Pure & Appl. Chem., Vol. 55, No. 7, pp. 1119-1136, 1983.
Printed in Great Britain.

0033-4545/83 $3.00+0.00
Pergamon Press Ltd.

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

INORGANIC CHEMISTRY DIVISION

COMMISSION ON ATOMIC WEIGHTS AND ISOTOPIC ABUNDANCES*

ISOTOPIC COMPOSITIONS OF THE ELEMENTS 1981

Prepared for publication by

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ISOTOPIC COMPOSITIONS OF THE ELEMENTS 1981

Abstract - The Commission's biennial review of isotopic compositions as determined by mass spectrometry has been undertaken by the Subcommittee for the Assessment of Isotopic Composition (SAIC). A critical evaluation of the published literature forms the basis of the Table of Isotopic Compositions and Atomic Weights as Determined by Mass Spectrometry 1981, which is presented here. Atomic Weights calculated from the tabulated isotopic abundances are generally consistent with $A_r(E)$ values in the Table of Standard Atomic Weights 1981 with the most notable exceptions being the elements zinc, germanium and selenium, where the uncertainty intervals just meet or barely overlap.

INTRODUCTION

At its 1973 Munich meeting, the Commission, at the request of the IUPAC Inorganic Division, undertook to assemble, evaluate, and ultimately disseminate data on the mass-spectrometrically determined isotopic compositions of the elements. It was recognized at the time that the atomic weight value calculated on the basis of the best isotopic composition evaluated by mass spectrometry for a given element may not necessarily agree precisely with the best atomic weight value derived from all significant published measurements by all methods. At the 1975 meeting in Madrid, a Subcommittee for the Assessment of Isotopic Composition (SAIC) within the Commission on Atomic Weights was established, with the function of undertaking the desired evaluation of isotopic compositions incorporating not only mass-spectrometric data but also the results obtained from all other relevant methods. Since 1977, the Commission has published tables of critically evaluated isotopic compositions based on work done by SAIC. This second Part of the 1981 Report tabulates the range of credible published isotopic abundances determined by mass-spectrometry for each of the naturally occurring elements, together with the result of what is considered to be the best available mass-spectrometric measurement for a single natural source of each element, and a representative value for the isotopic composition for average elemental properties. This best mass-spectrometric measurement is not necessarily a good one in terms of 1981 knowledge, nor does it necessarily provide the best atomic weight value in terms of all techniques. Thus, for example, if a purely chemical determination is judged to be the most reliable, then the corresponding standard $A_r(E)$ value will be used as a constraint in the assignment of isotopic abundancies. The Commission has directed the SAIC to complete its exhaustive element-by-element review, including all measurements for deriving isotopic compositions, with the objective of publishing, in the 1983 Report, a Table of Isotopic Compositions which is entirely consistent with the Table of Standard Atomic Weights.

TABLE OF ISOTOPIC COMPOSITIONS AND ATOMIC WEIGHTS AS DETERMINED BY MASS SPECTROMETRY

The Subcommittee for the Assessment of Isotopic Compositions (SAIC) has examined all of the available literature published through August 1981. The Subcommittee has evaluated this data critically to produce an interim table of recommended isotopic abundances for the elements and the atomic weights calculated from these abundancies. The table is intended to include values for normal terrestrial samples only and does not include values published for meteoritic or other extra-terrestrial materials. The interim values of isotopic abundances when converted to atomic weights are not all fully consistent with the 1981 Table of Standard Atomic Weights published in Part 1 of the Report. As mentioned in the 1979 Report (Ref. 1), discrepancies continue to be most evident for the elements zinc (for which the uncertainty intervals just touch), germanium (for which the uncertainty intervals overlap, but neither of the $A_r(E)$ values lie within the uncertainty interval of the other) and selenium (for which the SAIC calculated value lies just at the boundary of the uncertainty interval of the Standard Atomic Weight). Following SAIC's reviews in 1980 and 1981 of the Table of Isotopic Compositions of the Elements, and the calculation of the corresponding Atomic Weights, a better correspondence between the latter and the official IUPAC standard Atomic Weight values has now been achieved for the elements N, Ti, Rb, Zr, Ag and Cd. As mentioned in Part 1 of the Report, the annotations to the Table have been designed to harmonize with those used for the Table of Standard Atomic Weights except that upper case letters have been employed in the present Table of Isotopic Compositions. This distinction is made because some elements have an annotation appended to their isotopic composition, tabulated here, but the corresponding atomic weights of Part I are not affected.

