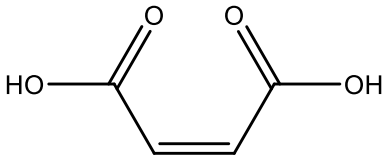
Certified Reference Material

Reference material certificate

Maleic acid

TraceCERT® Traceable Certified Reference Materials

Product no.:	92816
Lot no.:	BCCN5306
Description of CRM:	solid neat material
Expiry date:	AUG 2029
Storage:	15-25°C; storage under Argon
Chemical formula:	$C_4H_4O_4$
Molecular mass:	116.07 g/mol
CAS No.:	110-16-7



Sample	Certified value ± Expanded uncertainty, $U_{CRM}=k \cdot u_{CRM}$ (k=2)[1][2] as mass fraction
Maleic acid	**0.9982 g/g ± 0.0019 g/g** (99.82 % ± 0.19 %)

Metrological traceability: Traceable to the SI through an unbroken chain of comparisons via NIST PS1 (Benzoic acid)[3]

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.[4]

Intended use: Use this certified reference material (CRM) as standard for quantitative ^{1}H-NMR measurements.

Minimum sample size: The sample is solid at room-temperature. 10 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.

Test stability of the CRM in mixture and/or in solution for the desired duration of the experiment.

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.[5]

Certificate issue date: 28 AUG 2025

ISO 17034
SRMS 0001

Dr. P. Zell – Approving Officer
(Quality Assurance)

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Sigma-Aldrich Production GmbH is a subsidiary of Merck KGaA, Darmstadt, Germany.

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

Packaging: Brown glass bottle

Starting material details: Starting materials are checked with different analytical techniques (e.g. 1D/2D NMR methods) for suitability in terms of purity and compatibility with solvent and qNMR reference. Only materials of highest available purity are accepted.

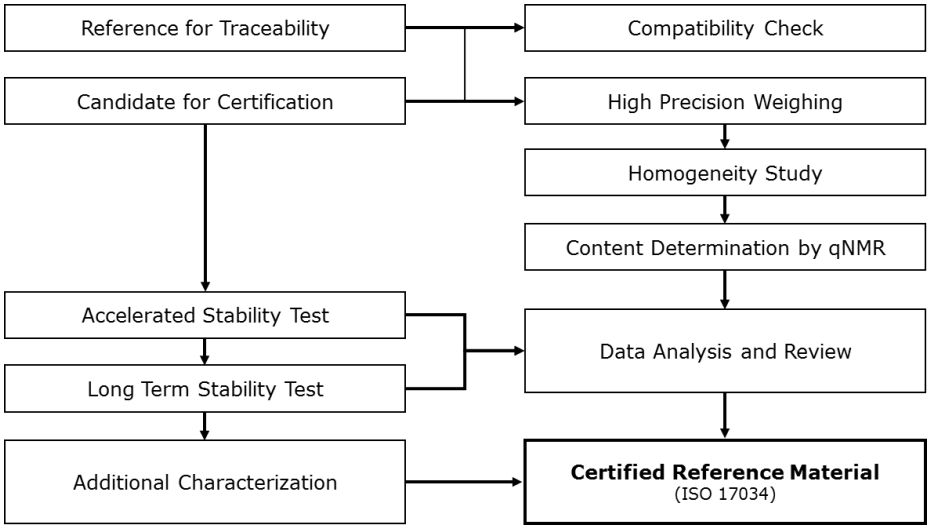
Certification process details:

In order to guarantee highest reliability of this *Trace***CERT** CRM a multi-component approach was applied whereby the certified value is determined by high-resolution quantitative NMR measurements (qNMR on a 600 MHz NMR spectrometer).[4][6] The whole workflow follows the ISO 17034 guidelines. The certificate is designed in accordance with ISO 33401.[7]

The certified values are confirmed by extended analytical data. These data are not covered by the scope of accreditation but determined following best practices in analytical measurements.

The high precision weighing steps are performed in accordance with ISO/IEC 17025[4] using ultra-micro balances certified by DKD and calibrated with OIML Class E2 weights.

Absolute content determination by qNMR is performed using 5-10 separate samples of the candidate substance which are each spiked with an adequate amount of internal reference and then immediately dissolved in deuterated solvent. In most cases 16-32 scans are recorded for every sample with a ^{1}H relaxation time of d1= 60 seconds. Quantification of the candidate content is directly calculated from the ^{1}H-NMR peak areas and the initial mass of the candidate and reference substance. After ANOVA the resulting standard deviation is included into the uncertainty calculation of the certified value. Extensive stability and homogeneity tests are considered for certification.[8]



Homogeneity assessment: Homogeneity of the material is tested by qNMR measurements using 5-10 subsamples which are taken from different positions in the entire bulk material. The recommended minimal sample size is taken for all the homogeneity test samples. Analysis of variance (ANOVA) results are included into the calculation of content uncertainty of this CRM.

