Isotopic Compositions of the Elements 1997

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The Commission's Subcommittee for the Isotopic Composition of the Elements has carried out its biennial review of isotopic compositions, as determined by mass spectrometry and other relevant methods. This involves a critical evaluation of the published literature, element by element, and forms the basis of the Table of Isotopic Compositions of the Elements as Determined by Mass Spectrometry presented here. New guidelines have been used to arrive at the uncertainties on the isotopic abundances and there are numerous changes to the table since it was last published in 1991. Atomic Weights calculated from this table are consistent with $A_r(E)$ values listed in the Table of Standard Atomic Weights 1997. © *1998 American Institute of Physics and American Chemical Society.* [S0047-2689(98)00106-8]

Key words: critical evaluation; elements; isotopic composition.

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1. Introduction

Previous compilations of "The isotopic compositions of the elements" were published in 1983,[1] 1984,[2] and 1991[3] for the purpose of yielding atomic weights consistent with the Commission's "Table of Standard Atomic Weights."[4–6]

During the past 6 years the Commission, through its Subcommittee for Isotopic Abundance Measurements (SIAM), has continued to assemble and evaluate new data which has led to improvements to the tabulated isotopic composition of a number of elements. In 1993, the statistical guidelines for assigning uncertainties to the representative abundances were revised and extended by the Commission's Working Party on Statistical Evaluation of Isotopic Abundances (members: K. J. R. Rosman (*Chairman*), P. De Bièvre and J. W. Gramlich). All the data presented in the table were reassessed according to these guidelines.

The present table was assembled for publication following the meeting of SIAM held at Kloster Seeon (Germany), just prior to the 39th IUPAC General Assembly held at Geneva (Switzerland) in 1997 and is presented here as a companion paper to the Atomic Weights of the Elements 1997.

The membership of the Commission for the period 1996–1997 was as follows: L. Schultz (FRG, *Chairman*), R. D. Vocke, Jr. (USA, *Secretary*), J. K. Böhlke (USA, Associate), H. J. Dietze (FRG, Associate), T. Ding (China, Associate), M. Ebihara (Japan, Titular), J. W. Gramlich (USA, Associate), A. N. Halliday (USA, Associate), H. R. Krouse (Canada, Titular), H. K. Kluge (FRG, Associate), R. D. Loss (Australia, Titular), G. I. Ramendik (Russia, Titular), D. E. Richardson (USA, Associate), M. Stiévenard (France, Associate), P. D. P. Taylor (Belgium, Titular), J. R. de Laeter (Australia, National Representative), P. De Bièvre (Belgium, National Representative), Y. Xiao (China, National Representative), M. Shima (Japan, National Representative), A. Pires de Matos (Portugal, National Representative), N. N. Greenwood (UK, National Representative), and H. S. Peiser (USA, National Representative).

The membership of the Subcommittee for Isotopic Abundance Measurements 1991–1997 was as follows: P. D. P. Taylor (Belgium, *Chairman 1995–97*); R. D. Loss (Australia, *Secretary 1995–97*); *Members*: P. De Bièvre (Belgium), J. Césario (France), J. R. de Laeter (Australia), H. J. Dietze (FRG), M. Ebihara (Japan), J. W. Gramlich (USA), A. N. Halliday (USA,), N. E. Holden (USA), K. G. Heumann (FRG), H. K Kluge (FRG), T. J. Murphy (USA), H. S. Peiser (USA), D. E. Richardson (USA), D. J. Rokop (USA), E. R. Roth (France), K. J. R. Rosman (Australia), M. Shima (Japan), and R. D. Vocke (USA).

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1.1. References for the Introduction

[1]N. E. Holden, R. L. Martin, and I. L. Barnes, Pure Appl. Chem. **55**, 1119 (1983).
[2]N. E. Holden, R. L. Martin, and I. L. Barnes, Pure Appl. Chem. **56**, 675 (1984).
[3]IUPAC Commission on Atomic Weights and Isotopic Abundances, Pure Appl. Chem. **63**, 991–1002 (1991).
[4]IUPAC Commission on Atomic Weights and Isotopic Abundances, Pure Appl. Chem. **55**, 1101–1118 (1983).
[5]IUPAC Commission on Atomic Weights and Isotopic Abundances, Pure Appl. Chem. **56**, 653–674 (1984).
[6]IUPAC Commission on Atomic Weights and Isotopic Abundances, Pure Appl. Chem. **63**, 975–990 (1991).