The membership of SAIC during the past two years has been P. De Bièvre (Chairman), I.L. Barnes (Secretary), the late A.E. Cameron, R. Hagemann, N.E. Holden, and H.G. Thode. Additional assistance has been provided by J. de Laeter, T.J. Murphy, H.S. Peiser, E. Roth and M. Shima.

REFERENCES

1. Atomic Weights of the Elements, 1979: Report of the IUPAC Commission on Atomic Weights and Isotopic Abundances, Pure Appl. Chem., 42, 2349 (1980).

TABLE OF ISOTOPIC COMPOSITIONS AS DETERMINED BY MASS SPECTROMETRY

Introduction

The Subcommittee for the Assessment of Isotopic Composition (SAIC) has examined all of the literature available to it through August 1981. The Subcommittee 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 only and does not include values published for meteoritic or other extra-terrestrial materials.

Description of the contents of each of the Columns

Column 1: The atomic numbers of the elements are given in ascending order.

Column 2: The names of the elements are listed using the abbreviations recommended by IUPAC.

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

Column 4: Evaluated limits of Published Values

Given are the highest and lowest abundances published for each isotope from measurements which have been evaluated and accepted by the Subcommittee. The limits given include known natural variations and published data which may exceed those variations. No data are given in this Column when the absence of 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:

R Range in isotopic composition in normal terrestrial material is responsible for part, or all, of the difference between limits of reported values.

G Geologically exceptional specimens are known in which the element has an isotopic composition outside the limits of reported values.

O One measurement only provides the available data.

M Modified isotopic compositions may be found in commercial material that will fall outside the limits listed, because the material has, either deliberately or inadvertently (see notes), been subjected to isotopic separation.

L Longest half-life isotope is chosen for the A_r quoted.

Column 6: In this column are given the data from the best measurement of a sample 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 SAIC indicates this as follows: 1, 2, 3σ indicates 1, 2, or 3 standard deviations, P indicates some other error as defined by the author, and SE (standard deviation of the mean) indicates standard error. Where no errors are listed, none were given by the author. "C" is appended when the measurement has been calibrated and is thus believed to be "absolute" within the errors stated in the original publication.

The user is cautioned that: a) Since the data are reproduced from the literature, the sum of the isotopic abundances may not equal to 100 percent. 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) A "Best Measurement" is not necessarily a good one in SAIC's opinion.

Column 7: The reference to the literature containing the best measurement is given. The complete citation is given in Appendix A.

Column 8: Reference materials or samples which are known to be available and which relate to the best measurement are listed. Where one or more materials are available which represent the best measurement, these are marked with an asterisk. Additional information is contained in Appendix B.

Column 9: In this Column are listed the values for the isotopic composition of the elements which, in the opinion of SAIC, will include 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. Uncertainties quoted are from one to nine in the last digit except for a few cases where rounded values would be outside of the observed range. In those cases uncertainties greater than nine have been used.

<u>Warning</u>

1) Representative isotopic composition should be used to evaluate average properties of material of unspecified natural terrestrial origin, though no actual sample having the most exact composition listed may be available.

2) When precise work is 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 OF ISOTOPIC COMPOSITIONS OF THE ELEMENTS AS DETERMINED BY MASS SPECTROMETRY

