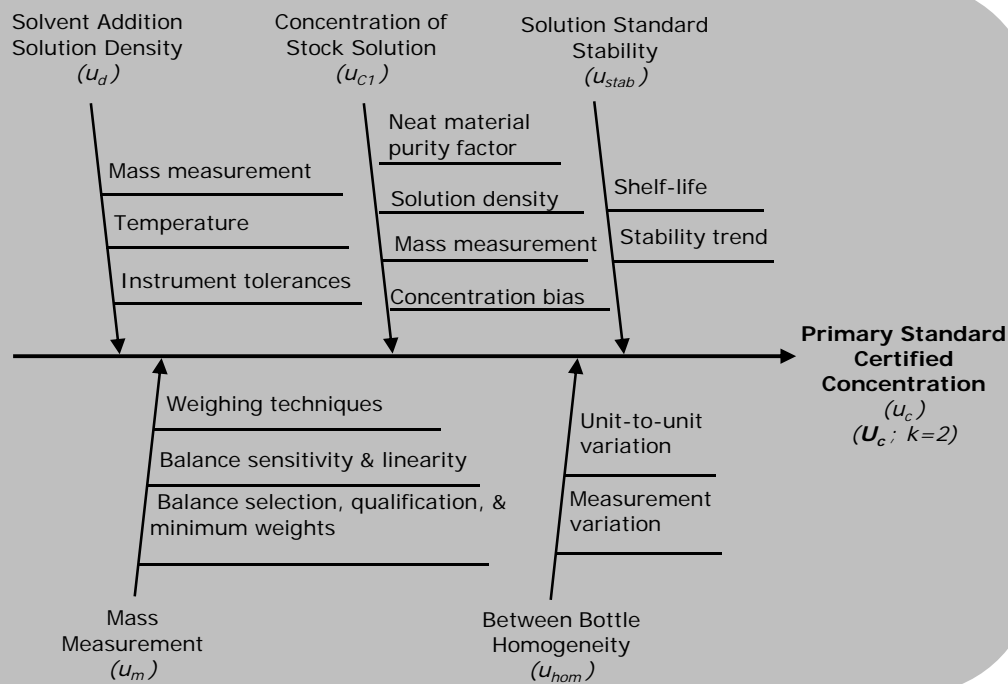
The uncertainty has been calculated by statistical analysis of all aspects of our production system and incorporated uncertainty of the mass balance purity factor, material density, balance, weighing technique, and homogeneity. Uncertainty components of the gravimetrically prepared Primary Standard concentration are shown in the figure below. Uncertainty is expressed as an expanded uncertainty in accordance with ISO 17034 at the approximate 95% confidence interval using a coverage factor of k=2. Uncertainty contribution from neat material homogeneity was established to be negligible through establishment of process controls and verification of the control process. Stability uncertainty was determined to be negligible by regression analysis.

Relative uncertainty contributions

- $u_d = 0.086\%$
- $u_m = 0.035\%$
- $u_{c1} = 0.276\%$
- $u_{stab} = 0.000\%$
- $u_{hom} = 0.07\%$
- $u_{bias} = 0.866\%$

Combined uncertainty
 $u_c = 0.92\%$

Expanded uncertainty (k=2)
 $U_c = 1.84\%$



Details on metrological traceability:

- ♦ This standard has been gravimetrically prepared using balances that have been fully qualified and calibrated to ISO 17025 requirements. All calibrations utilize NIST traceable weights which are calibrated externally by a qualified ISO 17025 accredited calibration laboratory to NIST standards. Qualification of each balance includes the assignment of a minimum weighing by a qualified and ISO 17025 accredited calibration vendor taking into consideration the balance and installed environmental conditions to ensure compliance with USP tolerances of NMT 0.10% relative error.
- ♦ Fill volume to predetermined specifications is gravimetrically verified throughout the dispensing process using qualified and calibrated balances.
- ♦ The density and material Mass Balance Purity Factor of each raw material is traceable to the SI and higher order reference materials through mass measurement and instrument qualification and calibrations.

Details about certification process:

This standard has been prepared and certified under the ISO 17034, ISO/IEC 17025, ISO 9001 and ISO 13485 standards. This standard meets the requirements of a Certified Reference Material and a Primary Standard as defined by ISO and is traceable to the SI and higher order standards through an unbroken chain of comparisons.

- ♦ Nominal concentration is calculated based on: the actual mass; Mass balance purity factor of the analyte(s); measured mass of the solution; and the density of the pure diluent at 20°C.
- ♦ Fill volume is gravimetrically verified throughout the dispensing process using qualified and calibrated balances.
- ♦ Concentration is verified against an independently prepared calibration solution gravimetrically prepared.
- ♦ Additional certification information available upon request.

