

# The importance of traceability

## OR HOW TO ACHIEVE COMPARABILITY OF CHEMICAL MEASUREMENTS

Eurachem Scientific Workshop 2023

May 22-23, 2023



**Eurachem**

*A focus for analytical chemistry in Europe*



**METAS**



**SCS**

Swiss Chemical  
Society

Markus Obkircher  
Director R&D  
Head of Customer Solutions R&D

**Supelco**<sup>®</sup>

Analytical Products

**MERCK**

**Metrological  
Traceability  
Considera-  
tions**

**1**

**Key  
Reference  
Material  
Concepts**

**2**

**Supelco®**  
Analytical Products

**Traceability of  
Certified Reference  
Materials**

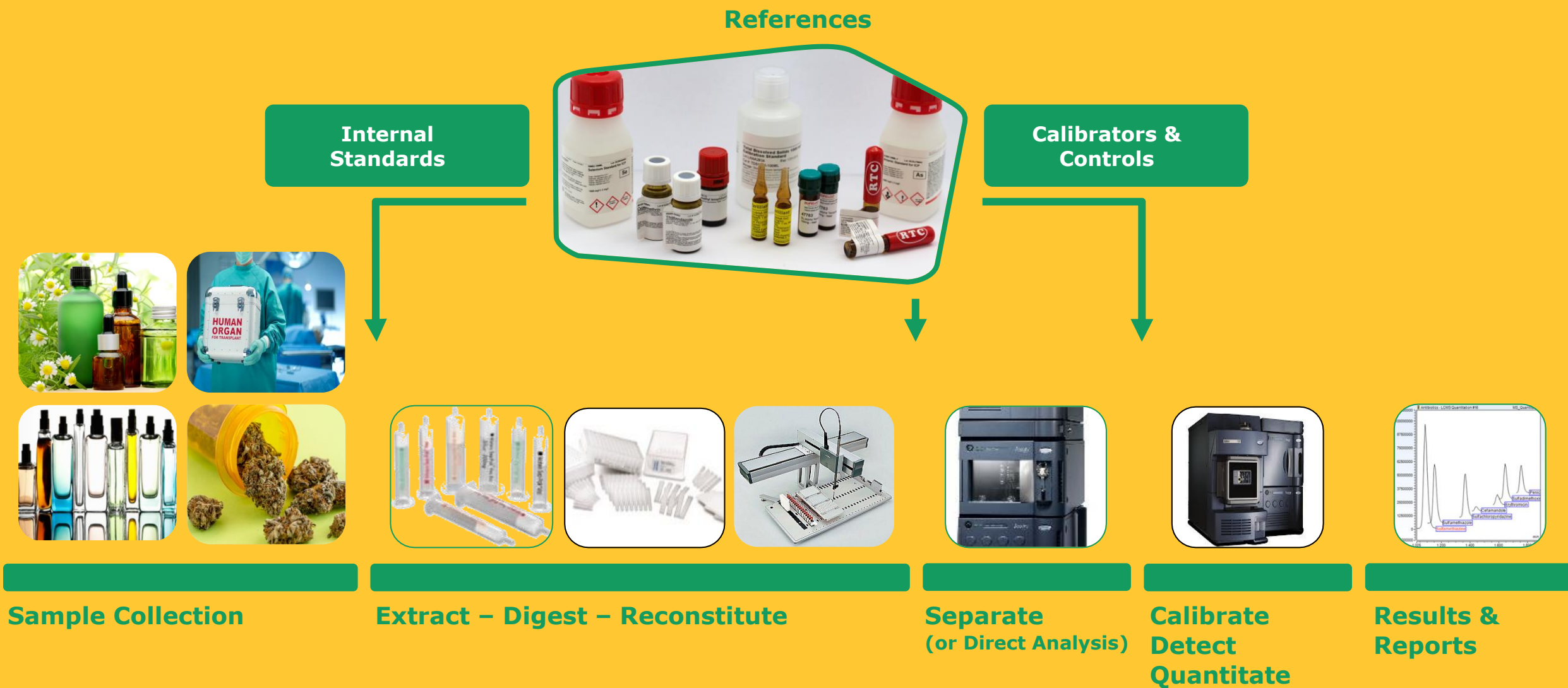
**3**

**4**

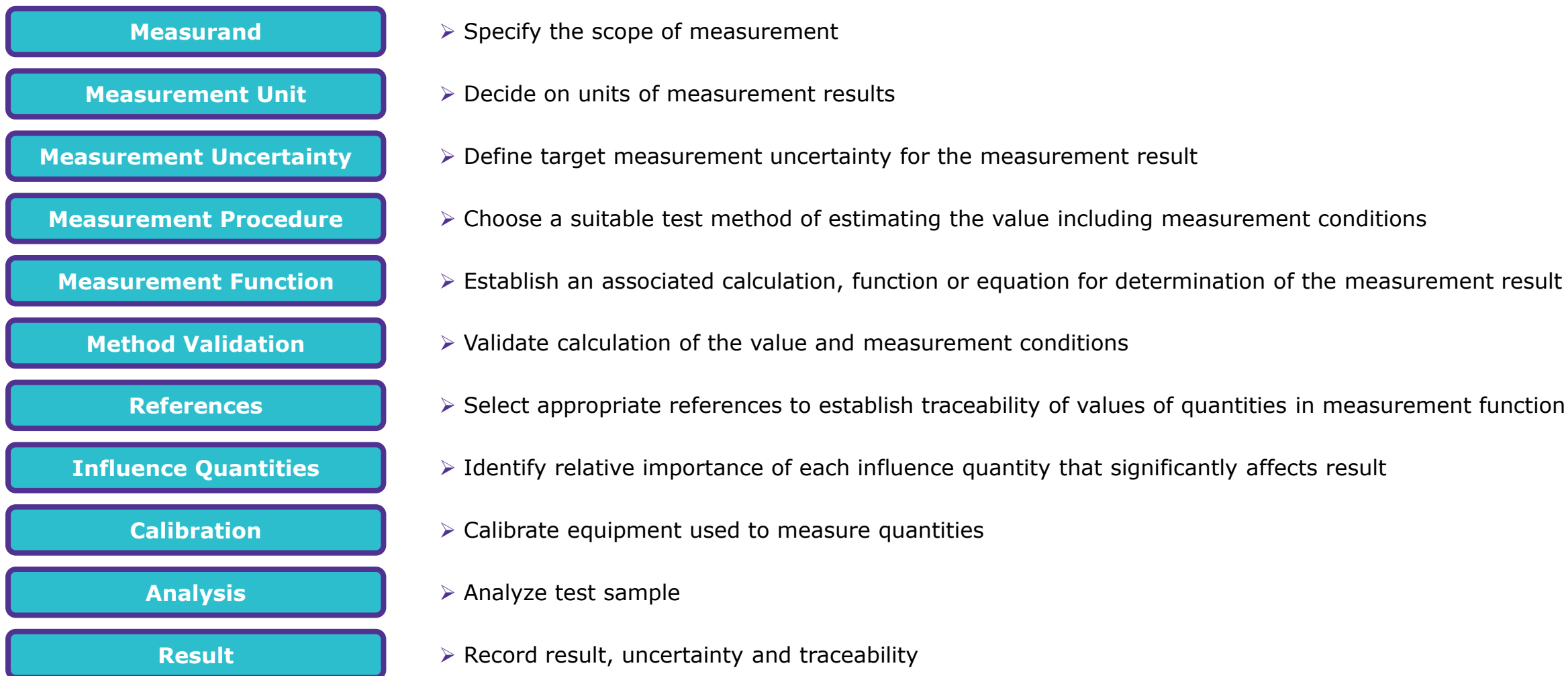
**Summary**

# Chemical Measurements

## High level analytical workflow



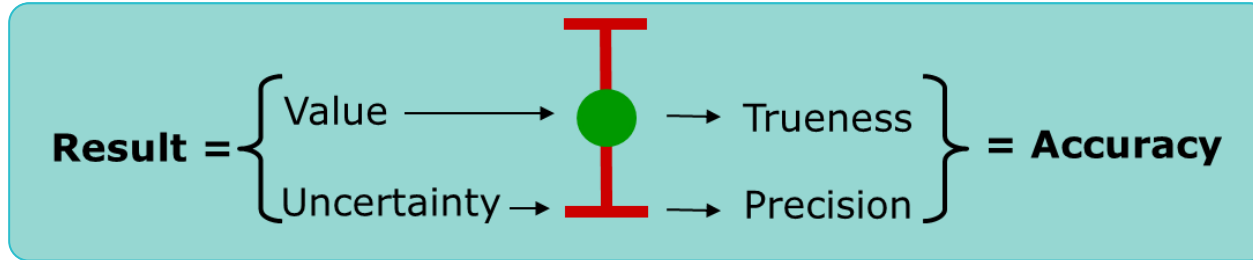
## Key stages for analytical laboratory to establish metrological traceability



# Metrological Traceability Considerations

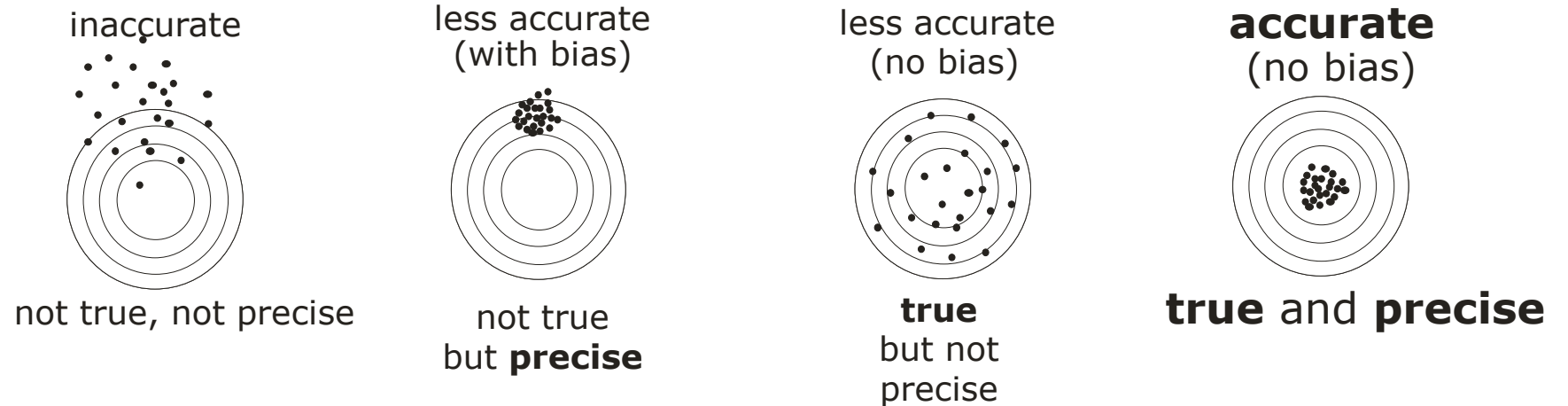
## Measurement procedure, result and accuracy

