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BAM Bundesanstalt für Materialforschung und -prüfung

in co-operation with the Committee of Chemists of the GDMB
Gesellschaft der Metallurgen und Bergleute e.V.

Certified Reference Material

BAM-M383c

Pure Copper

Certified Values

Element	Mass fraction [1] in mg/kg	Uncertainty [2] in mg/kg
Ag	10.6	0.4
As	1.54	0.28
Bi	1.01	0.18
Cd	2.06	0.06
Co	1.21	0.11
Mg	1.11	0.28
Mn	1.52	0.28
Ni	4.2	0.4
Pb	3.0	0.5
Sb	2.13	0.10
Se	2.5	0.5
Sn	1.9	0.4
Te	4.6	0.9
Zn	2.5	0.5

[1] Unweighted mean value of the means of accepted sets of data (consisting of at least 3 but usually 6 single results), each set being obtained by a different laboratory and/or a different method of measurement. The values are traceable to the SI (Système International d'Unités) via calibration using pure metals or substances of known stoichiometry.

[2] Estimated expanded uncertainty *U* with a coverage factor of *k*=2, corresponding to a level of confidence of approx. 95 %, as defined in the Guide to the expression of uncertainty in measurement, (GUM, ISO/IEC Guide 98-3:2008).

Sample description

The Reference Material is available in the form of discs (38 mm diameter and 30 mm height).

Indicative values

Element	Mass fraction [1] in mg/kg	Uncertainty [2] in mg/kg
Al	1.6	0.6
Cr	< 1.5	
Fe	1.4	0.5
P	< 1	
S	4.6	1.0
Si	< 2.5	
Ti	2.6	1.2
Zr	2.9	1.2

[1] Values were not certified, but given as indicative values, when the number of accepted data sets was considered to be too low (< 5) or when the uncertainty from the inter-laboratory certification was considerably larger than the expected range. The values are traceable to the SI (Système International d'Unités) via calibration using pure metals or substances of known stoichiometry.

[2] Estimated expanded uncertainty *U* with a coverage factor of $k = 2$, as defined in the Guide to the expression of uncertainty in measurement, (GUM, ISO/IEC Guide 98-3:2008).

Informative Value

Element	Mass fraction [1] in %	Uncertainty [2] in %
O	0.40	0.07

[1] Value was not certified, but given as informative value, because no homogeneity test was carried out and calibration was partly performed using other CRMs.

[2] Estimated expanded uncertainty *U* with a coverage factor of $k = 2$, as defined in the Guide to the expression of uncertainty in measurement, (GUM, ISO/IEC Guide 98-3:2008).

Recommended Use

The CRM is intended for establishing or checking the calibration of optical emission and X-ray spectrometers for the analysis of samples of similar matrix composition. The minimum sample size for wet chemical analysis is 0.5 g.

Instructions for Use

Before use, the surface of the material must be prepared by milling or turning on a lathe. For wet chemical analysis chips have to be prepared by turning or milling of the sample surface.

Transport and Storage

The material should be stored in a dry and clean environment at room temperature (approx. 20 °C). Transport under normal ambient conditions.

