Bundesanstalt für Materialforschung und -prüfung (BAM)

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

Certified Reference Material

BAM-M376a

Pure Copper

Certified Values

Element	Mass fraction [1] in mg/kg	Uncertainty [2] in mg/kg
Ag	163	3
As	200	3
Bi	200	5
Cd	186	3
Co	208	2
Fe	235	3
Mn	206	3
Ni	209	6
P	203	5
Pb	236	4
Sb	202	5
Se	210	4
Sn	247	3
Te	215	7
Zn	217	3
Zr	42.2	1.9

[1] Unweighted mean value of the means of accepted sets of data (consisting of at least 5 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 uncertainty *U* at level of confidence of 95 %.

Sample description

The Reference Material is available in the form of discs (ca. 40 mm diameter and ca. 30 mm height). It is based on the same batch of candidate material as BAM-376. The mass fractions of the elements Be, Cr, Mg and S differ slightly from the original material. Therefore these elements are given only for information with a higher uncertainty. All mass fractions are obtained from the certification inter-laboratory comparison of BAM-376 from 1996.

Informative values

Element	Mass fraction [1] in mg/kg	Uncertainty [2] in mg/kg
Al	182	10
Be	41	6
Cr	400	60
Mg	124	19
S	133	19
Ti	4.5	1.7

[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 or in case of possible inhomogeneities. The values are traceable to the SI (Système International d'Unités) via calibration using pure metals or substances of known stoichiometry.

[2] Estimated uncertainty *U* at level of confidence of 95 %.

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.

Participating Laboratories

Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin (Germany)
Diehl GmbH u. Co., Röthenbach (Germany)
Hahn-Meitner-Institut GmbH, Berlin (Germany)
Hüttenwerke Kayser AG, Lünen (Germany)
KM Europa Metal AG, Osnabrück (Germany)
Krupp VDM GmbH, Werdohl (Germany)
Mansfeld Kupfer und Messing GmbH - Nord, Hettstedt (Germany)
Mansfeld Kupfer und Messing GmbH - Süd, Hettstedt (Germany)
Max-Planck-Institut für Metallforschung, Stuttgart (Germany)
Montanwerke Brixlegg GmbH, Brixlegg (Austria)
Norddeutsche Affinerie AG, Hamburg (Germany)
TU Bergakademie Freiberg, Freiberg (Germany)
Union Miniere, Olen (Belgium)
Wieland-Werke AG, Ulm (Germany)

Means of Accepted Data Sets (certification inter-laboratory comparison of BAM-376)