2. The Table of Isotopic Compositions of the Elements as Determined by Mass Spectrometry

The SIAM has examined the literature available to it through July 1997 and has evaluated these data to produce a table of recommended isotopic abundances for the elements. The table is intended to include values for normal terrestrial samples and does not include values published for meteoritic or other extra-terrestrial materials.

The column contents are as follows:

Column 1: The elements are tabulated in ascending order of their atomic numbers.

Column 2: The symbols for the elements are listed using the abbreviations recommended by IUPAC.

Column 3: The mass number for each isotope is listed.

Column 4: Range of natural variations.
Given are the highest and lowest abundances published for each isotope from measurements which have been accepted by the Subcommittee. No data are given in this Column unless a range has been reliably established. The limits given do not include certain exceptional samples. These are noted with a "g" in column 5.

Column 5: Annotations.
The letters appended in this Column have the following significance:

- g: geologically exceptional specimens are known in which the element has an isotopic composition outside the reported range (refers to column 4);
- m: modified isotopic compositions may be found in commercially available material because it has been subjected to an undisclosed or inadvertent isotopic fractionation. Substantial deviations from the isotopic compositions given can occur (refers to column 9);
- r: range in isotopic composition existing in normal terrestrial material limits the precision of the isotopic abundances (refers to column 9).

Column 6: The best measurement from a single terrestrial source. The values are reproduced from the original literature. The uncertainties on the last digits are given in parenthesis as reported in the original publication. As they are not reported in any uniform manner in the literature, SIAM indicates this as follows: ls, 2s, 3s indicates 1, 2, or 3 standard deviations, P indicates some other error as defined by the author, and se indicates standard error (standard deviation of the mean). Where data are published as isotopic ratios, they, including their uncertainties, are converted to abundances using orthodox procedures.
"C" is appended when calibrated mixtures have been used to correct the mass spectrometer for bias, giving an "absolute" result within the errors stated in the original publication.
"F" is appended when calibrated mixtures have been used to correct for isotopic fractionation but the measurement fails to fulfill all of the requirements of a C measurement.
"L" is appended when the linearity of the mass spectrometer has been established for the relevant abundance ratios by using synthetic mixtures of isotopes or certified materials produced by an appropriate Standards laboratory.
"N" is appended when none of the above requirements are met.

The user is cautioned that:

(a) Since the data are reproduced from the literature, the sum of the isotopic abundances may not equal 100%.

(b) When a range of compositions has been established, the samples used for the best measurement may come from any part of the range.

(c) An uncalibrated "Best Measurement" is not necessarily free of systematic errors.

Column 7: The reference shown is that from which the data shown in column 6 were taken (Appendix A).

Column 8: Reference materials or samples with normal terrestrial isotopic values which are known to be available are listed. An asterisk indicates the reference material used for the best measurement. When additional reference materials are available, the distributors are listed in lieu of specific reference materials (Appendix B).

Column 9: Representative isotopic composition. In this column are listed the values which, in the opinion of SIAM, represent the isotopic composition of the chemicals and/or materials most commonly encountered in the laboratory. They may not, therefore, correspond to the most abundant natural material. For example, in the case of hydrogen, the deuterium abundance quoted corresponds to that in fresh water in temperate climates rather than to ocean water. The uncertainties listed in parenthesis cover the range of probable variations of the materials as well as experimental errors. The number of significant figures is chosen to be consistent with the uncertainties, which in turn are derived by applying the statistical guidelines SIAM uses for assigning uncertainties to published isotope abundance measurements. An atomic weight calculated from these abundances will be consistent with $A_r(E)$ values listed in the Table of Standard Atomic Weights 1997.