- Measurand
- Measurement Unit
- Measurement Uncertainty
- Measurement Procedure**
- Measurement Function
- Method Validation
- References
- Influence Quantities
- Calibration
- Analysis
- Result



- **Measurement procedure**

Intended, developed and documented to provide estimates for the values of measurands



- **Result**

Estimated values for measurands following measurement using an appropriate procedure, including properties such as uncertainty and traceability

# Metrological Traceability Considerations

## Measurand and Measurement Unit

Measurand

Measurement Unit

Measurement Uncertainty

Measurement Procedure

Measurement Function

Method Validation

References

Influence Quantities

Calibration

Analysis

Result

- **Measurand**

Quantity intended to be measured (e.g. mass, volume, concentration) – it is critical that quantity is unambiguously defined including units of measurement results (e.g. mgkg<sup>-1</sup>)



OUTCOME: UNSUCCESSFUL

Mission Elapsed Time

00: 09: 11: 05: 14: 09  
YRS MOS DAYS HRS MINS SECS

Dec. 11, 1998 – Sep. 23, 1999

# Metrological Traceability Considerations

## NASA Mars Climate Orbiter

<https://solarsystem.nasa.gov/missions/mars-climate-orbiter/in-depth/>

Measurand

Measurement Unit

Measurement Uncertainty

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Method Validation

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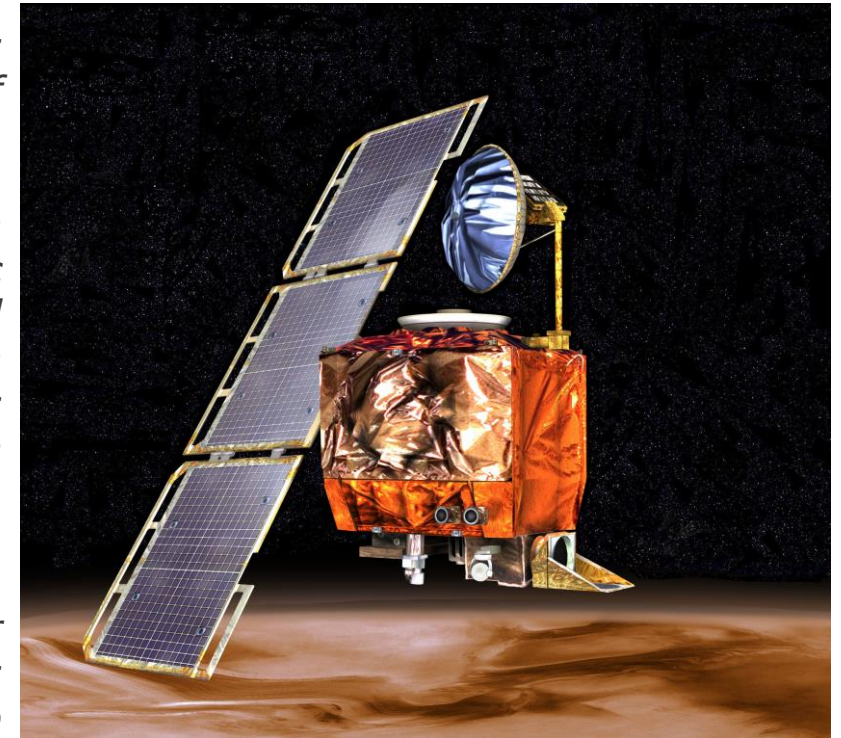
- **Measurand**

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*[...] NASA's Mars Climate Orbiter was designed to [...] conduct investigations of Mars' atmosphere, climate and surface.*

*Scientists hoped that such information would aid in reconstructing Mars' climatic history and provide evidence of buried water reserves. After the end of its main mapping mission Jan. 15, 2001, Mars Climate Orbiter would have acted as a communications relay for future NASA missions to Mars.*

*At 09:00:46 UT Sept. 23, 1999, the orbiter began its Mars orbit insertion burn as planned. The spacecraft was scheduled to re-establish contact after passing behind Mars, but, unfortunately, no signals were received from the spacecraft. [...]*



OUTCOME: UNSUCCESSFUL

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- **Measurand**

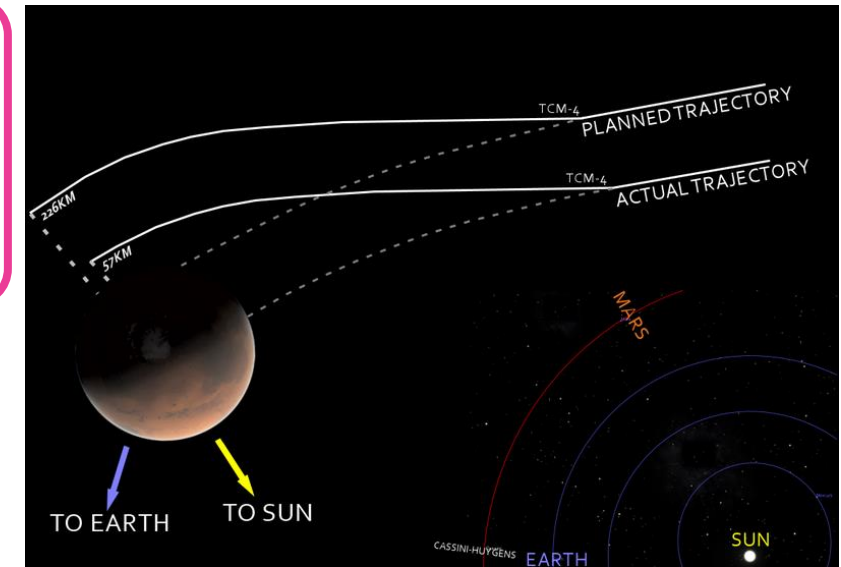
Quantity intended to be measured (e.g. mass, volume, concentration). It is critical that quantity is unambiguously defined including units of measurement results (e.g. mgkg<sup>-1</sup>)

[...]

An investigation indicated that the failure resulted from a navigational error due to commands from Earth being sent in English units (in this case, pound-seconds) without being converted into the metric standard (Newton-seconds).

The error caused the orbiter to miss its intended orbit (87 to 93 miles or 140 to 50 kilometers) and to fall into the Martian atmosphere at approximately 35 miles (57 kilometers) in altitude and to disintegrate due to atmospheric stresses.

[...]



OUTCOME: UNSUCCESSFUL

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*NASA's lack of processes resulted in the loss of 193 MUSD Mars Climate Orbiter satellite disintegration (total loss estimated to ~700 MUSD).*



OUTCOME: UNSUCCESSFUL

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## Calibration and references are key for traceability of results

Measurand

Measurement Unit

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Measurement Procedure

Measurement Function

Method Validation

References

Influence Quantities

**Calibration**

Analysis

Result

- **Calibration**

Process to establish the relationship between values shown by a measuring instrument and the values provided by measurement standards - validity assured through appropriate controls and recalibration

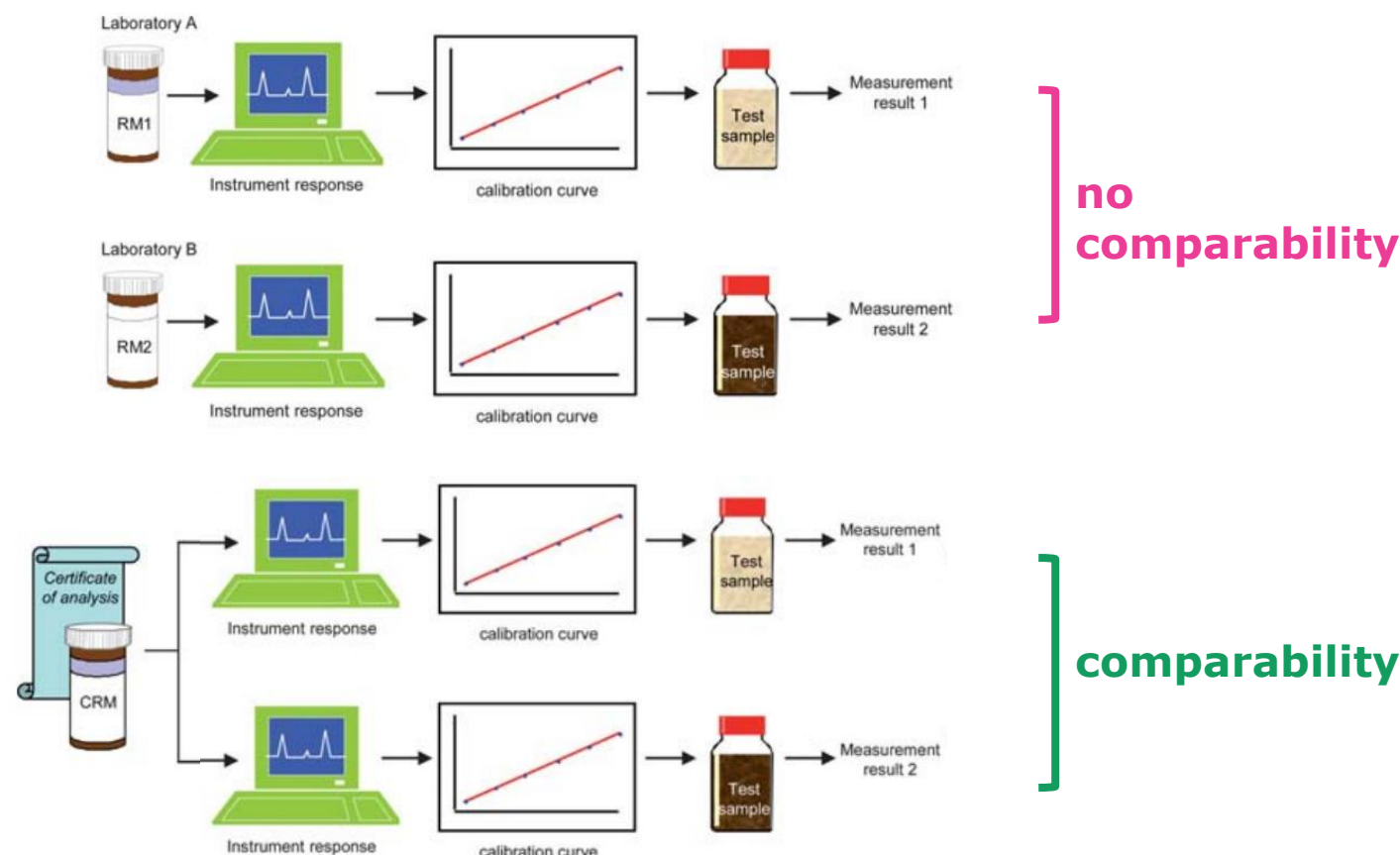


## Calibration and references are key for traceability of results

- Measurand
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- **References**

Right choice of reference impacts accuracy of measurement result, provides traceability to the SI unit and leads to comparability of results



## What is Metrological Traceability? Answer from an expert ...



Metrological traceability refers to the property of a measurement result or a measurement standard whereby it can be related to a recognized reference through an unbroken chain of comparisons, each having a stated uncertainty. In simpler terms, it refers to the ability to trace the value of a measurement back to a recognized and well-established reference standard.