Solution Standard Verification

Concentration accuracy and within- and between-bottle homogeneity are analytically verified against an independently prepared calibration solution and to the prior lot.

Solution standard verification demonstrates confirmation that the specified requirements for the Primary Measurement Standard have been fulfilled and validated under ISO 13485.

Standard Solution Assay Parameters		Calibration Curve	
Analysis Method:	HPLC/UV	Calibration Curve:	Linear Regression
Column:	Luna C18 (2), 3 µm, 4.6 x 150 mm	Number of Points:	4
Mobile Phase:	Methanol:Water:Tetrahydrofuran (71:24:5)	Linearity (r) :	1.000
Flow Rate:	1.0 mL/min		
Wavelength:	228 nm		
		Verified Concentration (mg/mL)	%RSD - Homogeneity
Standard Solution	Lot Number	Actual Results	Actual Results
New Lot	FE04222001	0.996	0.6
Previous Lot	FE02072001	0.991	0.1
<ul style="list-style-type: none"> Concentration is verified through multiple analyses and is calculated as the average of multiple analyses compared to an independently prepared calibration solution. Within-sample and between-sample homogeneity of the New Lot is ensured through rigorous production process controls statistically analyzed to evaluate risk and verified by analysis. Multiple samples pulled from across the lot using a random stratified sampling plan were analyzed to verify homogeneity. % RSD results shown above for the New Lot demonstrate ampoule-to-ampoule homogeneity. 			
Standard Solution	Lot Number	Verified Concentration against USP Standard HPLC Analysis	
New Lot	FE04222001	1.032	
<ul style="list-style-type: none"> Concentration is verified against an independently prepared calibration solution using USP Standard 1651621 Lot R045H0 			

Analyte Certification - Mass Balance Purity Factor

Each analyte is thoroughly identified and characterized using an orthogonal approach. A mass balance purity factor is assigned incorporating chromatographic purity and residual impurities. The mass balance purity factor is utilized to calculate the weighing adjustment necessary to ensure accuracy of the solution standard concentration.

Material Name:	(-)- Δ^9 -THC	Chemical Formula:	C ₂₁ H ₃₀ O ₂
Material Lot:	FC02181901	CAS Number:	1972-08-3
		Molecular Weight:	314.46

Material Characterization Summary

Analytical Test	Method	Results
Chromatographic Purity by HPLC/UV Analysis	AM1280	99.0% ¹
exo-THC Determination by GC/FID Analysis	AM1266	0.1%
Identity by GC/MS Analysis	SP10-0105	Consistent with Structure
Identity by ¹ H-NMR Analysis	USP <761>, SP10-0116	Consistent with Structure
Residual Solvent Analysis by GC/FID Headspace	AM1087 ²	0.22%
Residual Water Analysis by Karl Fischer Coulometry	AM1346 ²	0.32%
Mass Balance Purity Factor		98.51%

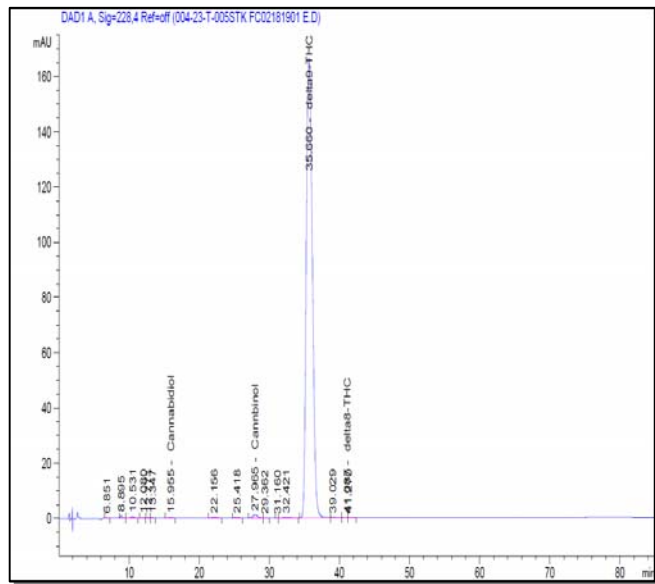
¹ Purity value adjusted for known impurities as shown on the trace below.

² Validated analytical method

- ♦ The chromatographic purity value is used to calculate the Mass Balance Purity Factor.
- ♦ Mass Balance Purity Factor = [(100 - wt% residual solvent - wt% residual water - wt% residual inorganics) x Chromatographic Purity/100].
- ♦ Mass Balance Purity Factor does not include adjustment for chiral and/or isotopic purity.