Warning

(1) Values in column 9 should be used to determine the average properties of material of unspecified natural terrestrial origin, though no actual sample having the exact composition listed may be available.
(2) When precise work is to be undertaken, such as assessment of individual properties, samples with more precisely known isotopic abundances (such as those listed in column 8) should be obtained or suitable measurements should be made.

TABLE 1. Isotopic compositions of the elements as determined by mass spectrometry

Atomic No.	Symbol	Mass No.	Range of natural variations (Atom %)	Annotations	Best measurement from a single terrestrial source (Atom %)		Reference (App. A)	Available reference materials[a] (App. B)	Representative isotopic composition (Atom %)
1	2	3	4	5	6		7	8	9
1	H	1	99.9816–99.9975	m,r	99.984426 (5) 2s	C	70HAG1	VSMOW[b]	99.9885 (70)
		2	0.0184–0.0025		0.015574 (5)			CEA	0.0115 (70)[c]
								IAEA	(in water)
								NIST	
2	He	3	4.6×10^{-8}–0.0041	g,r	0.0001343 (13) 1s	C	88SAN1	Air[b]	0.000137 (3)
		4	100–99.9959		99.9998657 (13)				99.999863 (3)
									(in air)
3	Li	6	7.21–7.71	m,r	7.589 (24) 2s	C	97QI1	IRMM-016[b]	[7.59(4)][d]
		7	92.79–92.29		92.411 (24)			IAEA	[92.41(4)]
								IRMM	
								NIST	
4	Be	9			100		63LEI1		100
5	B	10	18.927–20.337	m,r	19.82 (2) 2s	C	69BIE1	IRMM-011[b]	19.9 (7)
		11	81.073–79.663		80.18 (2)			NIST	80.1 (7)
6	C	12	98.85–99.02	r	98.8922 (28) P	C	90CHA1	NBS19[b]	98.93 (8)
		13	1.15–0.98		1.1078 (28)			IAEA	1.07 (8)
								NIST	
7	N	14	99.890–99.652	r	99.6337 (4) P	C	58JUN1	Air[b]	99.632 (7)[e]
		15	0.411–0.348		0.3663 (4)			IAEA	0.368 (7)
								NIST	
8	O	16	99.7384–99.7756	r	99.7628 (5) 1s	N	76BAE1	VSMOW[b]	99.757 (16)
		17	0.0399–0.0367		0.0372 (4)[f]		88LI1	IAEA	0.038 (1)
		18	0.2217–0.1877		0.20004 (5)			NIST	0.205 (14)
9	F	19			100		20AST1		100
10	Ne	20	90.514–88.47	g,m	90.4838 (90) 1s	C	84BOT1	Air[b]	90.48 (3)
		21	1.71–0.266	r	0.2696 (5)				0.27 (1)
		22	9.96–9.20		9.2465 (90)				9.25 (3)
									(in air)
11	Na	23			100		56WHI1		100
12	Mg	24			78.992 (25) 2s	C	66CAT1	NIST-SRM980[b]	78.99 (4)
		25			10.003 (9)				10.00 (1)
		26			11.005 (19)				11.01 (3)
13	Al	27			100		56WHI1		100
14	Si	28	92.21–92.25	r	92.22968 (44) 2s	C	97GON1	IAEA	92.2297 (7)
		29	4.69–4.67		4.68316 (32)			IRMM	4.6832 (5)
		30	3.10–3.08		3.08716 (32)			NIST	3.0872 (5)
15	P	31			100		63LEI1		100
16	S	32	94.537–95.261	r	95.018 (4) P	C	50MAC1	CEA	94.93 (31)
		33	0.787–0.731		0.750 (7)			IAEA	0.76 (2)
		34	4.655–3.993		4.215 (4)			NIST	4.29 (28)
		36	0.021–0.015		0.017 (2)				0.02 (1)
17	Cl	35	75.64–75.86	m	75.771 (45) 2s	C	62SHI1	NIST-SRM975[b]	75.78 (4)
		37	24.36–24.14		24.229 (45)				24.22 (4)

TABLE 1. Isotopic compositions of the elements as determined by mass spectrometry—Continued