In order to ensure the reliability and comparability of measurements, metrological traceability is essential. It provides a way to establish the accuracy and validity of measurement results by relating them to internationally accepted measurement standards or references.

The concept of traceability involves a series of comparisons that link the measurement being performed to a known reference standard. These comparisons are typically made through a calibration process using measurement instruments and methods that are themselves traceable to national or international measurement standards.

The traceability chain includes all the measurement steps, instruments, and calibration procedures used to establish the connection between the measured quantity and the reference standard. Each step in the chain must be carefully documented, and the uncertainties associated with each comparison must be quantified and reported.

By ensuring metrological traceability, measurement results can be compared across different laboratories, instruments, and time periods. This allows for the consistency and accuracy of measurements and enhances confidence in the reliability of scientific and industrial measurements.

Metrological traceability is particularly important in fields such as metrology, scientific research, quality assurance, manufacturing, and regulatory compliance, where precise and accurate measurements are critical for decision-making, product quality, and safety.

## What is Metrological Traceability? Answer from an expert ...



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**In order to ensure the reliability and comparability of measurements, metrological traceability is essential. It provides a way to establish the accuracy and validity of measurement results by relating them to internationally accepted measurement standards or references.**

### VIM definition on metrological traceability

“Property of a measurement result whereby the result can be related to a reference through a documented **unbroken chain of calibrations**, each contributing to the **measurement uncertainty**.”

# Metrological Traceability

## VIM definition and supplemental notes

1

Metrological traceability means measurements can be **meaningfully compared**.

2

Even when made...

- at different times
- at different places
- by different people
- using different equipment

3

VIM supplemental notes on metrological traceability:

- Metrological traceability requires an established **calibration hierarchy**
- For measurements with more than one input quantity, **each** of the input quantity values **should itself be metrologically traceable**
- Each input quantity value should be commensurate with its **relative contribution to the measurement result**

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<https://www.bipm.org/en/publications/guides/vim.html>

# Metrological Traceability

## Certified Reference Materials & ISO/IEC 17025

### ILAC P10 Policy on CRMs & Metrological Traceability

“**The values assigned to CRMs** produced by NMIs [...] or produced by an accredited RMP under its scope of accreditation to ISO 17034 **are considered to have established valid traceability.**”

“The majority of RMs and CRMs are produced by other RMPs.”

“These can be considered as critical consumables and **the laboratory shall demonstrate** that each RM or CRM is **suitable for its intended use** as required by [...] ISO/IEC 17025 [...]”

ILAC P10 policy; ILAC General Assembly resolution ILAC 8.12

### ISO/IEC 17025 Metrological Traceability via CRMs

“**Reference materials shall, where possible, be traceable to SI units of measurement, or to certified reference materials.**”

ISO/IEC 17025:2017, section 5.6.3.2

<https://www.isobudgets.com/measurement-traceability-complying-iso-17025-requirements/#traceability-requirements-iso17025>

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# Key Reference Material Concepts

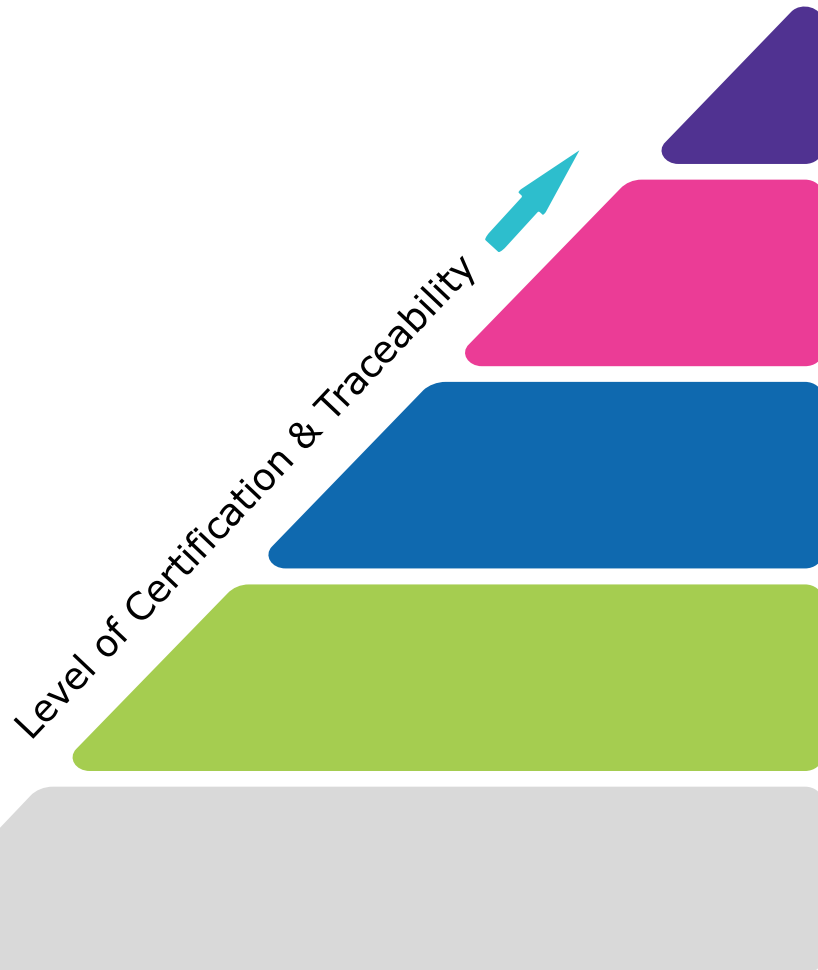
## Traceability pyramid shows traceability from SI to measurement in the laboratory





# Key Reference Material Concepts

## Traceability pyramid shows traceability from SI to measurement in the laboratory



### National Metrology (eg. NIST, PTB, BIPM, METAS)

- Issued by an authorized body
- Considered as highest level of accuracy and traceability



## Different quality levels and their most important attributes



Level of Certification & Traceability

### National Metrology (eg. NIST, PTB, BIPM, METAS)

- Issued by an authorized body
- Considered as highest level of accuracy and traceability

### Certified Reference Material (CRM) (ISO 17034, ISO/IEC 17025)

- Considered to provide the highest level of accuracy, uncertainty, and traceability to an SI unit of measurement
- Manufactured by an accredited Reference Material Producer

### Reference Material (RM) (ISO 17034)

- Characterized to requirements that are less demanding than for a certified reference material
- Manufactured by an accredited Reference Material Producer

### Analytical Standard (ISO 9001)

- Certificate of Analysis available
- Level of certification varies

### Reagent Grade / Research Chemical

- May come with a Certificate of Analysis
- Are not characterised for use as reference materials

## Different quality levels and their most important attributes



**Purity or Mass Fraction**

**Homogeneity**

**Stability**

**Uncertainty**

**Traceability**

Level of Certification & Traceability

Quality Level	Purity or Mass Fraction	Homogeneity	Stability	Uncertainty	Traceability
<b>PS</b> NMI					
<b>CRM</b> ISO 17034 ISO/IEC 17025					
<b>RM</b> ISO 17034					
<b>AS</b> ISO 9001					
<b>Reagent Grade Research Chemical</b>					

## Customer value added through optimal product design



**Neats**



**Solutions & Mixes**

Level of Certification & Traceability

**CRM**  
ISO 17034  
ISO/IEC 17025

- Handling of hazardous or toxic substances at larger scale
- Time consuming
- Error prone handling and sample prep



- Traceability** to SI unit
- Stability** and **homogeneity** testing
- Accurate determination of mass fractions including **uncertainties**

**AS**  
ISO 9001

- no traceability to SI unit
- limited stability and homogeneity testing
- no determination of mass fractions before dissolving step (only chrom purities)

customer convenience

# Key Reference Material Concepts

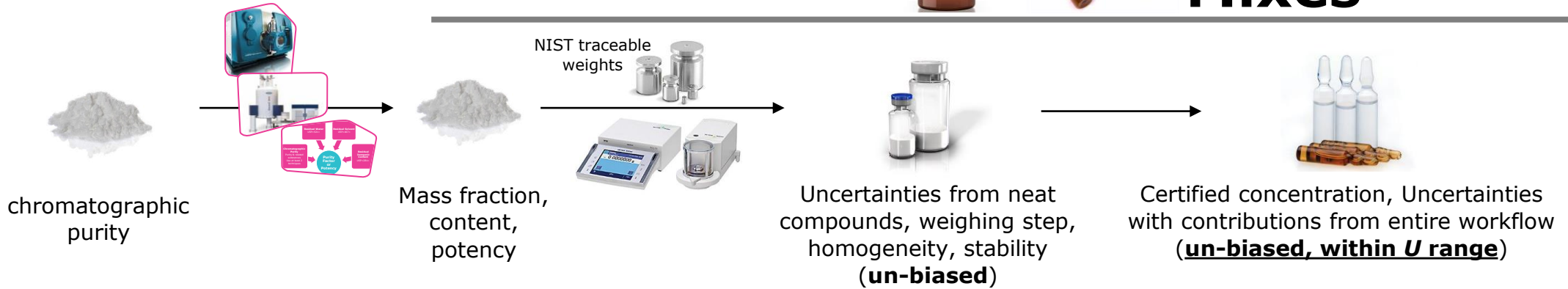
## Customer value added through optimal product design