Spectral and Physical Data

HPLC/UV



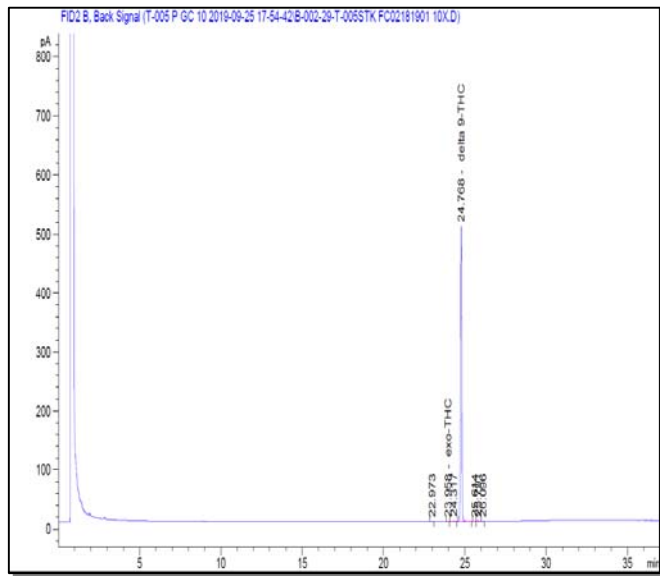
Column: Luna C18, 3 μ m, 4.6 x 150 mm
Mobile Phase: Methanol:Water:Tetrahydrofuran
 (71:24:5)
Flow Rate: 1.0 mL/min
Wavelength: 228 nm

Sample Name: FC02181901
Acquired: September 23, 2019

Peak #	Ret Time	Area %	
1	6.85	0.02	
2	8.90	0.14	
3	10.53	0.13	
4	12.08	0.01	
5	12.77	0.02	
6	13.35	0.02	
7	15.96	0.05	Cannabidiol
8	22.16	0.09	
9	25.42	0.04	
10	27.97	0.51	Cannabinol
11	29.36	0.00	
12	31.16	0.00	
13	32.42	0.10	
14	35.66	98.72	(-)- Δ^9 -THC
15	39.03	0.09	
16	41.09	0.02	(-)- Δ^8 -THC
17	41.27	0.02	

Spectral and Physical Data (cont.)

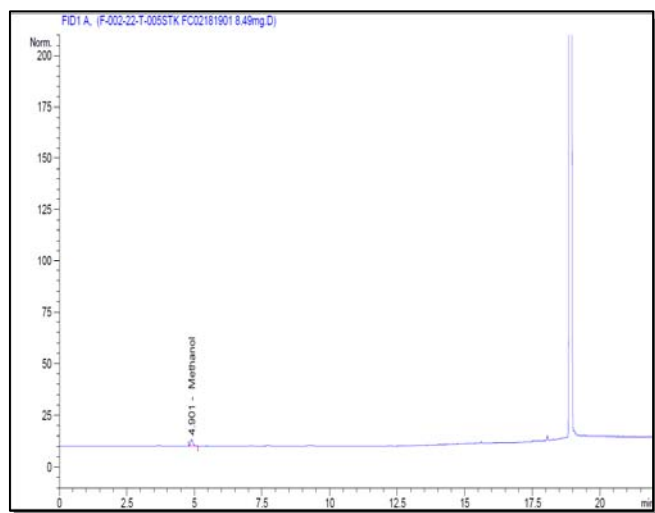
exo-THC by GC/FID



Column: DB-35ms, 30 m x 0.53 mm ID, 1.0 µm film thickness
Temp Program: 60°C to 200°C at 10°C/min
 200°C to 280°C at 5°C/min
 hold 7 min
Injector Temp: Cool-on-Column
Detector Temp: 325°C
Sample Name: FC02181901
Acquired: September 25, 2019

Peak #	Ret Time	Area %	
1	22.97	0.03	
2	23.96	0.05	exo-THC
3	24.32	0.20	
4	24.77	99.44	(-)-Δ ⁹ -THC
5	25.61	0.04	
6	25.79	0.20	
7	26.10	0.03	

