

Bundesanstalt für Materialforschung und -prüfung (BAM)

in cooperation with the International Commission on Glass (ICG) and Deutsche
Glastechnische Gesellschaft e.V. (DGG)

Certified Reference Material

BAM-S005c

Multielement Glass

Certified Values

Element		Mass fraction ¹⁾ in %		Uncertainty ²⁾ in %
Al	(Al ₂ O ₃)	0.587	(1.109)	0.018
Ca	(CaO)	7.43	(10.39)	0.12
K	(K ₂ O)	0.595	(0.717)	0.014
Mg	(MgO)	1.37	(2.28)	0.04
Na	(Na ₂ O)	10.33	(13.92)	0.24
Si	(SiO ₂)	33.1	(70.8)	0.5
		in mg/kg		in mg/kg
As	(As ₂ O ₃)	81	(107)	4
Ba	(BaO)	102	(114)	4
Cd	(CdO)	47	(54)	4
Ce	(CeO ₂)	80	(98)	5
Co	(CoO)	33.2	(42.3)	1.9
Cr	(Cr ₂ O ₃)	10.8	(15.8)	1.0
Cu	(CuO)	86	(107)	5
Fe	(Fe ₂ O ₃)	295	(422)	7
Mn	(MnO)	69.6	(89.9)	2.5
Mo	(MoO ₃)	215	(323)	7
Ni	(NiO)	41.3	(52.6)	1.7
Pb	(PbO)	182	(196)	8
Sb	(Sb ₂ O ₃)	103	(123)	4
Sn	(SnO ₂)	72.9	(92.5)	2.3
Sr	(SrO)	134	(158)	6
Ti	(TiO ₂)	101	(169)	6
V	(V ₂ O ₅)	189	(337)	8
Zn	(ZnO)	157	(196)	6
Zr	(ZrO ₂)	544	(735)	26
<p>¹⁾ Unweighted mean value of the means of accepted sets of data (consisting of at least 2 single results), each set being obtained by a different laboratory and/or a different method of measurement. Values in brackets are calculated from the elemental mass fractions using the molar masses of the elements.</p> <p>²⁾ Estimated expanded uncertainty <i>U</i> with a coverage factor of <i>k</i> = 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).</p>				

This certificate is valid until 08/2050.

Values for Information

Element	Mass fraction ¹⁾ in mg/kg	Uncertainty ²⁾ in mg/kg
P (P ₂ O ₅)	8.3 (19.0)	2.5
Se	2.5	0.8

¹⁾ Unweighted mean value of the means of accepted sets of data (consisting of at least 2 single results), each set being obtained by a different laboratory and/or a different method of measurement. Values were not certified, but given for information, because the uncertainty from the inter-laboratory certification was too large. Values in brackets are calculated from the elemental mass fractions using the molar masses of the elements.

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 (approx. 38 mm diameter and approx. 4 mm height).

Recommended Use

The CRM is intended for establishing or checking the calibration of X-ray spectrometers for the analysis of samples of similar matrix composition. The minimum sample size for wet chemical analysis is 0.2 g.

Instructions for Use

Before use, the surface of the material must be cleaned.

Transport and Storage

The material should be stored in a dry and clean environment at room temperature. Transport can be done under normal ambient conditions.

Participating Laboratories

Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany
 Cetim Grand Est, Schiltigheim, France
 Corning European Technology Center (CETC), S&T European Laboratory, Fontainebleau, France
 Dorfner Anzaplan GmbH, Hirschau, Germany
 Forschungsinstitut für Anorganische Werkstoffe -Glas/Keramik- GmbH, Höhr-Grenzhausen, Germany
 Fraunhofer Institute for Silicate Research ISC, Würzburg, Germany
 Glass Technology Services Ltd, Sheffield, South Yorkshire, United Kingdom
 TU Bergakademie Freiberg, Institut für Energieverfahrenstechnik und Chemieingenieurwesen, Freiberg, Germany
 IGR Institut für Glas- und Rohstofftechnologie GmbH, Göttingen, Germany
 INISMa (Institut Interuniversitaire des Silicates, Sols et Matériaux), Mons, Belgium
 NSG, Lathom, United Kingdom
 Schott AG, Mainz, Germany
 Stazione Sperimentale del Vetro, Murano, Italy
 T. Şişe ve Cam Fab. A.Ş. Science and Technology Center, Gebze Kocaeli, Turkey
 TU Bergakademie Freiberg, Institut für Analytische Chemie, Freiberg, Germany
 Zentrum für Glas- und Umweltanalytik GmbH, Ilmenau, Germany