### Neats



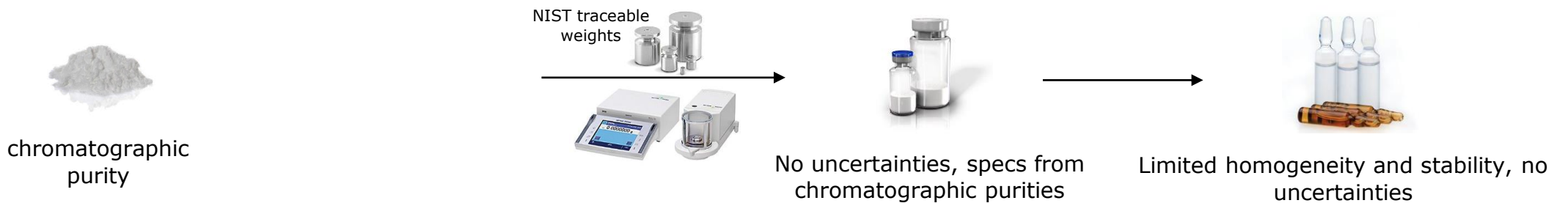
### Solutions & Mixes

**CRM**  
ISO 17034  
ISO/IEC 17025



**Some RMPs**  
"ISO 17034"

**AS**  
ISO 9001



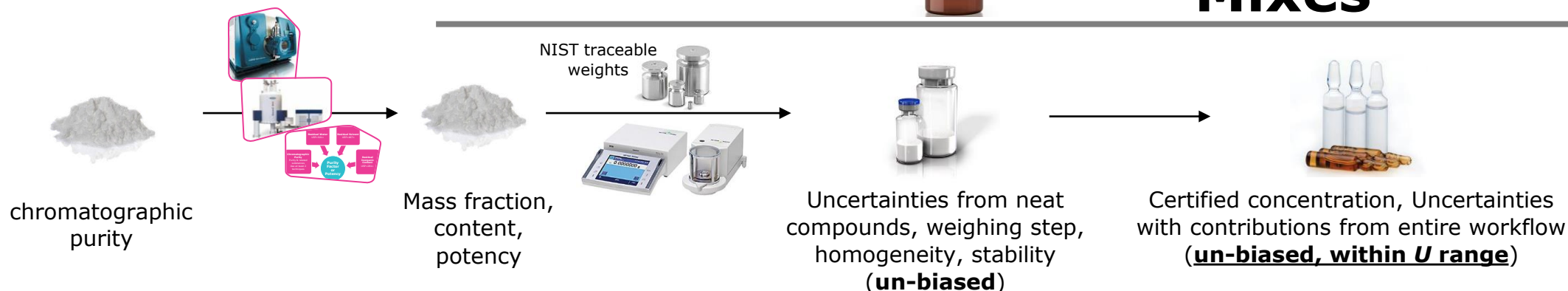
## Customer value added through optimal product design

### Neats



### Solutions & Mixes

**CRM**  
ISO 17034  
ISO/IEC 17025



- **Quantitative NMR**

- Traceable through primary materials from NMI to SI unit
- Higher order method

- **Isotope Dilution Mass Spectrometry**

- **Mass Balance**

- Uses multiple techniques for chromatographic purity and residuals
- Traceable through calibration

# Traceability of Neat Certified Reference Materials

## Development and manufacturing process

### Preparative Work

- Sourcing
- Synthesis
- Purification

### Accredited Certification

- Neat materials
- qNMR

### Certificate of Analysis

- Traceability
- Uncertainty calculation
- Creation of certificate



# Traceability of Neat Certified Reference Materials

## Characterization by quantitative NMR: Concept and value assignment

Supelco®



### Primary Ratio Method

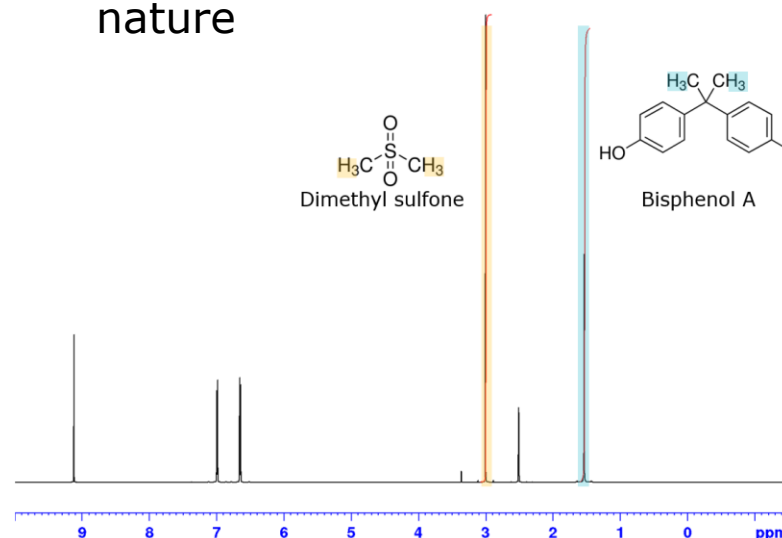
- Peak areas are proportional to the number of corresponding nuclei
- Signal intensity is independent of chemical nature

### Direct Traceability to the Reference

- Direct measurement of analyte vs. sample signal

### Impurities Do Not Affect the Result

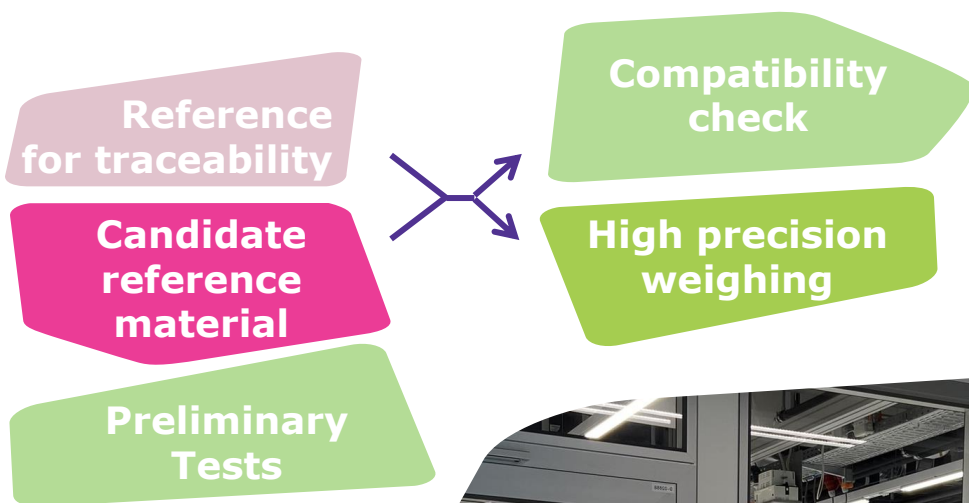
- Only one sample signal must be pure (minimum requirement)





# Traceability of Neat Certified Reference Materials

## Characterization by quantitative NMR: Concept and value assignment



### Preliminary Tests

- Hygroscopy
- Volatility
- Purity peak of interest
- Solubility and relaxation times

### Compatibility Check

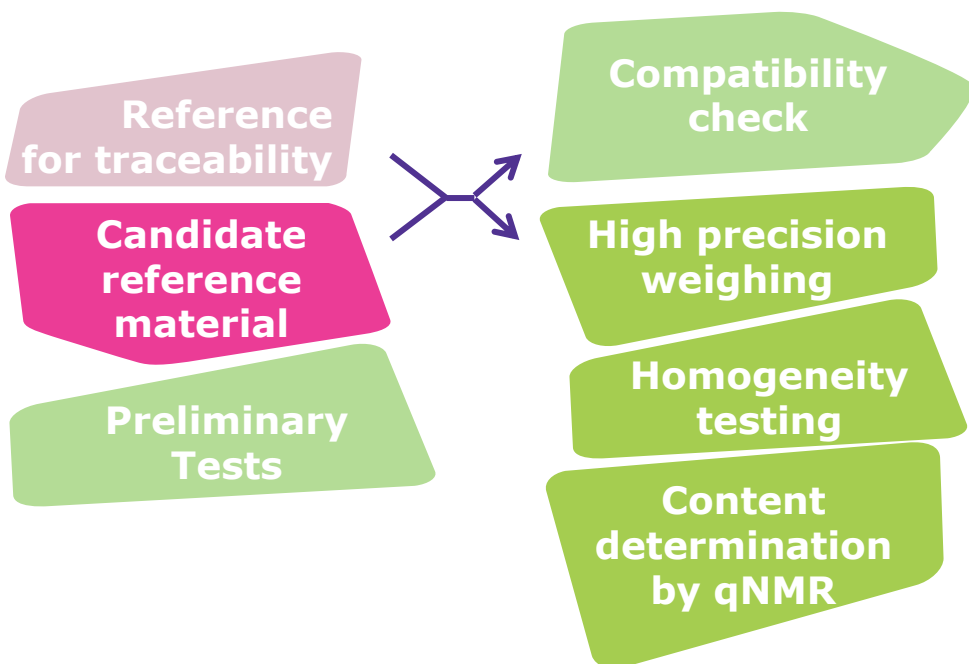
- No overlap
- Inertness

### Metrological Weighing

- Mettler-Toledo UMT-6
- OIML Class E2 calibration weights
- 1000 kg weighing table
- Air buoyancy correction
- Humidity, pressure and temperature monitoring / control

# Traceability of Neat Certified Reference Materials

## Characterization by quantitative NMR: Concept and value assignment



$$P_{\text{Sample}} = \frac{I_{\text{Analyte}}}{I_{\text{Ref}}} \cdot \frac{N_{\text{Ref}}}{N_{\text{Analyte}}} \cdot \frac{M_{\text{Analyte}}}{M_{\text{Ref}}} \cdot \frac{m_{\text{Ref}}}{m_{\text{Sample}}} \cdot P_{\text{Ref}}$$

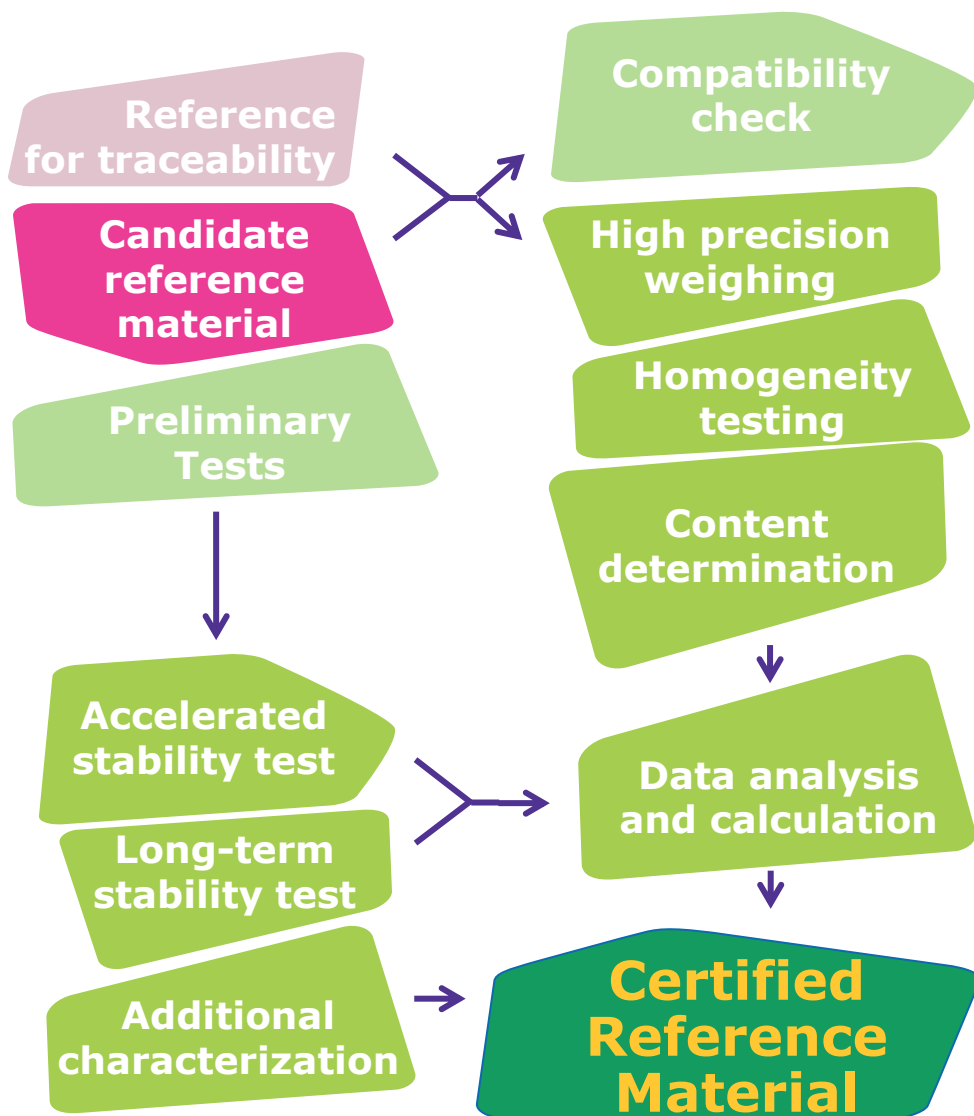
- P Purity as mass fraction
- I Integral of the <sup>1</sup>H NMR signal
- N Number of protons
- M Molecular mass
- m Mass