Residual Solvent Analysis by GC/FID Headspace



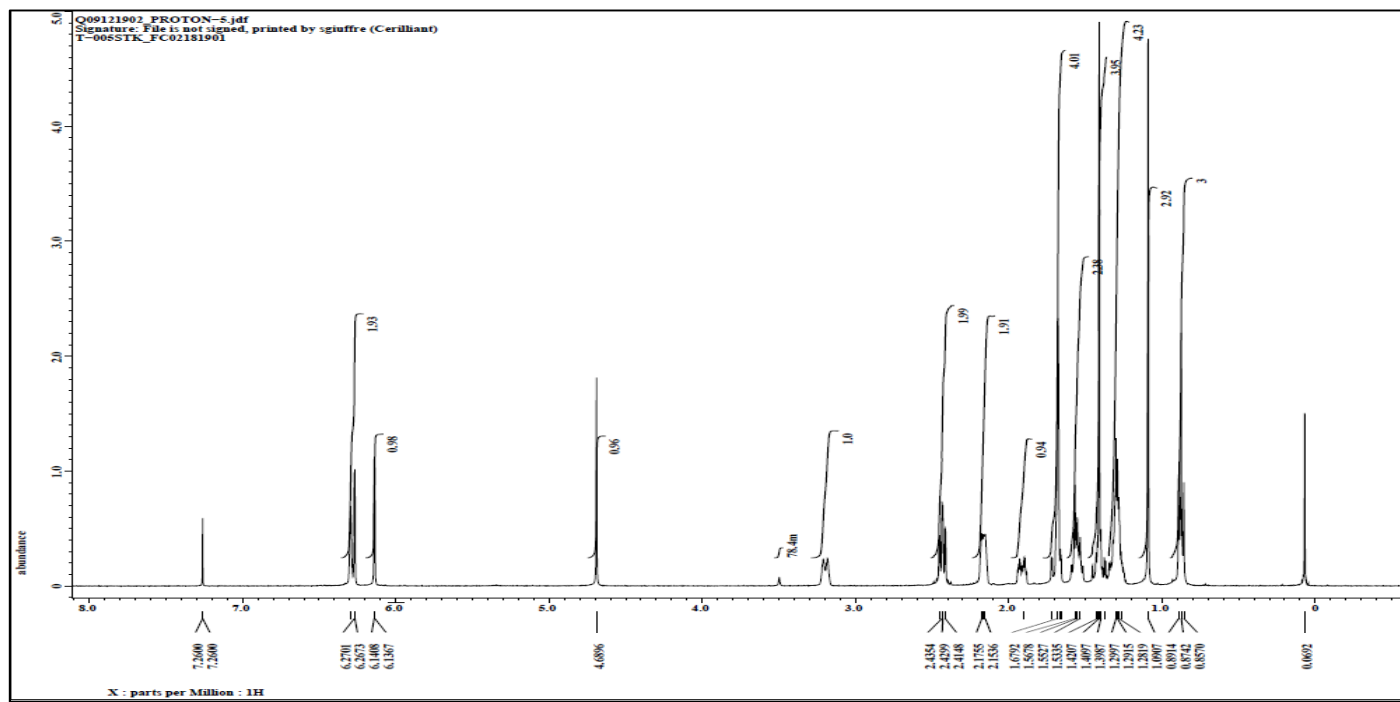
Column: DB-ALC1 30 m x 0.53 mm, 3 µm film thickness
Temp Program: 40°C hold 12 min to 220°C at 40°C/min hold 5.5 min
Carrier Gas: Helium
Flow Rate: 2.0 mL/min
Detector Heater Temp: 250°C
Injector: Headspace Sampler
HS Oven Temp: 60°C
Vial Equilibration: 10 minutes
Sample Name: FC02181901
Acquired: September 13, 2019

Peak	Compound	Area	Weight %
1	Methanol	20.94	0.22
2	NMP	NA	NA
Total			0.22

Spectral and Physical Data (cont.)