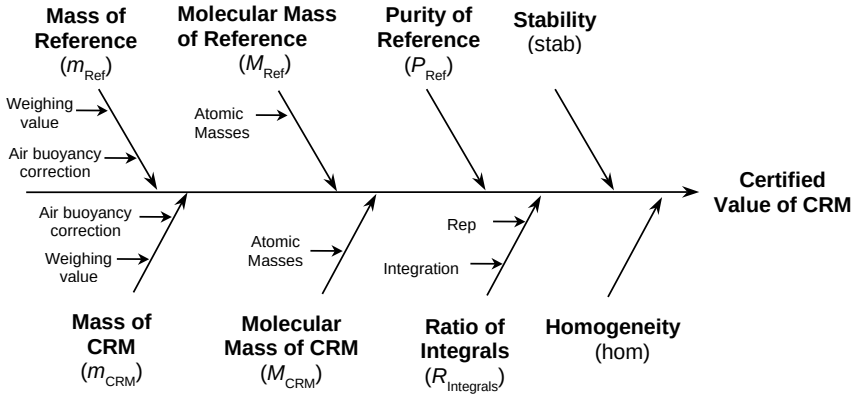
Stability assessment: An accelerated stability test is performed with samples which are stored above the recommended storage temperature. The material is tested by qNMR double determination at appropriate time intervals, e.g. 3 months.
The long-term stability test is performed with samples which are stored at the recommended storage temperature and applying qNMR double determination at appropriate time intervals, e.g. 24 months.

Uncertainty evaluation:

The uncertainty contributions are illustrated by the following cause-effect diagram.

Typical relative contributions are:

$u(P_{Ref})$	< 0.05 %
$u(m_{Ref})$	< 0.05 %
$u(m_{CRM})$	< 0.05 %
$u(M_{Ref})$	< 0.003 %
$u(M_{CRM})$	< 0.003 %
$u(R_{Integrals})$	< 0.10 %
u_{hom}	< 0.05 %
u_{stab}	< 0.05 %



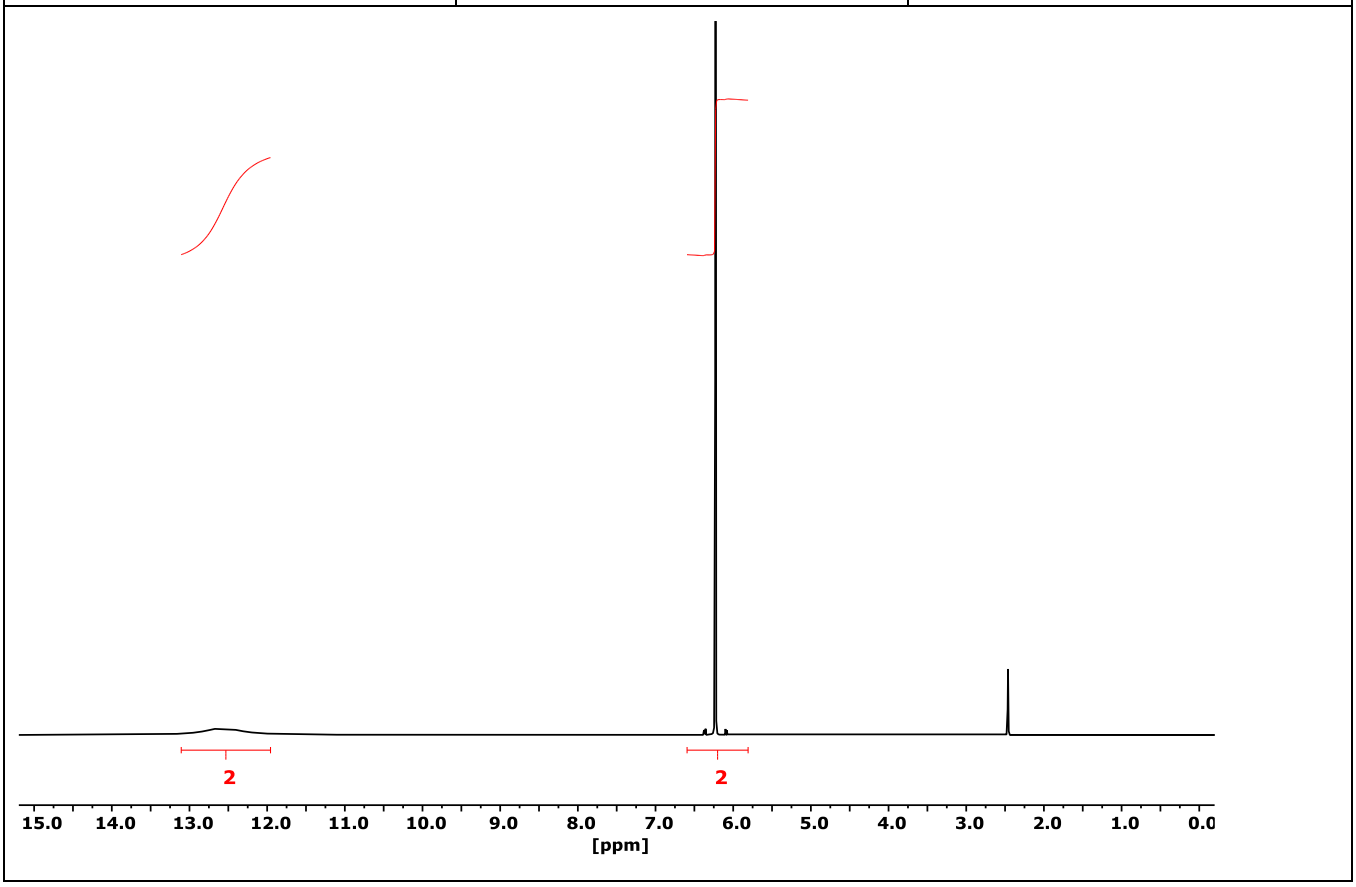
The combined standard uncertainty is calculated by combination of the standard uncertainties of the input estimates according to Eurachem/CITAC Guide "Quantifying Uncertainty in Analytical Measurement" and ISO 17034.[2][5]