### Homogeneity Testing & Purity Determination

- Homogeneity assessment by qNMR
- One-way ANOVA
- 2 Bruker and 2 Jeol 600 MHz (BBO and TCI Prodigy Cryo Probe)
- 90° pulse with D1 of 60 sec
- no spinning
- manual shape / baseline correction

## Characterization by quantitative NMR: Concept and value assignment



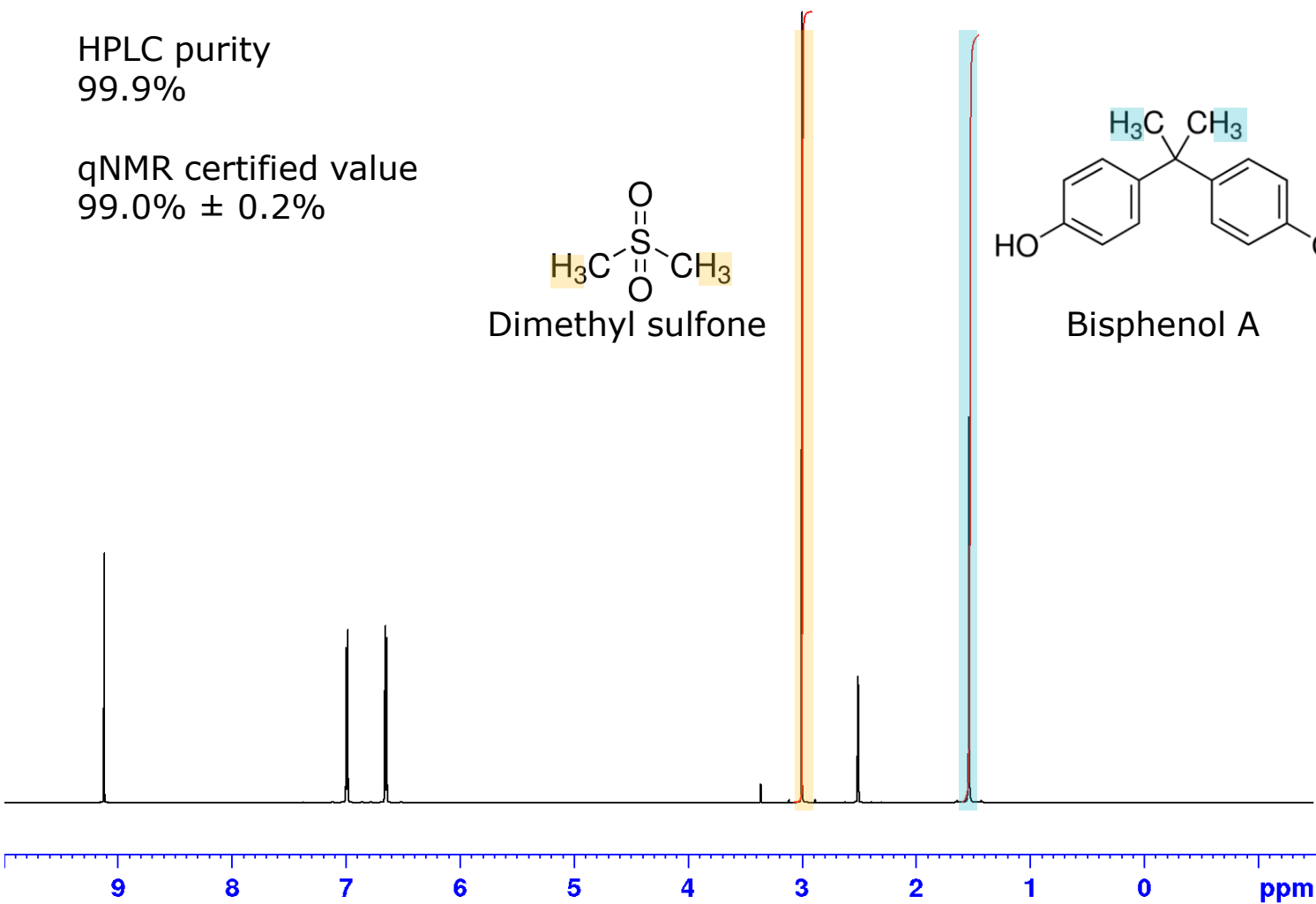
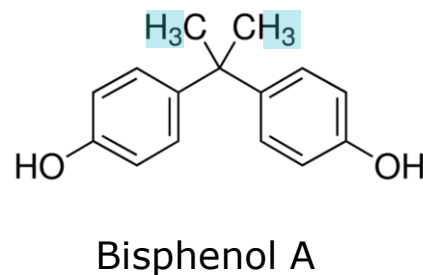
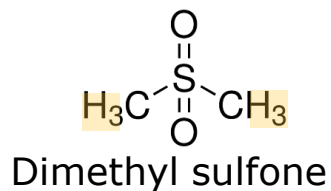
$$u_{CRM} = \sqrt{u_{char}^2 + u_{homo}^2 + u_{stab}^2}$$
$$U = k u_{CRM} (k = 2)$$

# Traceability of Neat Certified Reference Materials

## Example: Bisphenol A

HPLC purity  
99.9%

qNMR certified value  
99.0% ± 0.2%



www.sigmaaldrich.com

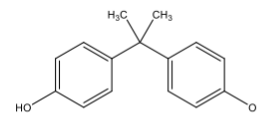
**Supelco®**

**Certified Reference Material**  
Reference material certificate

TraceCERT®  
Transferable Certified Reference Materials

**Bisphenol A**

<b>Product no.:</b>	42088
<b>Lot no.:</b>	BCCG8672
<b>Description of CRM:</b>	Solid neat material
<b>Expiry date:</b>	JAN 2026
<b>Storage:</b>	15-25°C
<b>Chemical formula:</b>	C <sub>15</sub> H <sub>16</sub> O <sub>2</sub>
<b>Molecular mass:</b>	228.29 g/mol
<b>CAS No.:</b>	80-05-7



Sample	Certified value ± Expanded uncertainty, $U = k \cdot u$ ( $k = 2.8$ ) <sup>[1][2]</sup> as mass fraction (g/g)
Bisphenol A	<b>99.0 % ± 0.6 %</b>

**Metrological traceability:** NIST SRM 841 (KHP)<sup>[3]</sup>  
Details see "Certification process details" on page 2.

**Measurement method:** The certified value is established by high-resolution quantitative NMR measurements (qNMR) in accordance with ISO/IEC 17025.<sup>[4]</sup>


**Intended use:** Use this certified reference material (CRM) as calibrant for chromatography or any other analytical technique.

**Minimum sample size:** The sample is solid at room-temperature. 20 mg is recommended as the minimum sample size. If less material is used, it is recommended to increase the certified uncertainty by a factor of two for half of sample and a factor of four for a quarter of sample.

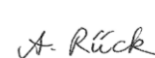
**Instructions for handling and correct use:** This material does not require drying before use. The CRM should be stored in the original bottle. After use the bottle should be tightly closed and protected from excessive moisture and light.

**Accreditation:** Sigma-Aldrich Production GmbH is accredited by the Swiss Accreditation Service SAS as reference material producer under no. SRMS 0001 in accordance with international standard ISO 17034.<sup>[5]</sup>


**Certificate issue date:** 10 FEB 2022



ISO 17034  
SRMS 0001



Dr. A. Rück – CRM Operations



Dr. P. Zell – Approving Officer

Sigma-Aldrich Production GmbH, Industriestrasse 25, 9471 Buchs, Switzerland;  
Tel +41-91-755-2511; Fax +41-91-756-5449; www.sigmaaldrich.com  
Sigma-Aldrich Production GmbH is a subsidiary of Merck KGaA, Darmstadt, Germany.

Certificate Page 1 of 4 Certificate version 01



# Traceability of Neat Certified Reference Materials

## Example: Bisphenol A

HPLC purity  
99.9%

qNMR certified value  
99.0% ± 0.2%

Some  
RMPs

“ISO 17034”

Small uncertainty based on  
weighing step (**bias**)

Supelco® www.sigmaaldrich.com

**Certified Reference Material**  
Reference material certificate

**TraceCERT®**  
Traceable Certified Reference Materials

**Bisphenol A**

**Product no.:** 42088  
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Cc1ccc(cc1)C(C)(c2ccc(O)cc2)C

Sample	Certified value ± Expanded uncertainty, $U = k \cdot u$ ( $k = 2.8$ ) <sup>[1][2]</sup> as mass fraction (g/g)
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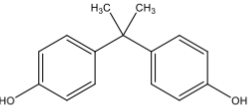
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www.sigmaaldrich.com