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values 4	Annotations 5	Best Measurement from a Single Natural Source 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition 9
1	H	1	99.9918 - 99.9816	R,G	99.984426 (5) 2σ C	70HAG1	IAEA-V-SMOW*	99.985 (1)[a]
		2	0.0184 - 0.0082	M	0.015574 (5)		IAEA-SLAP	0.015 (1)
							C.E.A.	(for water only)
2	He	3	0.0041 - $6x10^{-8}$	R,G	0.0001384 (6) σ	76CLA1	Air*	0.000138 (3)
		4	100 - 99.9959		99.9998616 (6)			99.999862 (3)
								(for air only)
3	Li	6	7.68 - 7.30	R,G	7.68 (2) σ C	73FLE1	NBS-RS LSVEC*	7.5 (2)[b]
		7	92.70 - 92.32	M	92.32 (2)			92.5 (2)
4	Be	9	---		100	63LEI1		100
5	B	10	20.316 - 19.098	R,M	19.82 (2) 2σ C	69BIE1	CBNM-GEEL*,	19.9 (2)
		11	80.902 - 79.684		80.18 (2)		NBS-SRM 951	80.1 (2)
6	C	12	98.99 - 98.86	R,G	98.889 (3) P	57CRA1	NBS-RS 20*	98.90 (3)
		13	1.14 - 1.01		1.111 (3)			1.10 (3)
7	N	14	99.639 - 99.625	R	99.634 (1) C	58JUN1	Air	99.634 (9)
		15	0.375 - 0.361		0.366 (1)		NBS-RS NSVEC*	0.366 (9)
8	O	16	99.7771 - 99.7539	R	99.7628 (5) σ	76BAE1	NBS-RS 20	99.762 (15)[c]
		17	0.0407 - 0.035		0.0372 (4)		IAEA-V-SMOW*,	0.038 (3)
		18	0.2084 - 0.1879		0.20004 (5)		IAEA-SLAP	0.200 (12)
9	F	19	---		100	20AST1		100
10	Ne	20	90.514 - 88.47	R,G	90.514 (31) σ C	66WAL1	Air*	90.51 (9)
		21	1.71 - 0.266	M	0.266 (5)			0.27 (2)
		22	9.96 - 9.20		9.220 (29)			9.22 (9)
								(for air only)
11	Na	23	---		100	56WHI1		100

[a] Available hydrogen gases vary from 0.044% to 0.0184% D with corresponding atomic weights of 1.007869 to 1.00801.
[b] Enriched ^{7}Li is a commercial source of lithium.
[c] The reference reported a calibrated $^{16}O/^{18}O$ ratio on V-SMOW, the ^{17}O abundance was derived from a measurement on air.

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values 4	Annotations 5	Best Measurement from a Single Natural Source 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition 9
12	Mg	24	---	G	78.992 (25) 3σ C	66CAT1	NBS-SRM 980*	78.99 (3)
		25			10.003 (9)			10.00 (1)
		26			11.005 (19)			11.01 (2)
13	Al	27	---		100	56WHI1		100
14	Si	28	92.41 - 92.14	R	92.22933 (155) 3σ C	75BAR2	NBS-SRM 990*	92.23 (1)
		29	4.73 - 4.57		4.66982 (124)			4.67 (1)
		30	3.14 - 3.01		3.10085 (74)			3.10 (1)
15	P	31	---		100	63LEI1		100
16	S	32	95.253 - 94.638	R	95.018 (4) P	50MAC1	TROILITE*	95.02 (6)
		33	0.780 - 0.731		0.750 (7)		IAEA	0.75 (1)
		34	4.562 - 4.001		4.215 (4)		C.E.A.	4.21 (8)
		36	0.0199 - 0.0153		0.017 (2)			0.02 (1)
17	Cl	35	---		75.771 (45) 3σ C	62SHI2	NBS-SRM 975*	75.77 (5)
		37			24.229 (45)			24.23 (5)
18	Ar	36	---	G	0.3365 (6) P,C	50NIE1	Air*	0.337 (3)
		38			0.0632 (1)			0.063 (1)
		40			99.6003 (6)			99.600 (3) (for air only)
19	K	39	---		93.25811 (292) 3σ C	75GAR1	NBS-SRM 985*	93.2581 (30)
		40			0.011672 (41)			0.0117 (1)
		41			6.73022 (292)			6.7302 (30)
20	Ca	40	96.98213- 96.88	R,G	96.941 (5) 2σ	72MOO1	NBS-SRM 915*	96.941 (13)
		42	0.6562 - 0.640		0.647 (1)			0.647 (3)
		43	0.1457 - 0.1312		0.135 (1)			0.135 (3)
		44	2.13 - 2.05675		2.086 (2)			2.086 (5)
		46	0.0046 - 0.00313		0.004 (1)			0.004 (3)
		48	0.200 - 0.179		0.187 (1)			0.187 (3)
21	Sc	45	---		100	50LEL1		100