^1H NMR

Instrument: JEOL ECS 400
Solvent: Chloroform-D

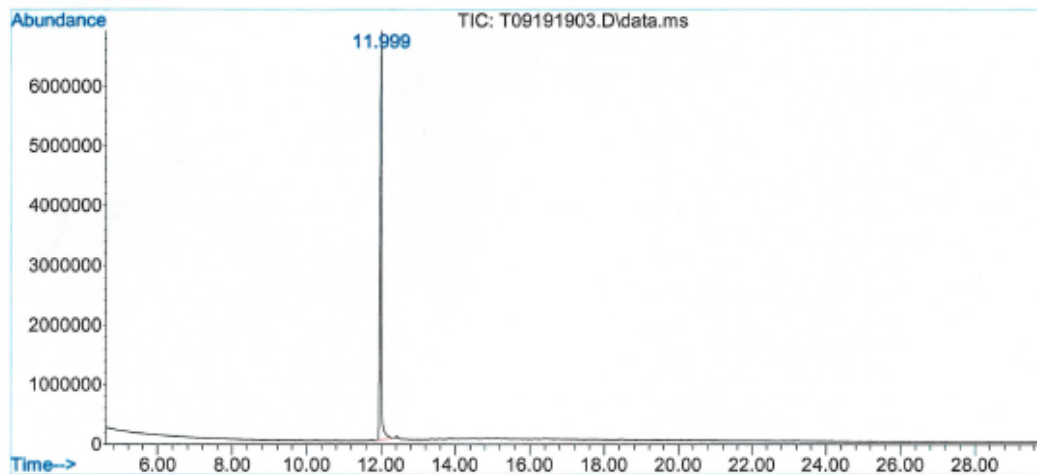


Spectral and Physical Data (cont.)

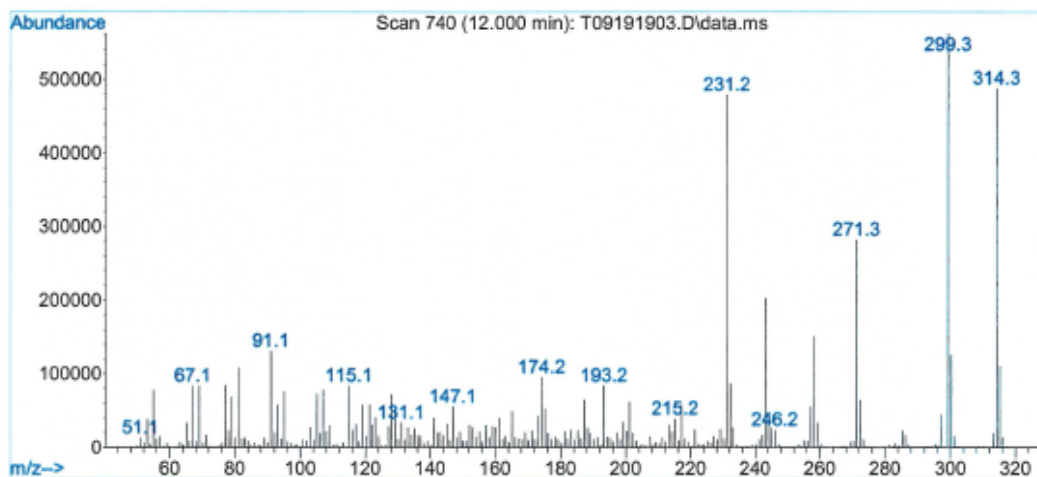
GC/MS

Compound Name : (-)-delta9-THC
Lot Number : FC02181901
Instrument : Agilent GCMS
Operator : ECM(SGIUFFRE)
Date Reported : Thu Sep 19 09:33:31 2019
Column Type : DB-5ms, 30m x 0.25mm ID, 0.25um film thickness
Temp. Program : 50°C to 200°C@40°C/min, 200°C to 300°C@10°C/min, 16min hold
Injector Temp. : Cool on-column
Carrier Gas : Helium
Flow Rate (mL\min) : 0.80 mL/min
Transfer Line Temp. : 280°C
Scan Range : 50-500

Total Ion Chromatogram



Mass Spectrum



Stability		
<i>Short term stability studies have been performed in multiple storage conditions for a period of up to four weeks. Short term data is utilized to support transport conditions and normal laboratory use. Real-time stability studies are performed at the recommended storage conditions over the life of the product.</i>		
Short Term Stability: <i>A summary of stability findings for this product is listed below.</i>		
Storage Condition	Mean Kinetic Temperature (MKT)	Time Period/Result
Freezer	-15°C	No decrease in purity was noted after four weeks.
Refrigerator	4°C	
Room Temperature	21°C	
40°C	40°C	
Transport/Shipping: <i>Stability studies support the transport of this product at ambient conditions.</i>		
Long Term Stability: <i>Long term stability has been assessed for Freezer storage (-10 °C to -25 °C) conditions. Stability of a minimum of 60 months has been established through real-time stability studies.</i>		

Commutability

This standard is a solution of a pure substance in an organic solvent and is a Primary Standard. This Primary Standard is suitable for use in the preparation of calibrators and/or controls in any biological matrix. This standard is not in a biological matrix and therefore commutability to methods or standards in biological matrices does not apply.

COA Revision History

Revision No.	Date	Reason for Revision
00	June 29, 2020	Initial version.
01	December 29, 2020	Updated expanded uncertainty from ± 0.006 to ± 0.018 mg/mL.
		Updated uncertainty fishbone diagram.

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