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ISO 17034  
SRMS 0001



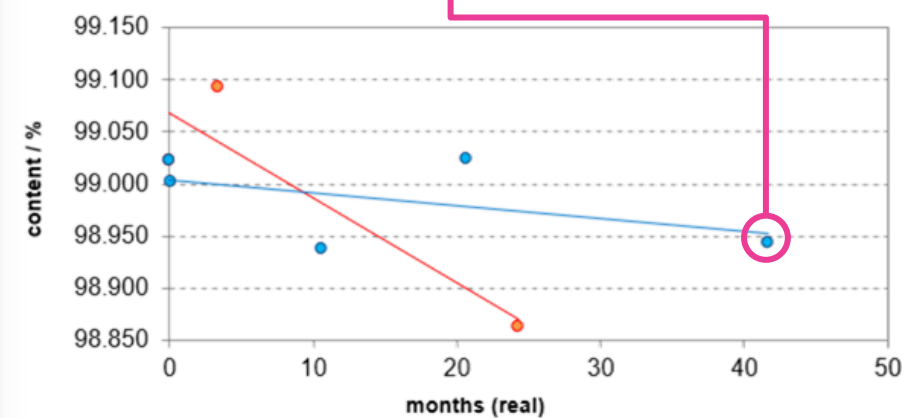
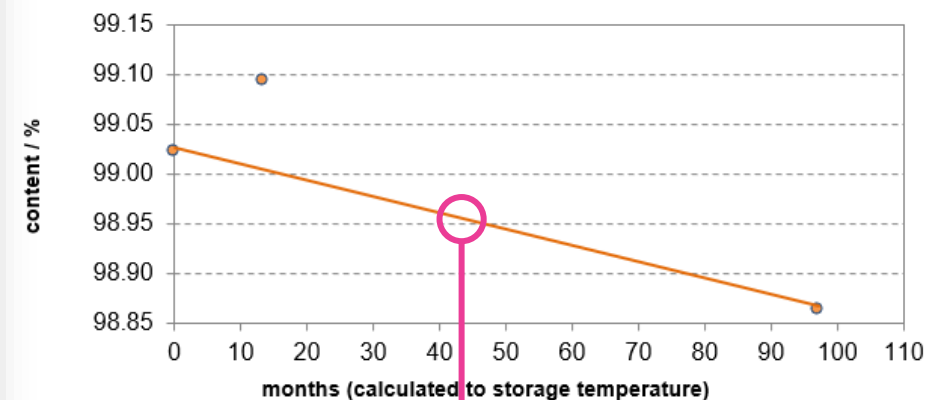
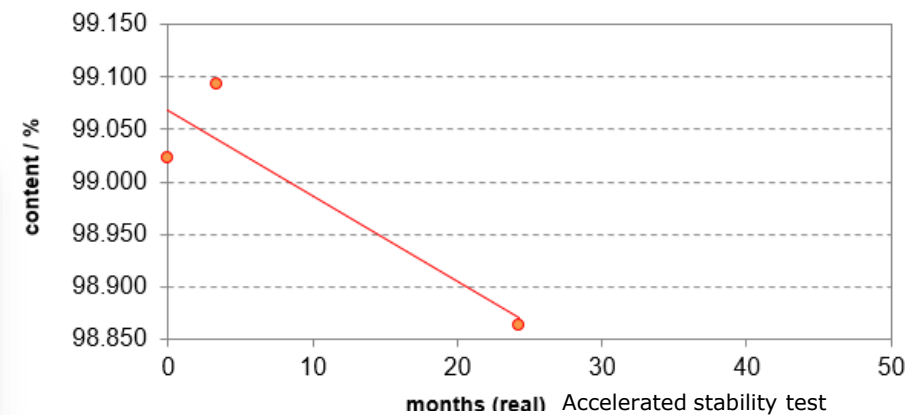
Dr. A. Rück – CRM Operations



Dr. P. Zell – Approving Officer

Sigma-Aldrich Production GmbH, Industriestrasse 25, 9471 Buchs, Switzerland;  
 Tel +41-81-755-2511; Fax +41-81-756-5449; www.sigmaaldrich.com  
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Certificate Page 1 of 4
Certificate version 01



# Traceability of Neat Certified Reference Materials

## Example: Bisphenol A

### ISO Guide 31

Guide for documentation, certificates

### ISO Guide 35

Guide for homogeneity and stability

### ISO / IEC 17025

Norm for calibration, testing laboratories

### ISO 17034

Norm for CRM Producer

**Supelco®** www.sigmaldrich.com

**Certified Reference Material**  
Reference material certificate

**TraceCERT®**  
Traceable Certified Reference Materials

**Bisphenol A**

**Product no.:** 42088  
**Lot no.:** BCCG8672  
**Description of CRM:** Solid neat material  
**Expiry date:** (1) JAN 2026  
**Storage:** (2) 15-25°C  
**Chemical formula:** C<sub>15</sub>H<sub>16</sub>O<sub>2</sub>  
**Molecular mass:** 228.29 g/mol  
**CAS No.:** 80-05-7

Sample	Certified value ± Expanded uncertainty, $U = k \cdot u$ ( $k = 2.8$ ) <sup>[1][2]</sup> as mass fraction (g/g)
Bisphenol A	(3) 99.0 % ± 0.6 % (4)

**Metrological traceability:** NIST SRM 841 (KHP)<sup>[3]</sup> (5) Details see "Certification process details" on page 2. (6)

**Measurement method:** The certified value is established by high-resolution quantitative NMR measurements (qNMR) in accordance with ISO/IEC 17025.<sup>[4]</sup>

**Intended use:** (7) Use this certified reference material (CRM) as calibrant for chromatography or any other analytical technique.

**Minimum sample size:** The sample is solid at room-temperature. 20 mg is recommended as the minimum sample size. If less material is used, it is recommended to increase the certified uncertainty by a factor of two for half of sample and a factor of four for a quarter of sample.

**Instructions for handling and correct use:** This material does not require drying before use. The CRM should be stored in the original bottle. After use the bottle should be tightly closed and protected from excessive moisture and light.

**Accreditation:** Sigma-Aldrich Production GmbH is accredited by the Swiss Accreditation Service SAS as reference material producer under no. SRMS 0001 in accordance with international standard ISO 17034.<sup>[5]</sup>

**Certificate issue date:** 10 FEB 2022

(8) ISO 17034  
SRMS 0001

Dr. A. Rück – CRM Operations

Dr. P. Zell – Approving Officer

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Certificate Page 1 of 4 Certificate version 01

## Certificate

- (1) Expiration date
- (2) Storage conditions
- (3) Certified value (g/g)
- (4) Expanded uncertainty (g/g)
- (5) Traceability statement
- (6) Measurement method
- (7) Intended use
- (8) Signatures and accreditation stamp

# Traceability of Neat Certified Reference Materials

## Development and manufacturing process

### Preparative Work

- Sourcing
- Synthesis
- Purification

### Accredited Certification

- Neat materials
- qNMR

### Certificate of Analysis

- Traceability
- Uncertainty calculation
- Creation of certificate





# Traceability of Certified Reference Materials Solutions and Mixes

## Development and manufacturing process

### Preparative Work

- Sourcing
- Synthesis
- Purification

1



### Accredited Certification

- Neat materials
- qNMR

2



### BULK Solution

- Dissolving
- Gravimetric dilution

3



4



### Ampoule Filling

- Method validation

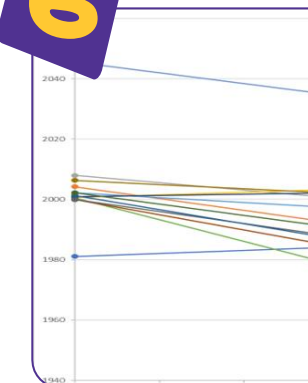
5



### Homogeneity Testing

- LC-IDMS and GC-IDMS
- wb and bb

6



### Stability Testing

- LC-IDMS and GC-IDMS
- AST and LTS

7



# Traceability of Certified Reference Materials Solutions and Mixes

## Individual uncertainties contribute to overall uncertainty

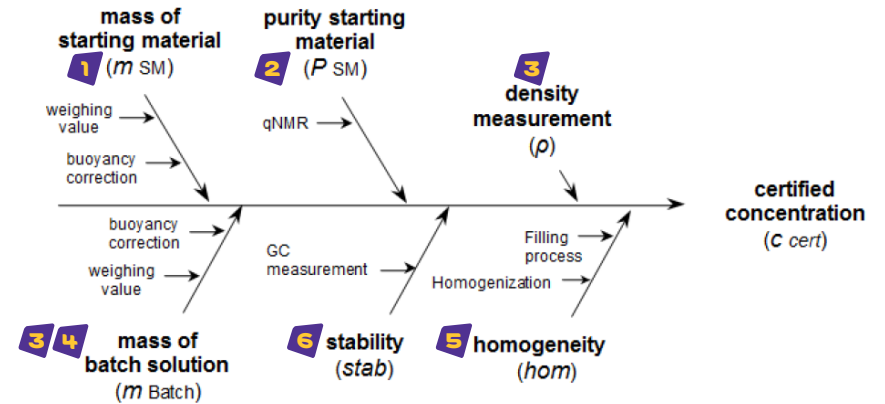
### Extractables and Leachables Screening Standard for LC

Product no.: 95636  
 Lot no.: BCCF4251  
 Description of CRM: Extractables and Leachables Screening Standard, 21 components in Acetonitrile  
 Expiry date: APR 2025  
 Storage: Store at -20°C ± 5°C  
 Density (certified) at 20°C: 782.4 kg m<sup>-3</sup> ± 0.4 kg m<sup>-3</sup>



Constituent	Certified values at 20°C and expanded uncertainties, $U = k \cdot u$ ( $k = 2$ ) <sup>(1)(2)</sup>	
Pentaerythritol tetrakis(3,5-di-tert-butyl-4-hydroxyhydrocinnamate)	63.91 mg/kg ± 5.49 mg/kg	50.00 mg/l ± 4.29 mg/l
Octadecyl 3-(3,5-di-tert-butyl-4-hydroxyphenyl)propionate	63.99 mg/kg ± 5.73 mg/kg	50.07 mg/l ± 4.48 mg/l
Drometrizole	63.80 mg/kg ± 4.64 mg/kg	49.92 mg/l ± 3.63 mg/l
ε-Caprolactam	63.79 mg/kg ± 4.22 mg/kg	49.91 mg/l ± 3.31 mg/l
Dibenzylamine	64.31 mg/kg ± 4.58 mg/kg	50.32 mg/l ± 3.58 mg/l
Benzoic acid	64.16 mg/kg ± 3.77 mg/kg	50.20 mg/l ± 2.95 mg/l
2-Mercaptobenzothiazole	63.89 mg/kg ± 4.88 mg/kg	49.99 mg/l ± 3.82 mg/l
Bisphenol A	64.33 mg/kg ± 5.27 mg/kg	50.34 mg/l ± 4.12 mg/l
2-Ethylhexanoic acid	64.79 mg/kg ± 3.02 mg/kg	50.69 mg/l ± 2.36 mg/l
Bis(4-chlorophenyl) sulfone	64.17 mg/kg ± 5.69 mg/kg	50.20 mg/l ± 4.45 mg/l
3,5-Di-tert-butyl-4-hydroxybenzyl alcohol	63.81 mg/kg ± 5.50 mg/kg	49.93 mg/l ± 4.30 mg/l
Butylhydroxytoluene (BHT)	63.73 mg/kg ± 5.75 mg/kg	49.86 mg/l ± 4.50 mg/l
1,3-Di-tert-butylbenzene	64.50 mg/kg ± 5.82 mg/kg	50.47 mg/l ± 4.56 mg/l
Oleamide	64.21 mg/kg ± 9.44 mg/kg	50.24 mg/l ± 7.39 mg/l
Bis(2-ethylhexyl) phthalate	63.99 mg/kg ± 4.67 mg/kg	50.06 mg/l ± 3.63 mg/l
Stearic acid	63.89 mg/kg ± 2.80 mg/kg	49.99 mg/l ± 2.28 mg/l
cis-13-Docosenoamide	64.18 mg/kg ± 10.64 mg/kg	50.13 mg/l ± 8.48 mg/l
Tris(3,5-di-tert-butyl-4-hydroxybenzyl) isocyanurate	64.13 mg/kg ± 3.02 mg/kg	50.13 mg/l ± 2.36 mg/l
Tris(2,4-di-tert-butylphenyl)phosphate	64.33 mg/kg ± 5.27 mg/kg	50.34 mg/l ± 4.12 mg/l
2,4-Di-tert-butylphenol	64.33 mg/kg ± 5.27 mg/kg	50.34 mg/l ± 4.12 mg/l
Palmitic acid	64.33 mg/kg ± 5.27 mg/kg	50.34 mg/l ± 4.12 mg/l