Expanded uncertainty is then calculated to a confidence level of 95 %, typically by multiplying with a coverage factor of k=2.

Qualitative NMR analysis:

Identity assessment is carried out by NMR analysis in accordance with ISO/IEC 17025.[4]

Method	Conditions	Result
^{1}H-NMR	600 MHz, DMSO-d_6	Consistent with Structure



Indicative values:

Solubility, T_1 Relaxation time and Chemical shift

Solvent	Solubility (mg/ml)	Chemical shift (ppm), ^{1}H-NMR (δ: 0 ppm, TMS, 25°C)	T_1 relaxation time (s)
$CDCl_3$	not soluble	-	-
DMSO-d_6	>250	6.3	3.0
CD_3OD	~ 10	6.3	3.9
CD_3CN	~ 20	6.4	6.2
D_2O	>250	6.3	6.1

Solubility tests were done at room-temperature using commercially available NMR solvents. Tests were performed starting from 1 mg/ml up to 250 mg/ml (mg CRM/ml solvent). T_1 relaxation times were recorded for the CRM only (c ≈ 10-15 mg/ml at 25°C), but may vary in the mixture. Therefore, it is recommended to check the T_1 delay prior to the qNMR experiment. Chemical shifts and T_1 relaxation times were recorded on a Bruker 600MHz spectrometer.

References:

[1] ISO Guide 35:2017, "Reference materials - Guidance for characterization and assessment of homogeneity and stability"
[2] Eurachem/CITAC Guide, 3rd Ed. (2012), "Quantifying uncertainty in analytical measurement"
[3] Eurachem/CITAC Guide, 2nd Ed. (2019), "Metrological traceability in chemical measurement"
[4] The accredited testing laboratory STS 0490 performs the measurements and weighing steps for the certification of this CRM under ISO/IEC 17025:2017, "General requirements for the competence of testing and calibration laboratories"
[5] ISO 17034:2016, "General requirements for the competence of reference material producers"
[6] Weber M, Hellriegel C, Rueck A, Sauermoser R, Wuethrich J, Accred. Qual. Assur. 18 (2013) 91-98
[7] ISO 33401:2024, "Reference materials - Contents of certificates, labels and accompanying documentation"
[8] Weber M, Hellriegel C, Rueck A, Wuethrich J, Jenks P, JPBA 93 (2014) 102-110

Certificate of analysis revision history:

Certificate version	Date	Reason for version
01	28 AUG 2025	Initial version

The most recent version of the Certificate is available online (www.sigmaaldrich.com)

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