Means of Accepted Data Sets

Certified values
Mass fraction in %

mass fraction in mg/kg

Line No.	Al	Ca	K	Mg	Na	Si	As	Ba	Cd	Ce	Co	Cr	Cu	Fe	Mn	Mo
1	---	---	0.560	---	---	32.69	69.4	90.6	37.2	68.2	27.7	---	73.7	---	62.8	---
2	0.548	---	0.564	1.31	---	32.74	70.0	94.5	41.8	71.8	28.9	8.22	74.2	---	64.7	205
3	0.558	7.21	0.579	1.33	---	32.82	75.5	94.5	42.2	77.8	29.6	8.93	75.1	283	65.3	206
4	0.559	7.28	0.583	1.35	9.93	33.10	76.3	94.8	44.6	79.3	30.5	9.40	81.8	283	66.4	206
5	0.570	7.32	0.585	1.36	10.19	33.16	76.6	97.0	45.1	80.0	31.1	9.50	82.6	284	66.6	208
6	0.573	7.38	0.587	1.36	10.25	33.17	76.8	98.1	45.2	80.5	31.3	9.83	84.7	288	68.6	210
7	0.585	7.41	0.602	1.36	10.28	33.18	81.8	100.1	46.1	80.7	32.4	9.98	85.0	288	69.2	214
8	0.588	7.48	0.604	1.36	10.31	33.26	82.3	101.7	46.3	81.1	33.6	10.22	85.0	290	70.0	215
9	0.602	7.48	0.604	1.37	10.36	33.27	83.2	102.0	47.2	87.8	33.8	10.79	86.2	298	70.6	217
10	0.603	7.48	0.604	1.37	10.36	33.61	83.7	104.0	48.2	90.9	34.7	10.83	86.3	298	71.6	218
11	0.605	7.49	0.605	1.39	10.40		85.4	107.8	50.4	---	35.4	11.13	86.6	298	71.6	225
12	0.607	7.50	0.610	1.40	10.45		86.4	108.4	50.7	---	35.8	11.20	89.5	301	71.7	227
13	0.617	7.50	0.613	1.40	10.45		89.3	109.0	52.3		35.9	12.22	93.0	302	72.4	233
14	0.620	7.51	0.624	1.42	10.63		90.8	112.2	52.4		38.1	12.50	99.2	306	75.3	---
15		7.55	---	1.46				114.4	53.4		39.6	13.04	100.8	306	77.5	
16												13.73		307	---	
17														---		
<i>M</i>	0.587	7.43	0.595	1.37	10.33	33.10	80.5	101.9	46.9	79.8	33.2	10.77	85.6	295	69.6	215
<i>s_M</i>	0.024	0.11	0.019	0.04	0.18	0.29	6.7	7.2	4.6	6.7	3.5	1.58	8.0	9	4.1	10
\bar{s}_i	0.013	0.17	0.015	0.03	0.10	0.23	2.8	4.4	1.2	2.4	0.7	0.72	2.3	8	1.7	6