- Uncertainty contributions and traceability:

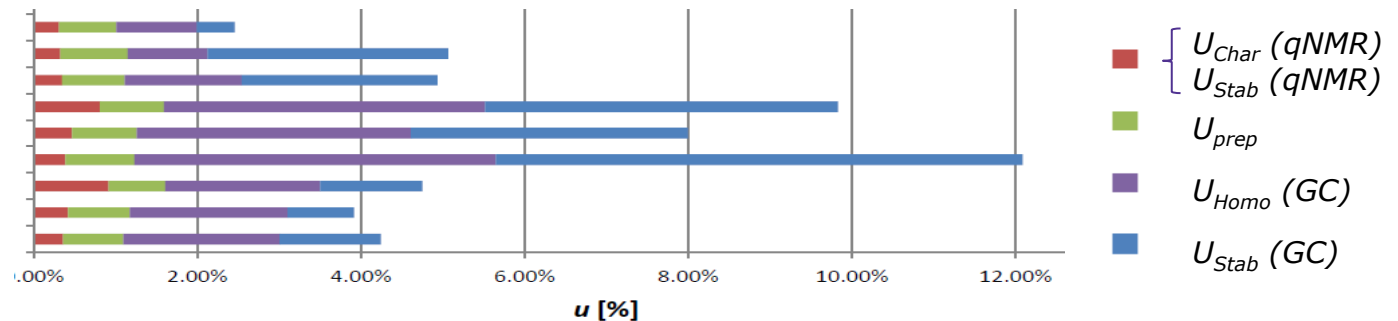


- Overall Expanded Uncertainty:

$$u_{CRM} = \sqrt{u_{char}(qNMR)^2 + u_{stab}(qNMR)^2 + u_{prep}^2 + u_{Homo}(LC/GC)^2 + u_{Stab}(LC/GC)^2}$$

$$U = k \cdot u_{CRM} (k = 2)$$

- Creation of certificate including expanded uncertainty for each individual component



# Traceability of Certified Reference Materials Solutions and Mixes

## Example 2: MOSH MOAH CRM Calibration Mixture

www.sigmaaldrich.com

**Certified Reference Material**  
Reference material certificate

**MOSH/MOAH Standard Mix**

Product no.: **TraceCERT®**  
Lot no.:  
Description of:  
Expiry date:  
Storage:  
Density (certified) at 20°C: 867.3 kg m<sup>-3</sup> ± 0.4 kg m<sup>-3</sup>

**The certified value of TraceCERT® reference materials is based on this approach and directly traceable to the SI unit kilogram.**

**The starting material is measured against a certified reference material which is traceable to SRM® from NIST followed by gravimetric preparation using balances calibrated with SI-traceable weights.**

**Consequently, the value calculated by this unbroken chain of comparisons is traceable to the reference to which the starting material is compared.**

Constituent:  
Perylene  
5-α-Cholestane  
n-Undecane  
n-Tridecane  
Tri-tert-butylbenzene  
Bicyclohexyl  
1-Methylnaphthalene  
2-Methylnaphthalene  
Pentylbenzene  
1,4-di(2-ethylhexyl)benzene

Metric:  
Measurement method:  
Intended use:  
Instructions for handling and correct use:  
Health and safety information:  
Packaging:  
Accreditation:  
Certificate issue date:

Shake well, sonicate the ampule thoroughly, warm to room temperature before opening for each measurement series.  
Please refer to the Safety Data Sheet for detailed information about the nature of any hazard and appropriate precautions to be taken.  
Amber glass ampule  
Sigma-Aldrich Production GmbH is accredited by the Swiss Accreditation Service SAS as registered reference material producer under no. SRMS 0001 in accordance with international standard ISO 17034.1<sup>3</sup>  
JAN 31, 2023

H. Sprecher – CRM Operations  
Dr. P. Zell – Approving Officer

ISO 17034  
SRMS 0001

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Certificate Page 1 of 4

May 23, 2023

**CERTIFIED REFERENCE MATERIAL**

**Certificate of Analysis**

ACCREDITED  
ISO 17034 Accredited  
Reference Material Producer  
Certificate #322101

ILAC-MPA  
ACCREDITED  
Reference Laboratory  
Certificate #17034

**Concentration is based upon gravimetric preparation using either a balance whose calibration has been verified daily using NIST traceable weights, and/or dilutions with Class A glassware.**

This Reference Material is intended for Laboratory Use Only as a standard for the gravimetric preparation of calibration solutions.

Catalog No.: 33170 Lot No.: A0178816

Expiration Date: November 30, 2023 Storage: 10°C or colder  
Handling: Sonication, sealed, and by photosensitization Temp: Ambient

**CERTIFIED VALUES**

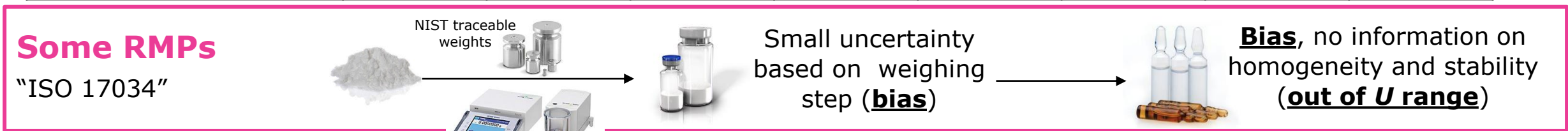
Elution Order	Compound	Grav. Conc. (weight/volume)	Expanded Uncertainty (95% C.L.; K=2)	
1	n-Undecane (C11)	300.4 µg/mL (Lot SHBM4122)	+/- 1.7506	Gravimetric
	CAS # 1120-21-4		+/- 13.5307	Unstressed
	Purity 99%		+/- 15.0139	Stressed
2	n-Pentylbenzene	300.8 µg/mL (Lot MKBG5289V)	+/- 1.7529	Gravimetric
	CAS # 538-68-1		+/- 13.5487	Unstressed
	Purity 99%		+/- 15.0339	Stressed
3	n-Tridecane (C13)	150.5 µg/mL (Lot MKCM6532)	+/- 0.8878	Gravimetric
	CAS # 629-50-5		+/- 6.7803	Unstressed
	Purity 99%		+/- 7.5232	Stressed
4	1-Methylnaphthalene	301.3 µg/mL (Lot 5234.00-3)	+/- 1.7558	Gravimetric
	CAS # 90-12-0		+/- 13.5713	Unstressed
	Purity 99%		+/- 15.0589	Stressed
5	Bicyclohexyl	302.8 µg/mL (Lot SHBH0815V)	+/- 1.7646	Gravimetric
	CAS # 92-51-3		+/- 13.6388	Unstressed
	Purity 99%		+/- 15.1338	Stressed
6	2-Methylnaphthalene	302.4 µg/mL (Lot STBG8884)	+/- 1.7622	Gravimetric
	CAS # 91-57-6		+/- 13.6208	Unstressed
	Purity 99%		+/- 15.1139	Stressed
7	1,3,5-Tri-tert-butylbenzene	302.8 µg/mL (Lot 5G2FC)	+/- 1.7646	Gravimetric
	CAS # 1460-02-2		+/- 13.6388	Unstressed
	Purity 99%		+/- 15.1338	Stressed

01-Aug-2020 rev. 1 of 3

# Traceability of Certified Reference Materials Solutions and Mixes

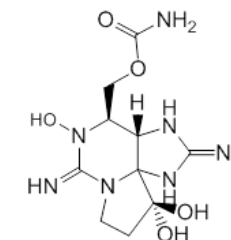
## Example 2: MOSH MOAH CRM Calibration Mixture

Name	Concentration	Gravimetric	Gravimetric [%]	Unstressed	Unstressed [%]	Stressed	Stressed [%]	Deviation [%]
n-Undecane	300.4	1.7506	0.58	13.5307	4.50	15.0139	5.00	-3.9
Pentylbenzene	300.8	1.7529	0.58	13.5487	4.50	15.0339	5.00	-2.9
n-Tridecane	150.5	0.8878	0.59	6.7803	4.51	7.5232	5.00	-0.7
2-Methylnaphthalene	302.4	1.7622	0.58	13.6208	4.50	15.1139	5.00	-6.2
Bicyclohexyl	302.8	1.7646	0.58	13.6388	4.50	15.1338	5.00	-3.2
1-Methylnaphthalene	301.3	1.7558	0.58	6.7803	2.25	15.0589	5.00	-12.2
1,3,5-Tri-tert-butylbenzene	302.8	1.7646	0.58	13.6388	4.50	15.1338	5.00	3.8
5-a-Cholestane	605.2	3.5268	0.58	27.2596	4.50	30.2477	5.00	-10.4
Perylene	602.3	3.5099	0.58	27.1290	4.50	30.1028	5.00	-17.4



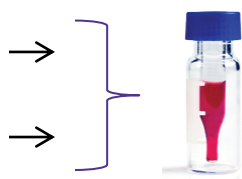
# Traceability of Certified Reference Materials Solutions and Mixes