Mass fraction in mg/kg

Certified values | Indicative values

Line no.	Ag	As	Bi	Cd	Co	Fe	Mn	Ni	P	Pb	Sb	Se	Sn	Te	Zn	Zr	*Al*	*Be*	*Cr*	*Mg*	*S*	*Ti*
1	157.7	---	188.0	---	---	---	199.8	191.3	191.3	222.8	186.2	---	---	191.8	209.3	38.6	*159.5*	*38.3*	*371.4*	---	---	*2.5*
2	158.8	190.9	189.2	175.8	204.6	227.8	199.9	196.7	195.2	228.2	190.3	203.2	242.3	201.7	209.3	40.5	*168.2*	*39.0*	*372.0*	*112.3*	*124.3*	*2.7*
3	159.7	194.5	192.2	177.4	205.0	228.2	201.0	202.2	200.7	228.2	195.2	204.0	243.8	209.2	211.3	40.6	*170.7*	*39.7*	*386.0*	*113.2*	*129.3*	*3.2*
4	159.8	197.3	194.2	184.3	205.5	230.3	203.3	204.5	201.2	231.5	195.5	205.8	243.9	210.5	212.7	40.8	*171.9*	*40.2*	*390.0*	*116.2*	*130.5*	*4.7*
5	159.8	197.8	199.2	184.4	205.5	233.2	204.2	205.7	201.9	231.3	195.7	206.0	245.7	211.5	215.2	41.1	*172.3*	*40.7*	*398.8*	*118.3*	*133.7*	*4.9*
6	161.4	198.7	199.6	185.7	205.8	234.0	204.7	206.8	205.2	233.7	201.4	210.5	246.2	213.0	216.7	42.0	*173.5*	*41.3*	*402.5*	*121.2*	*134.0*	*6.6*
7	161.8	200.4	201.7	185.7	206.4	234.9	205.3	209.5	206.0	234.2	202.8	212.0	247.0	214.9	217.1	42.3	*180.8*	*41.4*	*403.8*	*123.5*	*134.2*	*6.7*
8	162.8	200.5	204.4	186.0	206.7	234.9	205.6	209.7	206.7	234.2	203.8	213.0	247.3	218.7	217.2	43.8	*182.5*	*41.4*	*404.5*	*124.8*	*137.8*	
9	162.8	200.8	205.0	186.5	208.1	235.7	206.5	210.9	206.9	234.9	203.9	213.7	249.3	222.2	218.5	44.8	*189.9*	*41.6*	*406.5*	*125.7*	*139.9*	
10	163.0	201.5	208.2	186.8	208.2	235.7	206.9	211.2	207.4	237.5	203.9	214.1	253.5	223.5	219.4	47.9	*192.7*	*42.4*	*407.8*	*126.2*		
11	166.0	202.5	208.8	187.2	209.8	238.5	207.4	212.8	213.7	239.0	206.0	214.4	254.5	224.3	220.3	---	*202.8*	---	*410.5*	*126.5*		
12	167.2	203.7	209.2	187.6	211.0	239.0	211.5	213.3		239.4	208.6			225.2	221.3		*213.7*		*411.8*	*127.9*		
13	170.3	204.8		188.8	211.2	239.8	212.7	214.8		241.3	209.3			230.0	222.3				*414.0*	*128.2*		
14	170.7	205.7		191.5	214.9	242.6	214.0	216.1		241.9	213.7				222.4				*417.3*	*128.2*		
15	---			192.0		---		228.2		242.6	214.1				225.7					*130.3*		
16										244.2					---					*133.0*		
17										254.1										---		
M	163.0	199.9	200.0	186.1	207.9	234.6	205.9	208.9	203.3	236.4	202.0	209.7	247.3	215.1	217.3	42.2	*181.5*	*40.6*	*399.8*	*123.7*	*133.0*	*4.5*
s_M	4.1	4.1	7.6	4.6	3.0	4.4	4.4	8.9	6.2	7.4	8.1	4.4	4.1	10.6	4.9	2.6	*15.7*	*1.3*	*14.6*	*6.2*	*4.9*	*1.8*
$\bar{s}_i$	1.8	3.7	2.3	1.6	1.9	1.8	2.6	2.6	3.8	3.0	5.0	4.4	4.5	3.8	2.5	1.6	*5.5*	*0.4*	*6.1*	*2.0*	*3.4*	*0.5*

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 5 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)

Analytical Method used for Certification

Element	Line no.	Method
Ag	1	PAA
	2, 3, 5, 8, 9, 11, 12, 14	FAAS
	4, 7, 10, 13	ICP-OES
	6	INAA
As	1	INAA
	2, 3, 6, 10, 13, 14	ICP-OES
	4	PAA
	5, 9	ICP-OES, $La(OH)_3$-precipitation
	7	Spectrophotometry, molybdenum blue, extraction
	8	FAAS, $La(OH)_3$-precipitation
	11	DCP-OES
	12	FAAS
Bi	1, 6, 8, 9	FAAS
	2, 3, 5	FAAS, $La(OH)_3$-precipitation
	4	ICP-OES, $Fe(OH)_3$-precipitation
	7, 12	ICP-OES
	10	ET AAS
	11	Spectrophotometry, diethyldithiocarbaminate, extraction
Cd	1	INAA
	2, 6, 13, 14, 15, 16	ICP-OES
	3	PAA
	4, 5, 7, 8, 10, 11, 12	FAAS
	9	FAAS, electrolytic separation of Cu
Co	1, 5, 9, 10, 11, 12	ICP-OES
	2	INAA
	3, 4, 7, 8, 13	FAAS
	6	FAAS, electrolytic separation of Cu
	14	Spectrophotometry, nitroso R salt, extraction
Fe	1, 5, 6, 11, 14	ICP-OES
	2	FAAS, electrolytic separation of Cu
	3	FAAS, $La(OH)_3$-precipitation
	4, 7, 9, 10, 12, 13	FAAS
	8	Spectrophotometry, 1.10 phenantroline, extraction
	15	INAA
Mn	1	FAAS, electrolytic separation of Cu
	2, 3, 4, 9, 11, 12	FAAS
	5	ICP-OES, $La(OH)_3$-precipitation
	6, 7, 8, 13, 14	ICP-OES
	10	PAA