Certified values
Mass fraction in mg/kg

values for information
mass fraction in mg/kg

Line No.	Ni	Pb	Sb	Sn	Sr	Ti	V	Zn	Zr	P	Se	Ag	B	Li
1	35.9	155	89.5	68.8	119	---	170	---	482	3.1	1.1	0.20	14	3.3
2	37.6	161	96.3	69.4	121	89.9	175	140	489	4.1	1.3		39	
3	38.4	173	96.9	70.0	123	90.0	178	146	501	4.2	1.9			
4	40.1	175	99.1	70.7	125	94.1	179	149	517	7.7	2.2			
5	40.2	176	101.6	70.9	126	94.9	181	150	522	9.0	3.0			
6	40.4	177	103.8	71.6	129	95.4	182	153	527	10.2	3.1			
7	41.3	177	104.8	72.0	133	99.3	183	154	545	11.1	3.3			
8	41.3	183	105.1	72.7	135	101.7	189	155	549	12.1	4.1			
9	41.5	183	105.9	72.8	135	101.9	194	156	552	13.2	---			
10	42.2	183	107.2	76.1	140	105.4	195	156	584					
11	42.8	185	108.3	76.6	141	106.8	197	160	585					
12	43.3	187	108.6	77.3	143	107.3	204	162	586					
13	43.7	187	109.1	78.1	144	109.0	205	165	631					
14	45.4	188	---		155	119.8	209	168	---					
15	45.9	197						171						
16		201						174						
17		203												
<i>M</i>	41.3	182	102.8	72.9	134	101.2	189	157	544	8.3	2.5			
<i>s_M</i>	2.8	13	5.9	3.2	11	8.5	13	10	44	3.8	1.1			
\bar{s}_i	1.2	4	3.6	3.2	4	2.9	5	4	16	1.1	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. A data set consists of at least 2 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 Number	Method
Al	2, 12	ETV - ICP-OES
	3, 4, 7, 8, 14	ICP-OES
	5	Laser ablation ICP-MS
	6	FAAS
	9, 10, 13	XRF
	11	ICP-MS
Ca	3, 6, 7, 8, 9	ICP-OES
	4	Laser ablation ICP-MS
	5	Gravimetry
	10, 11, 13	XRF
	12, 15	ETV - ICP-OES
	14	FAAS
K	1, 2, 4, 6, 9	ICP-OES
	3	ICP-MS
	5	Spectrophotometry
	7	Laser ablation ICP-MS
	8	FAAS
	10, 13	ETV - ICP-OES
	11, 12, 14	XRF
Mg	2, 3, 8, 10	ICP-OES
	4	Laser ablation ICP-MS
	5	ICP-MS
	6	FAAS
	7, 9, 13	XRF
	11	Gravimetry
	12, 14	ETV - ICP-OES
Na	4	Spectrophotometry
	5	Laser ablation ICP-MS
	6, 8, 10	ICP-OES
	7, 9, 14	XRF
	11	FAAS
	12, 13	ETV - ICP-OES
Si	1, 2, 5	Gravimetry
	3, 7, 8, 9	XRF
	4	ETV - ICP-OES
	6, 10	ICP-OES
As	1, 2, 3, 4, 6, 8, 11, 12, 14	ICP-OES
	5	XRF
	7, 9	ETV - ICP-OES
	10	ICP-MS
	13	Laser ablation ICP-MS
Ba	1, 2, 3, 4, 5, 8, 9, 10, 12, 13, 14	ICP-OES
	6, 11	ETV - ICP-OES
	7	ICP-MS
	15	Laser ablation ICP-MS