## Example 3: Neosaxitoxin

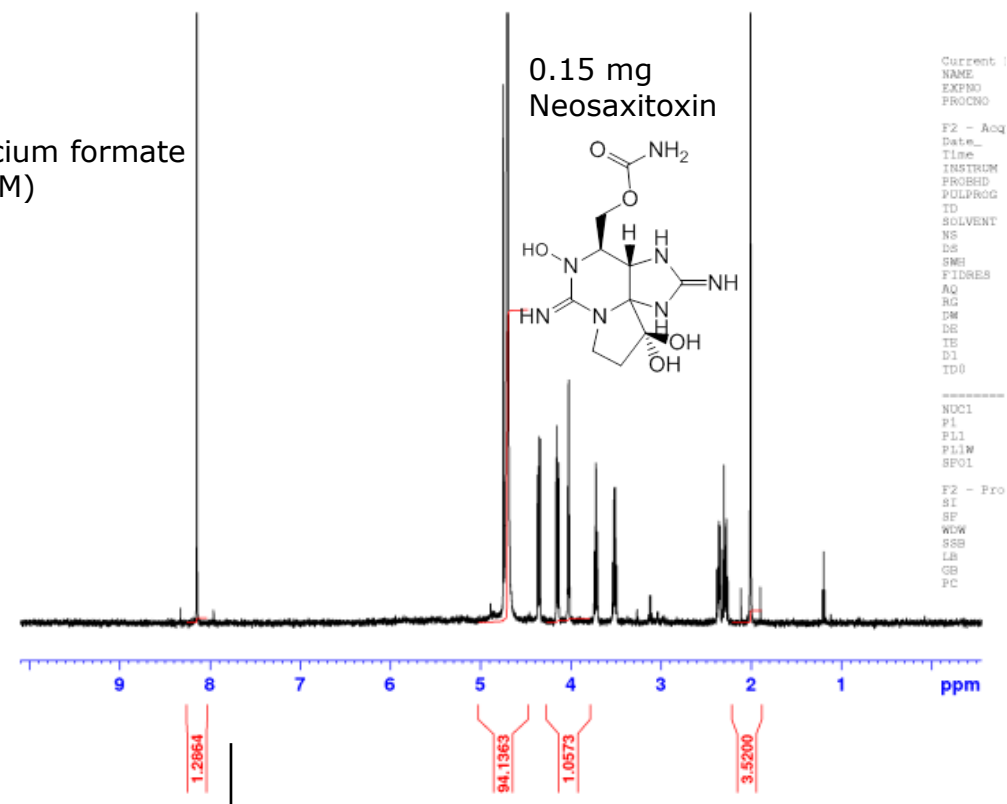


# Traceability of Certified Reference Materials Solutions and Mixes

## Example 3: Neosaxitoxin



Calcium formate (CRM)



Determination of the concentration



Gravimetric dilution



Ampule filling



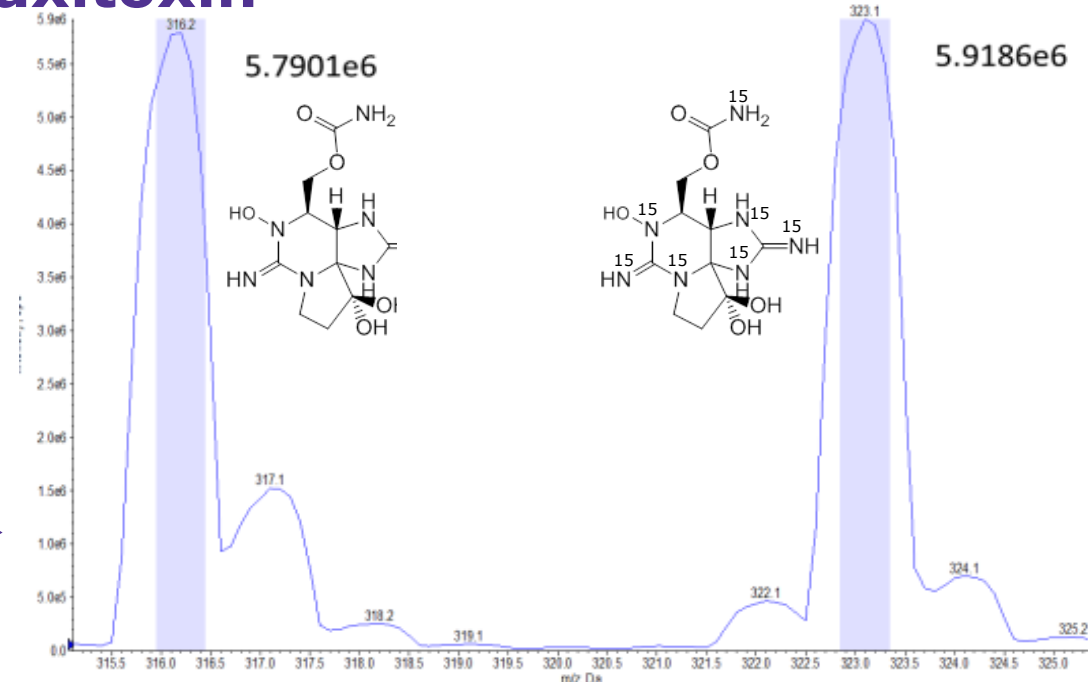
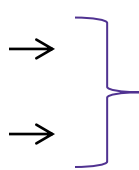
# Traceability of Certified Reference Materials Solutions and Mixes

## Example 3: Neosaxitoxin and $^{15}\text{N}_7$ -Neosaxitoxin

Supelco®



Neosaxitoxin solution (CRM)



Determination of the concentration



Gravimetric dilution



Ampule filling



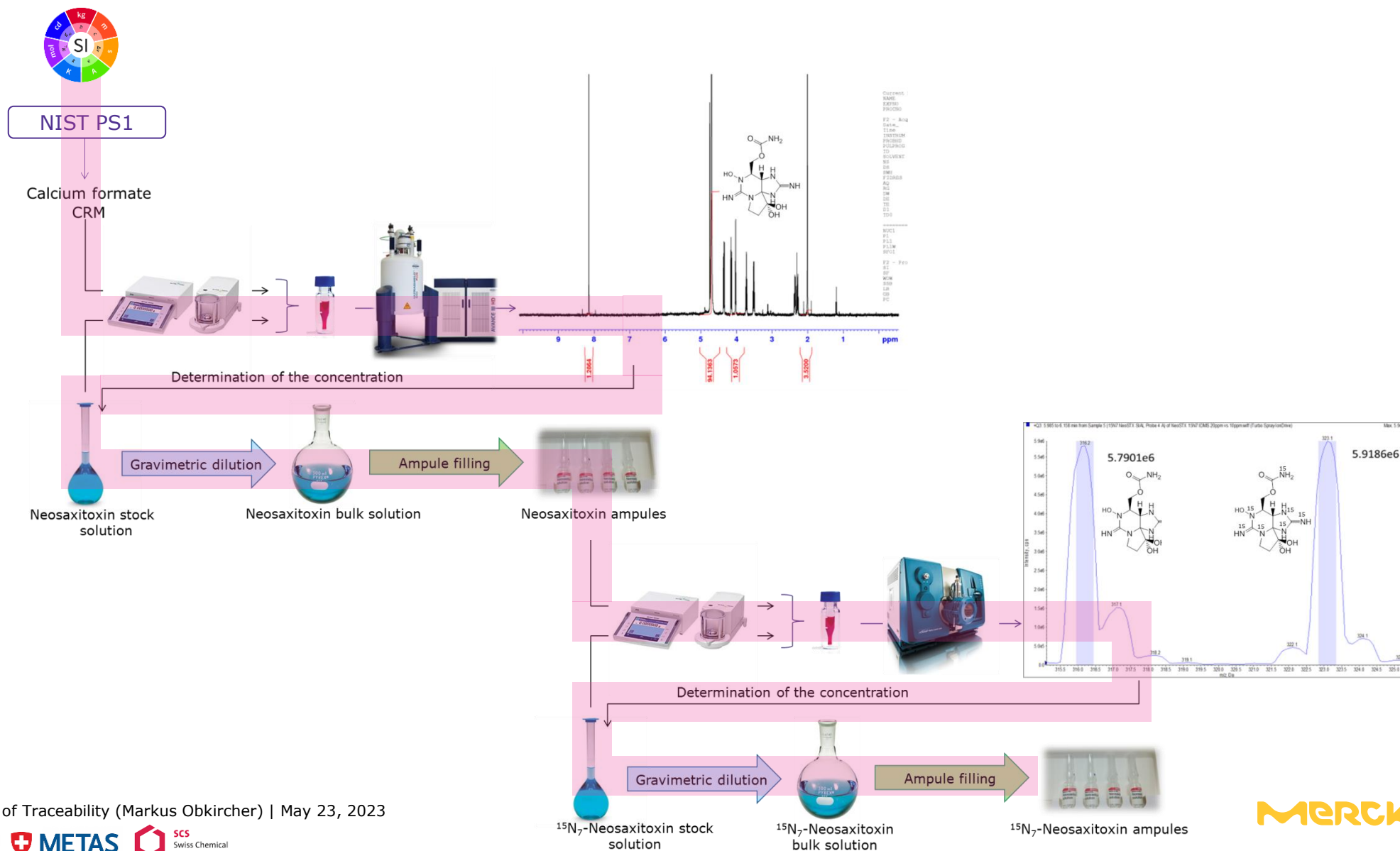
$^{15}\text{N}_7$ -Neosaxitoxin stock solution

$^{15}\text{N}_7$ -Neosaxitoxin bulk solution

$^{15}\text{N}_7$ -Neosaxitoxin ampoules (CRM)

# Traceability of Certified Reference Materials Solutions and Mixes

## Example 3: Neosaxitoxin and <sup>15</sup>N<sub>7</sub>-Neosaxitoxin



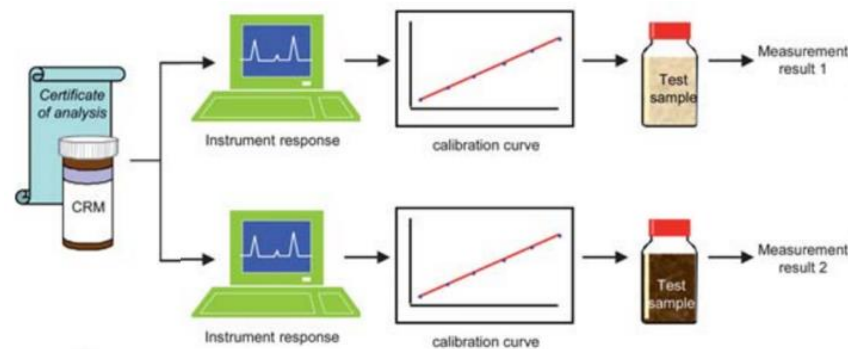


# The Importance of Traceability

## Summary

- Measurand
- Measurement Unit
- Measurement Uncertainty
- Measurement Procedure
- Measurement Function
- Method Validation
- References
- Influence Quantities
- Calibration
- Analysis
- Result

- Several aspects in a chemical measurement / analytical workflow need to be considered to achieve traceability of results
- The use of suitable reference materials (ideally CRM) is, together with an appropriate calibration, key factor in establishing metrological traceability and thus comparability of analytical measurements



- Certified Reference Materials themselves must offer a traceability to the SI unit through an unbroken chain of comparison to a primary standard

# The Importance of Traceability Acknowledgement

## □ R&D Team Buchs



## □ Partners (in presented examples)





**Markus Obkircher**  
Director R&D, Merck  
Head of Customer Solutions R&D



**Eurachem / CITAC Guide**

# **Metrological Traceability in Chemical Measurement**

**A guide to achieving comparable results  
in chemical measurement**

**2nd Edition in English**

**2019**

# **The importance of Traceability**

**or how to Achieve Comparability of  
Chemical Measurements**

**MERCK**