Atomic No.	Symbol	Mass No.	Range of natural variations (Atom %)	Annotations	Best measurement from a single terrestrial source (Atom %)	Reference (App. A)	Available reference materials[a] (App. B)	Representative isotopic composition (Atom %)
18	Ar	36		g	0.3365 (6) P C	50NIE1	Air[b]	0.3365 (30)
		38			0.0632 (1)			0.0632 (5)
		40			99.6003 (6)			99.6003 (30) (in air)
19	K	39			93.25811 (292) 2sC	75GAR1	NIST -SRM985[b]	93.2581 (44)
		40			0.011672 (41)			0.0117 (1)
		41			6.73022 (292)			6.7302 (44)
20	Ca	40	96.982–96.880	g,r	96.941 (6) 2s N	72MOO1	NIST--SRM915[b]	96.941 (156)[g]
		42	0.656–0.640		0.647 (3)			0.647 (23)
		43	0.146–0.131		0.135 (2)			0.135 (10)
		44	2.130–2.057		2.086 (4)			2.086 (110)
		46	0.0046–0.0031		0.004 (1)			0.004 (3)
		48	0.200–0.179		0.187 (1)			0.187 (21)
21	Sc	45			100	50LEL1		100
22	Ti	46			8.249 (21) 2s C	93SHI1		8.25 (3)
		47			7.437 (14)			7.44 (2)
		48			73.720 (22)			73.72 (3)
		49			5.409 (10)			5.41 (2)
		50			5.185 (13)			5.18 (2)
23	V	50	0.2502–0.2487	g	0.2497 (6) 1s F	66FLE1		0.250 (4)
		51	99.7513–99.7498		99.7503 (6)			99.750 (4)
24	Cr	50			4.3452 (85) 2s C	66SHI1	NIST-SRM979[b]	4.345 (13)
		52			83.7895 (117)			83.789 (18)
		53			9.5006 (110)			9.501 (17)
		54			2.3647 (48)			2.365 (7)
25	Mn	55			100	63LEI1		100
26	Fe	54			5.845 (23) 2s C	92TAY1	IRMM-014[b]	5.845 (35)
		56			91.754 (24)			91.754 (36)
		57			2.1191 (65)			2.119 (10)
		58			0.2819 (27)			0.282 (4)
27	Co	59			100	63LEI1		100
28	Ni	58			68.0769 (59) 2s C	89GRA1		68.0769 (89)
		60			26.2231 (51)			26.2231 (77)
		61			1.1399 (4)			1.1399 (6)
		62			3.6345 (11)			3.6345 (17)
		64			0.9256 (6)			0.9256 (9)
29	Cu	63	69.24–68.98	r	69.174 (20) 2s C	64SHI1	NIST-SRM976[b]	69.17 (3)
		65	31.02–30.76		30.826 (20)			30.83 (3)
30	Zn	64			48.63 (20) 2s F	72ROS1		48.63 (60)
		66			27.90 (9)			27.90 (27)
		67			4.10 (4)			4.10 (13)
		68			18.75 (17)			18.75 (51)
		70			0.62 (1)			0.62 (3)
31	Ga	69		m	60.1079 (62) 2s C	86MAC1	NIST-SRM994[b]	60.108 (9)
		71			39.8921 (62)			39.892 (9)
32	Ge	70			21.234 (31) 1s L	86GRE1		20.84 (87)[i]
		72			27.662 (29)			27.54 (34)

TABLE 1. Isotopic compositions of the elements as determined by mass spectrometry—Continued