Means of Accepted Data Sets

Mass fraction in mg/kg

Certified values | Indicative values

Line no.	Ag	As	Bi	Cd	Co	Mg	Mn	Ni	Pb	Sb	Se	Sn	Te	Zn		*Al*	*Cr*	*Fe*	*P*	*S*	*Si*	*Ti*	*Zr*	*O*
1	9.94	1.00	0.73	---	1.00	0.87	0.60	---	2.30	1.94	0.94	1.00	3.00	1.00		*< 1*	*0.54*	*0.50*	*< 0.2*	*< 1*	*< 1*	*< 1*	*< 1*	*3426*
2	10.00	1.36	0.77	2.00	1.00	< 1	1.21	---	2.47	1.97	1.98	1.50	3.92	1.45		*1.00*	*0.78*	*0.97*	*0.23*	*4.01*	*1.43*	*1.00*	*< 1*	*3770*
3	10.17	1.40	0.98	2.00	1.10	1.00	1.28	4.00	2.70	2.00	2.00	1.51	3.99	1.98		*1.36*	*0.93*	*< 1*	*0.35*	*4.46*	*2.33*	*1.50*	*1.07*	*3802*
4	10.40	1.41	1.00	2.00	1.16	1.00	1.43	4.05	2.93	2.06	2.47	1.56	4.24	2.05		*1.56*	*< 1*	*1.08*	*0.69*	*5.20*		*2.47*	*2.50*	*3837*
5	10.40	1.49	1.00	2.03	1.18	1.07	1.44	4.17	2.95	2.09	2.50	2.03	4.83	2.22		*1.74*	*< 1*	*1.18*	*1.00*			*2.50*	*3.32*	*3845*
6	10.52	1.56	1.00	2.06	1.18	1.20	1.60	4.18	3.00	2.10	2.64	2.18	4.85	2.50		*2.55*	*< 1*	*1.60*	*< 1*			*3.41*	*3.40*	*3851*
7	10.54	1.65	1.04	2.10	1.32	1.25	1.77	4.20	3.18	2.16	2.94	2.22	4.97	2.65			*1.31*	*1.64*				*3.56*	*3.46*	*4100*
8	10.92	1.70	1.06	2.11	1.35	1.37	1.84	4.21	3.50	2.19	3.28	2.50	5.16	2.78			*1.38*	*2.50*				*3.74*	*3.66*	*4157*
9	11.00	1.85	1.07	2.20	1.39		2.00	4.29	3.58	2.19	3.32	2.93	5.17	2.83				---						*4267*
10	11.08	2.00	1.40	---	1.42		2.00	4.32	---	2.23			5.18	3.01										*4600*
11	11.23				---			4.60		2.50			5.55	3.06										
12	---																							
13																								
M	10.6	1.54	1.01	2.06	1.21	1.11	1.52	4.22	2.96	2.13	2.45	1.94	4.62	2.45		*1.64*	*< 1.5*	*1.35*	*< 1*	*4.56*	*< 2.5*	*2.60*	*2.90*	*3965*
s_M	0.45	0.29	0.18	0.071	0.16	0.18	0.43	0.18	0.43	0.16	0.75	0.60	0.76	0.52		*0.58*		*0.64*		*0.60*		*1.06*	*0.99*	*325*
$\bar{s}_i$	0.32	0.13	0.15	0.068	0.07	0.11	0.12	0.22	0.32	0.25	0.22	0.22	0.29	0.25		*0.39*		*0.26*		*0.36*		*0.32*	*0.40*	*99*

The laboratory mean values have been examined statistically to eliminate outlying values. Where a " --- " appears in the table it indicates that an outlying value has been omitted (Grubbs 95 %). A data set consists of at least 3 but usually 6 single values of one laboratory.

M : mean of laboratory means

s_M : standard deviation of laboratory means

$\bar{s}_i$: averaged repeatability standard deviation (square root of the mean of laboratory variances)

Note: "< - values" were not included into the calculation of M and s_M

Analytical Method used for Certification

Element	Line no.	Method
Ag	1, 7	Glow discharge mass spectrometry
	2, 4, 9, 10, 11	Inductively coupled plasma optical emission spectrometry
	3	Electrothermal atomic absorption spectrometry
	5, 6	Instrumental neutron activation analysis
	8	Inductively coupled plasma mass spectrometry
As	1, 4, 7, 9	Inductively coupled plasma optical emission spectrometry
	2, 5	Glow discharge mass spectrometry
	3	Inductively coupled plasma optical emission spectrometry after electrothermal vaporisation
	6	Inductively coupled plasma mass spectrometry
	8, 10	Electrothermal atomic absorption spectrometry
Bi	1	Inductively coupled plasma optical emission spectrometry after electrothermal vaporisation
	2, 4, 5, 10	Inductively coupled plasma optical emission spectrometry
	3	Inductively coupled plasma mass spectrometry
	6, 8	Electrothermal atomic absorption spectrometry
	7, 9	Glow discharge mass spectrometry
Cd	2, 3, 4, 5, 6, 7	Inductively coupled plasma optical emission spectrometry
	8	Inductively coupled plasma mass spectrometry
	9	Glow discharge mass spectrometry
Co	1, 2, 3, 4, 5, 6, 8	Inductively coupled plasma optical emission spectrometry
	7	Inductively coupled plasma mass spectrometry
	9, 10	Glow discharge mass spectrometry
Mg	1, 7	Glow discharge mass spectrometry
	2, 3, 4, 5, 8	Inductively coupled plasma optical emission spectrometry
	6	Inductively coupled plasma mass spectrometry
Mn	1, 3, 4, 5, 9, 10	Inductively coupled plasma optical emission spectrometry
	2	Electrothermal atomic absorption spectrometry
	5, 7	Glow discharge mass spectrometry
	8	Inductively coupled plasma mass spectrometry
Ni	3, 4, 5, 6, 7, 11	Inductively coupled plasma optical emission spectrometry
	8	Inductively coupled plasma mass spectrometry
	9	Electrothermal atomic absorption spectrometry
	10	Glow discharge mass spectrometry
Pb	1, 7	Glow discharge mass spectrometry
	2, 6, 9	Inductively coupled plasma optical emission spectrometry
	3	Inductively coupled plasma optical emission spectrometry after electrothermal vaporisation
	4, 8	Electrothermal atomic absorption spectrometry
	5	Inductively coupled plasma mass spectrometry
Sb	1, 3, 6, 7, 11	Inductively coupled plasma optical emission spectrometry
	2, 4	Instrumental neutron activation analysis
	5	Electrothermal atomic absorption spectrometry
	8	Inductively coupled plasma mass spectrometry
	9, 10	Glow discharge mass spectrometry