Element	Line no.	Method
Ni	1, 3, 4, 8, 9, 11, 13	FAAS
	2	PAA
	5, 7, 10, 12, 14, 15	ICP-OES
	6	FAAS, electrolytic separation of Cu
P	1, 5	Spectrophotometry, phosphovanadomolybdate, extraction
	2, 3, 6, 7, 8, 10, 11	ICP-OES
	4, 9	Spectrophotometry, phosphovanadomolybdate, without extraction
Pb	1, 2, 12, 14, 16	ICP-OES
	3, 4, 6, 8, 9, 10, 15, 17	FAAS
	5	FAAS, electrolytic separation of Cu
	7	FAAS, $La(OH)_3$-precipitation
	11	PAA
	13	ICP-OES, $La(OH)_3$-precipitation
Sb	1	FAAS, $La(OH)_3$-precipitation
	2	PAA
	3, 4, 10, 11, 15	ICP-OES
	5	INAA
	6, 7, 8, 9	FAAS
	12	ET AAS
	13	Spectrophotometry, Rhodamine B, extraction
	14	DCP-OES
Se	1	FAAS, $La(OH)_3$-precipitation
	2, 6	ET AAS
	3, 8, 9, 11, 12, 13	ICP-OES
	4	PAA
	5	INAA
	7	ICP-OES, $La(OH)_3$-precipitation
	10	FAAS
Sn	1	FAAS
	2, 3, 5, 6, 7, 10	ICP-OES
	4	PAA
	8, 9	ICP-OES, $La(OH)_3$-precipitation
	11	FAAS, $La(OH)_3$-precipitation
Te	1	PAA
	2, 3, 14	ICP-OES
	4, 5, 7	FAAS
	6, 11	ICP-OES, $La(OH)_3$-precipitation
	8	ICP-OES, As-precipitation
	9	FAAS, As-precipitation
	10, 12	FAAS, $La(OH)_3$-precipitation
	13	ET AAS

Element	Line no.	Method
Zn	1, 4, 8, 10, 12, 13, 15	FAAS
	2, 3, 5, 7, 9, 14	ICP-OES
	6	INAA
	11	FAAS, electrolytic separation of Cu
	16	PAA
Zr	1	Spectrophotometry, pyrocatechol violet, extraction (TOPO/cyclohexane)
	2, 3, 4, 5, 6, 8, 10, 11	ICP-OES
	7	PAA
	9	Spectrophotometry
Al	*1, 4, 5, 6, 8, 9*	*ICP-OES*
	2	*FAAS*
	3, 7,	*ICP-OES, $La(OH)_3$-precipitation*
	10	*DCP-OES*
	11, 12	*FAAS, electrolytic separation of Cu*
Be	*1, 3*	*FAAS, $La(OH)_3$-precipitation*
	2	*DCP-OES*
	4, 5, 6, 8, 9, 10, 11	*ICP-OES*
	7	*FAAS*
Cr	*1, 6*	*FAAS*
	2	*PAA*
	3, 4, 7, 8, 9, 10, 12	*ICP-OES*
	5	*INAA*
	11, 14	*Titration, Fe(II)ammoniumsulfate*
	13	*Spectrophotometry, Cr(VI)-diphenylcarbazide, extraction*
Mg	*1, 2, 5, 6, 7, 8, 13, 14*	*FAAS*
	3, 9, 10, 11, 12, 15, 16	*ICP-OES*
	4	*FAAS, electrolytic separation of Cu*
S	*1, 6*	*ICP-OES*
	2, 4	*Combustion, iodometric titration*
	3	*Spectrophotometry, molybdenum blue*
	5, 8	*Combustion, infrared absorption*
	7	*Microtitration as sulphide*
	9	*Combustion, coulometric titration*
Ti	*1, 2, 3, 4, 5, 6*	*ICP-OES*
	7	*PAA*

Abbreviations:
ET AAS – Electrothermal atomic absorption spectrometry
FAAS – Flame atomic absorption spectrometry
ICP-OES – Inductively coupled plasma - optical emission spectrometry
INAA – Instrumental neutron activation analysis
PAA – Photon activation analysis

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