Atomic No.	Symbol	Mass No.	Range of natural variations (Atom %)	Annotations	Best measurement from a single terrestrial source (Atom %)	Reference (App. A)	Available reference materials[a] (App. B)	Representative isotopic composition (Atom %)
		73			7.717 (5)			7.73 (5)
		74			35.943 (25)			36.28 (73)
		76			7.444 (14)			7.61 (38)
33	As	75			100	63LEI1		100
34	Se	74		r	0.889 (3) 1s N	89WAC1		0.89 (4)
		76			9.366 (18)			9.37 (29)
		77			7.635 (10)			7.63 (16)
		78			23.772 (20)			23.77 (28)
		80			49.607 (17)			49.61 (41)
		82			8.731 (10)			8.73 (22)
35	Br	79			50.686 (26) 2s C	64CAT1	NIST-SRM977[b]	50.69 (7)
		81			49.314 (26)			49.31 (7)
36	Kr	78		g,m	0.35351 (7) 2s N	94VAL1		0.35 (1)
		80			2.28086 (29)			2.28 (6)
		82			11.58304 (76)			11.58 (14)
		83			11.49533 (35)			11.49 (6)
		84			56.98890 (62)			57.00 (4)
		86			17.29835 (26)			17.30 (22) (in air)
37	Rb	85		g	72.1654 (132) 2s C	69CAT1	NIST-SRM984	72.17 (2)
		87			27.8346 (132)			27.83 (2)
38	Sr	84	0.58–0.55	g,r	0.5574 (16) 2s C	82MOO1	NIST-SRM987[b]	0.56 (1)
		86	9.99–9.75		9.8566 (34)		NIST	9.86 (1)
		87	7.14–6.94		7.0015 (26)			7.00 (1)[g]
		88	82.75–82.29		82.5845 (66)			82.58 (1)
39	Y	89			100	57COL1		100
40	Zr	90		g	51.452 (9) 2s N	83NOM1		51.45 (40)
		91			11.223 (12)			11.22 (5)
		92			17.146 (7)			17.15 (8)
		94			17.380 (12)			17.38 (28)
		96			2.799 (5)			2.80 (9)
41	Nb	93			100	56WHI1		100
42	Mo	92		g	14.8362 (148) 2s N	74MOO1		14.84 (35)
		94			9.2466 (92)			9.25 (12)
		95			15.9201 (159)			15.92 (13)
		96			16.6756 (167)			16.68 (2)
		97			9.5551 (96)			9.55 (8)
		98			24.1329 (241)			24.13 (31)
		100			9.6335 (96)			9.63 (23)
43	Tc					…	…	…
44	Ru	96		g	5.5420 (1) 1s N	97HUA1		5.54 (14)
		98			1.8688 (2)			1.87 (3)
		99			12.7579 (6)			12.76 (14)
		100			12.5985 (4)			12.60 (7)
		101			17.0600 (10)			17.06 (2)
		102			31.5519 (11)			31.55 (14)
		104			18.6210 (11)			18.62 (27)
45	Rh	103			100	63LEI1		100

TABLE 1. Isotopic compositions of the elements as determined by mass spectrometry—Continued