Element	Line no.	Method
Se	1, 3, 5, 8	Inductively coupled plasma optical emission spectrometry
	2	Inductively coupled plasma optical emission spectrometry after electrothermal vaporisation
	4	Electrothermal atomic absorption spectrometry
	6, 9	Glow discharge mass spectrometry
	7	Instrumental neutron activation analysis
Sn	1, 2, 7, 9	Inductively coupled plasma optical emission spectrometry
	3, 6	Glow discharge mass spectrometry
	4	Inductively coupled plasma mass spectrometry
	5	Inductively coupled plasma optical emission spectrometry after electrothermal vaporisation
	8	Electrothermal atomic absorption spectrometry
Te	1, 3, 10, 11	Inductively coupled plasma optical emission spectrometry
	2, 9	Glow discharge mass spectrometry
	4	Instrumental neutron activation analysis
	5, 6, 7	Electrothermal atomic absorption spectrometry
	8	Inductively coupled plasma mass spectrometry
Zn	1, 2, 3, 4, 5, 11	Inductively coupled plasma optical emission spectrometry
	6	Inductively coupled plasma mass spectrometry
	7	Instrumental neutron activation analysis
	8, 10	Glow discharge mass spectrometry
	9	Flame atomic absorption spectrometry
Al	*1, 2, 3, 6*	*Inductively coupled plasma optical emission spectrometry*
	4, 5	*Glow discharge mass spectrometry*
Cr	*1, 2, 4, 5, 6*	*Inductively coupled plasma optical emission spectrometry*
	3, 7	*Glow discharge mass spectrometry*
	8	*Instrumental neutron activation analysis*
Fe	*1, 2, 3, 4, 5, 8*	*Inductively coupled plasma optical emission spectrometry*
	6	*Inductively coupled plasma mass spectrometry*
	7	*Glow discharge mass spectrometry*
P	*1, 2*	*Glow discharge mass spectrometry*
	3	*Inductively coupled plasma optical emission spectrometry after electrothermal vaporisation*
	4	*Spectrophotometry*
	5, 6	*Inductively coupled plasma optical emission spectrometry*
S	*1, 3*	*Inductively coupled plasma optical emission spectrometry*
	2	*Glow discharge mass spectrometry*
	4	*Combustion/iodometric titration*
Si	*1, 3*	*Inductively coupled plasma optical emission spectrometry*
	2	*Glow discharge mass spectrometry*
Ti	*1, 2, 3, 5*	*Inductively coupled plasma optical emission spectrometry*
	4, 8	*Glow discharge mass spectrometry*
	6	*Spectrophotometry*
	7	*Inductively coupled plasma mass spectrometry*
Zr	*1, 2, 3, 4, 6*	*Inductively coupled plasma optical emission spectrometry*
	5, 8	*Glow discharge mass spectrometry*
	7	*Inductively coupled plasma mass spectrometry*
O	*2, 4, 5, 6, 7, 8, 9*	*Carrier gas hot extraction*
	1, 3, 10	*Spark emission spectrometry*

Participating Laboratories

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Technical Report

A detailed technical report describing the analysis procedures and the treatment of the analytical data used to certify BAM-M383c is available on request or can be downloaded from BAM website (www.bam.de/en/fachthemen/referenzmaterialien/index.htm).

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