Element	Line Number	Method
Cd	1, 2, 3, 4, 6, 7, 8, 11, 13, 14, 15	ICP-OES
	5	ICP-MS
	9	Laser ablation ICP-MS
	10, 12	ETV - ICP-OES
Ce	1, 3, 5, 7, 8, 9	ICP-OES
	2, 10	ETV - ICP-OES
	4	Laser ablation ICP-MS
	6	ICP-MS
Co	1, 2, 4, 5, 6, 7, 9, 12, 13, 14, 15	ICP-OES
	3, 10	ETV - ICP-OES
	8	ICP-MS
	11	Laser ablation ICP-MS
Cr	2, 3, 4, 6, 7, 8, 10, 11, 13, 14, 15, 16	ICP-OES
	5	ICP-MS
	9	ETV - ICP-OES
	12	Laser ablation ICP-MS
Cu	1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 13	ICP-OES
	5	ICP-MS
	10	Laser ablation ICP-MS
	14, 15	ETV - ICP-OES
Fe	3, 4, 7, 8, 10, 11, 14, 16	ICP-OES
	5	ETV - ICP-OES
	6	ICP-MS
	9, 15	Spectrophotometry
	12	XRF
	13	Laser ablation ICP-MS
Mn	1, 2, 4, 7, 8, 10, 11, 12, 13, 14	ICP-OES
	3	Laser ablation ICP-MS
	5, 6	ETV - ICP-OES
	9	ICP-MS
	15	XRF
Mo	2, 3, 4, 5, 6, 8, 9, 10, 12	ICP-OES
	7	ETV - ICP-OES
	11	ICP-MS
	13	Laser ablation ICP-MS
Ni	1, 2, 3, 5, 6, 9, 10, 12, 13, 14, 15	ICP-OES
	4	ICP-MS
	7, 8	ETV - ICP-OES
	11	Laser ablation ICP-MS
Pb	1, 2, 3, 6, 8, 11, 12, 13, 14, 15, 16, 17	ICP-OES
	4	ICP-MS
	5	XRF
	7	Laser ablation ICP-MS
	9, 10	ETV - ICP-OES

Element	Line Number	Method
Sb	1, 2, 3, 4, 6, 7, 10, 11, 13	ICP-OES
	5	ETV - ICP-OES
	8	ICP-MS
	9	XRF
	12	Laser ablation ICP-MS
Sn	1, 2, 3, 4, 6, 8, 9, 11	ICP-OES
	5	XRF
	7, 10	ETV - ICP-OES
	12	ICP-MS
	13	Laser ablation ICP-MS
Sr	1	Laser ablation ICP-MS
	2, 4, 5, 7, 10, 11, 12, 13, 14	ICP-OES
	3, 8	ETV - ICP-OES
	6	XRF
	9	ICP-MS
Ti	2, 3, 4, 5, 6, 7, 8, 14	ICP-OES
	9	XRF
	10	Laser ablation ICP-MS
	11, 13	ETV - ICP-OES
	12	ICP-MS
V	1, 2, 3, 4, 5, 6, 7, 8, 12, 14	ICP-OES
	9, 13	ETV - ICP-OES
	10	ICP-MS
	11	Laser ablation ICP-MS
Zn	2	Laser ablation ICP-MS
	3, 4, 5, 6, 7, 9, 11, 12, 15, 16	ICP-OES
	8, 13	ETV - ICP-OES
	10	ICP-MS
	14	XRF
Zr	1, 6	ETV - ICP-OES
	2	XRF
	3, 5, 7, 8, 9, 10, 12, 13	ICP-OES
	4	Laser ablation ICP-MS
	11	ICP-MS
<i>P</i>	1, 2, 3, 4, 5, 7	<i>ICP-OES</i>
	6, 8	<i>ETV - ICP-OES</i>
	9	<i>ICP-MS</i>
<i>Se</i>	1, 2, 4, 6, 7	<i>ICP-OES</i>
	3	<i>ETV - ICP-OES</i>
	5, 8	<i>ICP-MS</i>
<i>Ag, Li</i>	1	<i>ETV - ICP-OES</i>
<i>B</i>	1, 2	<i>ETV - ICP-OES</i>

Abbreviations: ETV – ICP-OES – Electrothermal vaporization ICP-OES
FAAS – Flame atomic absorption spectrometry
ICP-OES – Inductively coupled plasma - optical emission spectrometry
ICP-MS – Mass spectrometry with inductively coupled plasma
XRF – X-ray fluorescence spectrometry

Metrological Traceability

To ensure traceability of the certified mass fractions to the SI (Système International d'Unités) calibration was performed using either standard solutions prepared from pure metals or stoichiometric compounds or well checked commercial calibration solutions or other certified reference materials or reference materials.

Technical Report

A detailed technical report describing the analysis procedures and the treatment of the analytical data used to certify BAM-S005c is available on request or can be downloaded from BAM website (www.bam.de).

Accepted as BAM-CRM on

Bundesanstalt für Materialforschung und -prüfung (BAM)

Dr. S. Richter
Committee for Certification

Dr. S. Recknagel
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