Atomic No.	Symbol	Mass No.	Range of natural variations (Atom %)	Annotations	Best measurement from a single terrestrial source (Atom %)	Reference (App. A)	Available reference materials[a] (App. B)	Representative isotopic composition (Atom %)
46	Pd	102		g,r	1.020 (8) 2s C	78SHI1		1.02 (1)
		104			11.14 (5)			11.14 (8)
		105			22.33 (5)			22.33 (8)
		106			27.33 (2)			27.33 (3)
		108			26.46 (6)			26.46 (9)
		110			11.72 (6)			11.72 (9)
47	Ag	107		g	51.8392 (51) 2s C	82POW1	NIST-SRM978[b]	51.839 (8)
		109			48.1608 (51)			48.161 (8)
48	Cd	106		g	1.25 (2) 2s F	80ROS1		1.25 (6)
		108			0.89 (1)			0.89 (3)
		110			12.49 (6)			12.49 (18)
		111			12.80 (4)			12.80 (12)
		112			24.13 (7)			24.13 (21)
		113			12.22 (4)			12.22 (12)
		114			28.73 (14)			28.73 (42)
		116			7.49 (6)			7.49 (18)
49	In	113		g	4.288 (5) 2s N	91CHA1		4.29 (5)
		115			95.712 (5)			95.71 (5)
50	Sn	112		g	0.973 (3) 1s C	83DEV1		0.97 (1)
		114			0.659 (3)[h]	84ROS1		0.66 (1)
		115			0.339 (3)[h]			0.34 (1)
		116			14.536 (31)			14.54 (9)
		117			7.676 (22)			7.68 (7)
		118			24.223 (30)			24.22 (9)
		119			8.585 (13)			8.59 (4)
		120			32.593 (20)			32.58 (9)
		122			4.629 (9)			4.63 (3)
		124			5.789 (17)			5.79 (5)
51	Sb	121		g	57.213 (32) 2s C	93CHA1		57.21 (5)
		123			42.787 (32)			42.79 (5)
52	Te	120		g	0.096 (1) 2se N	78SMI1		0.09 (1)[i]
		122			2.603 (1)			2.55 (12)
		123			0.908 (1)			0.89 (3)
		124			4.816 (2)			4.74 (14)
		125			7.139 (2)			7.07 (15)
		126			18.952 (4)			18.84 (25)
		128			31.687 (4)			31.74 (8)
		130			33.799 (3)			34.08 (62)
53	I	127			100	49LEL1		100
54	Xe	124		g,m	0.08913 (3) 2s N	94VAL1		0.09 (1)
		126			0.08880 (2)			0.09 (1)
		128			1.91732 (12)			1.92 (3)
		129			26.43964 (17)			26.44 (24)
		130			4.08271 (15)			4.08 (2)
		131			21.17961 (19)			21.18 (3)
		132			26.89157 (11)			26.89 (6)
		134			10.44232 (17)			10.44 (10)
		136			8.86890 (14)			8.87 (16)
55	Cs	133			100	56WHI1		100
56	Ba	130		g	0.1058 (2) 3se F	69EUG1		0.106 (1)
		132			0.1012 (2)			0.101 (1)

TABLE 1. Isotopic compositions of the elements as determined by mass spectrometry—Continued

Atomic No.	Symbol	Mass No.	Range of natural variations (Atom %)	Annotations	Best measurement from a single terrestrial source (Atom %)	Reference (App. A)	Available reference materials[a] (App. B)	Representative isotopic composition (Atom %)
		134			2.417 (3)			2.417 (18)
		135			6.592 (2)			6.592 (12)
		136			7.853 (4)			7.854 (24)
		137			11.232 (4)			11.232 (24)
		138			71.699 (7)			71.698 (42)
57	La	138		g	0.09017 (5) 2se N	87MAK1		0.090 (1)
		139			99.90983 (5)			99.910 (1)
58	Ce	136	0.186–0.185	g	0.186 (1) 2s C	95CHA1		0.185 (2)
		138	0.254–0.251		0.251 (1)			0.251 (2)[g]
		140	88.449–88.446		88.449 (34)			88.450 (51)
		142	11.114–11.114		11.114 (34)			11.114 (51)
59	Pr	141			100	57COL1		100
60	Nd	142	27.30–26.80	g	27.16 (4) 2se N	81HOL1		27.2 (5)
		143	12.32–12.12		12.18 (2)			12.2 (2)[g]
		144	23.97–23.795		23.83 (4)			23.8 (3)
		145	8.35–8.23		8.30 (2)			8.3 (1)
		146	17.35–17.06		17.17 (3)			17.2 (3)
		148	5.78–5.66		5.74 (1)			5.7 (1)
		150	5.69–5.53		5.62 (1)			5.6 (2)
61	Pm				...			...
62	Sm	144		g	3.0734 (9) 2s F	97CHA1		3.07 (7)
		147			14.9934 (18)			14.99 (18)
		148			11.2406 (15)			11.24 (10)
		149			13.8189 (18)			13.82 (7)
		150			7.3796 (14)			7.38 (1)
		152			26.7421 (66)			26.75 (16)
		154			22.7520 (68)			22.75 (29)
63	Eu	151		g	47.810 (42) 2se C	94CHA1		47.81 (3)
		153			52.190 (42)			52.19 (3)
64	Gd	152		g	0.2029 (4) 2se N	70EUG1		0.20 (1)
		154			2.1809 (4)			2.18 (3)
		155			14.7998 (17)			14.80 (12)
		156			20.4664 (6)			20.47 (9)
		157			15.6518 (9)			15.65 (2)
		158			24.8347 (16)			24.84 (7)
		160			21.8635 (7)			21.86 (19)
65	Tb	159			100	57COL1		100
66	Dy	156		g	0.056 (1) 2se N	81HOL1		0.06 (1)
		158			0.096 (2)			0.10 (1)
		160			2.34 (2)			2.34 (8)
		161			18.91 (5)			18.91 (24)
		162			25.51 (7)			25.51 (26)
		163			24.90 (7)			24.90 (16)
		164			28.19 (8)			28.18 (37)
67	Ho	165			100	57COL1		100
68	Er	162		g	0.137 (1) 2se N	81HOL1		0.14 (1)
		164			1.609 (5)			1.61 (3)
		166			33.61 (7)			33.61 (35)
		167			22.93 (5)			22.93 (17)

TABLE 1. Isotopic compositions of the elements as determined by mass spectrometry—Continued

Atomic No.	Symbol	Mass No.	Range of natural variations (Atom %)	Annot–ations	Best measurement from a single terrestrial source (Atom %)	Reference (App. A)	Available reference materials[a] (App. B)	Representative isotopic composition (Atom %)
		168			26.79 (7)			26.78 (26)
		170			14.93 (5)			14.93 (27)
69	Tm	169			100	57COL1		100
70	Yb	168		g	0.127 (2) 2se N	81HOL1		0.13 (1)
		170			3.04 (2)			3.04 (15)
		171			14.28 (8)			14.28 (57)
		172			21.83 (10)			21.83 (67)
		173			16.13 (7)			16.13 (27)
		174			31.83 (14)			31.83 (92)
		176			12.76 (5)			12.76 (41)
71	Lu	175		g	97.416 (5) 2se N	83PAT1		97.41 (2)
		176			2.584 (5)			2.59 (2)
72	Hf	174	0.1621–0.1619		0.1620 (9) 2se N	83PAT1		0.16 (1)
		176	5.271–5.206		5.2604 (56)			5.26 (7)[g]
		177	18.606–18.593		18.5953 (12)			18.60 (9)
		178	27.297–27.278		27.2811 (22)			27.28 (7)
		179	13.630–13.619		13.6210 (9)			13.62 (2)
		180	35.100–35.076		35.0802 (26)			35.08 (16)
73	Ta	180			0.0123 (3) 1se N	56WHI1		0.012 (2)
		181			99.9877 (3)			99.988 (2)
74	W	180			0.1198 (2) 1s N	91VÖL2		0.12 (1)
		182			26.4985 (49)			26.50 (16)
		183			14.3136 (6)			14.31 (4)
		184			30.6422 (13)			30.64 (2)
		186			28.4259 (62)			28.43 (19)
75	Re	185			37.398 (16) 2s C	73GRA1	NIST- SRM989[h]	37.40 (2)
		187			62.602 (16)			62.60 (2)
76	Os	184		g,r	0.0197 (5) 1s N	91VÖL1		0.02 (1)
		186			1.5859 (44)			1.59 (3)
		187			1.9644 (12)			1.96 (2)[g]
		188			13.2434 (19)			13.24 (8)
		189			16.1466 (16)			16.15 (5)
		190			26.2584 (14)			26.26 (2)
		192			40.7815 (22)			40.78 (19)
77	Ir	191			37.272 (15) 1s N	93WAL1		37.3 (2)
		193			62.728 (15)			62.7 (2)
78	Pt	190			0.013634 (68) 1s N	96TAY1		0.014 (1)
		192			0.782659 (35)			0.782 (7)
		194			32.96700 (77)			32.967 (99)
		195			33.831557 (42)			33.832 (10)
		196			25.24166 (36)			25.242 (41)
		198			7.16349 (42)			7.163 (55)
79	Au	197			100	63LEI1		100
80	Hg	196			0.15344 (19) 1s N	89ZAD1		0.15 (1)
		198			9.968 (13)			9.97 (20)
		199			16.873 (17)			16.87 (22)
		200			23.096 (26)			23.10 (19)
		201			13.181 (13)			13.18 (9)

TABLE 1. Isotopic compositions of the elements as determined by mass spectrometry—Continued

Atomic No.	Symbol	Mass No.	Range of natural variations (Atom %)	Annot-ations	Best measurement from a single terrestrial source (Atom %)	Reference (App. A)	Available reference materials[a] (App. B)	Representative isotopic composition (Atom %)
		202			29.863 (33)			29.86 (26)
		204			6.865 (7)			6.87 (15)
81	Tl	203			29.524 (9) 2s C	80DUN1	NIST-SRM997[b]	29.524 (14)
		205			70.476 (9)			70.476 (14)
82	Pb	204	1.65–1.04	g,r	1.4245 (12) 2s C	68CAT1	NIST-SRM981[b]	1.4 (1)
		206	27.48–20.84		24.1447 (57)		NIST	24.1 (1)[g]
		207	23.65–17.62		22.0827 (27)			22.1 (1)[g]
		208	56.21–51.28		52.3481 (86)			52.4 (1)[g]
83	Bi	209			100	63LEI1		100
84	Po							
85	At							
86	Rn							
87	Fr							
88	Ra							
89	Ac							
90	Th	232		g	100	36DEM1		100
91	Pa	231			100	77BRO1		100
92	U	234	0.0059–0.0050	g,m	0.00548 (2)[j] 1s N	69SMI1	IRMM-184	[0.0055(2)]
		235	0.7202–0.7198	r	0.7200 (1)	76COW1	CEA	[0.7200(51)][d,g]
		238	99.2752–99.2739		99.2745 (10)		IRMM	[99.2745(106)]
							NBL	

[a]NIST materials were previously labelled NBS. IRMM materials were previously labelled CBNM.
[b]Reference material used for the best measurement.
[c]The range of ^{2}H in tank hydrogen is 0.0032–0.0184 at. %.
[d]Materials depleted in ^{6}Li and ^{235}U are commercial sources of laboratory shelf reagents. In the case of Li such samples are known to have ^{6}Li abundances in the range 2.007–7.672 at. %, with natural materials at the higher end of this range.
[e]The Commission recommends that the value of 272 be employed for ^{14}N/^{15}N of N_2 in air for the calculation of at. % ^{15}N from measured δ^{15}N values.
[f]The reference reported a calibrated ^{16}O/^{18}O ratio on VSMOW; ^{17}O abundance was derived from 88LI1.
[g]Evaluated isotopic composition is for most but not all commercial samples.
[h]Due to ^{115}In contamination and an error in the ^{114}Sn abundance the ^{115}Sn and ^{114}Sn abundances reported by 83DEV1 were adjusted using data from 84ROS1.
[i]An electron multiplier was used for these measurements and the measured abundances were adjusted using a square root of the masses.
[j]The ^{234}U abundance is from 69SMI1, and ^{235}U and ^{238}U are from 76COW1.

3. Appendixes

3.1. Appendix A: References for Table 1

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3.2. Appendix B: Sources of Reference Materials

IAEA

Reference and intercomparison samples such as VSMOW, SLAP, GISP, LSVEC, NSVEC, NBS18 and NBS19 may be purchased from:
International Atomic Energy Agency
Section of Isotope Hydrology
P.O. Box 100
1400 Vienna, Austria

NIST

NIST Standard Reference Materials may be purchased through:
Standard Reference Material Program
National Institute of Standards and Technology
Gaithersburg, MD 20899 U.S.A.

IRMM

Reference Materials may be obtained through:
Institute for Reference Measurements and Materials
Commission of the European Communities-JRC
B-2440 Geel, Belgium

CEA

CEA distributes stable isotopes through its daughter company:
EUROISA-TOP
Parc des Algorithmes (Bat. Homère),
F-91190 St Aubin,
France

For nuclear reference materials, see also:
CETAMA
CEA/DCC
Centre d'Etudes Nucléaires de Fontenay aux Roses
BP 6
F 92265 Fontenay aux Roses
France

NBL

Standards may be obtained through:
U.S. Department of Energy
New Brunswick Laboratory
9800 S. Cass Ave.
Argonne IL 60439