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22	Ti	46	---		8.0124 (4) 2σ	81NIE2		8.0 (1)
		47			7.3309 (4)			7.3 (1)
		48			73.8145 (40)			73.8 (1)
		49			5.4964 (3)			5.5 (1)
		50			5.3458 (3)			5.4 (1)
23	V	50	---	G	0.2497 (6) S.E. C	66FLE1		0.250 (2)
		51			99.7503 (6)			99.750 (2)
24	Cr	50	---		4.3452 (85) 3σ C	66SHI1	NBS-SRM 979*	4.35 (1)
		52			83.7895 (117)			83.79 (1)
		53			9.5006 (110)			9.50 (1)
		54			2.3647 (48)			2.36 (1)
25	Mn	55	---		100	63LEI1		100
26	Fe	54	6.04 - 5.77		5.81	47VAL1		5.8 (1)
		56	91.79 - 91.52		91.75			91.72 (30)
		57	2.25 - 2.11		2.15			2.2 (1)
		58	0.34 - 0.28		0.29			0.28 (1)
27	Co	59	---		100	63LEI1		100
28	Ni	58	68.274 - 67.76		68.274 (1) 2σ	73BAR1		68.27 (1)
		60	26.424 - 26.095		26.095 (1)			26.10 (1)
		61	1.25 - 1.134		1.134 (1)			1.13 (1)
		62	3.711 - 3.593		3.593 (1)			3.59 (1)
		64	1.16 - 0.904		0.904 (1)			0.91 (1)
29	Cu	63	69.24 - 68.98	R	69.174 (20) 3σ C	64SHI1	NBS-SRM 976*	69.17 (2)
		65	31.02 - 30.76		30.826 (20)			30.83 (2)
30	Zn	64	48.9 - 48.6		48.63 (13) 2σ	72ROS1		48.6 (3)
		66	27.9 - 27.6		27.90 (8)			27.9 (2)
		67	4.17 - 4.07		4.10 (3)			4.1 (1)
		68	18.75 - 18.48		18.75 (16)			18.8 (4)
		70	0.69 - 0.62		0.62 (1)			0.6 (1)
31	Ga	69	60.5 - 59.988		60.078 (108) 2σ C	76LAE1		60.1 (2)
		71	40.012 - 39.5		39.922 (108)			39.9 (2)

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32	Ge	70	21.11 - 19.92		20.52 (17) P	53REY1		20.5 (5)
		72	27.67 - 27.26		27.43 (21)			27.4 (6)
		73	7.88 - 7.51		7.76 (8)			7.8 (2)
		74	37.41 - 36.09		36.53 (23)			36.5 (7)
		76	7.97 - 7.45		7.76 (8)			7.8 (2)
33	As	75	---		100	63LEI1		100
34	Se	74	0.888 - 0.877	R	0.88 (1)	48WHI1		0.9 (1)
		76	9.002 - 8.932		8.95 (3)			9.0 (2)
		77	7.680 - 7.640		7.65 (3)			7.6 (2)
		78	23.560 - 23.497		23.51 (11)			23.5 (6)
		80	49.655 - 49.538		49.62 (14)			49.6 (7)
		82	9.399 - 9.331		9.39 (9)			9.4 (5)
35	Br	79	---		50.686 (47) 3σ C	64CAT1	NBS-SRM 977*	50.69 (5)
		81			49.314 (47)			49.31 (5)
36	Kr	78	0.36 - 0.341	G,M	0.360 (4) P	73WAL1	Air*	0.35 (2)
		80	2.29 - 2.223		2.277 (4)			2.25 (2)
		82	11.59 - 11.49		11.58 (1)			11.6 (1)
		83	11.55 - 11.44		11.52 (1)			11.5 (1)
		84	57.14 - 56.90		56.96 (1)			57.0 (3)
		86	17.44 - 17.24		17.30 (1)			17.3 (2)
37	Rb	85	72.24 - 72.14	G	72.1654 (132) 3σ C	69CAT1	NBS-SRM 984*	72.165 (13)
		87	27.86 - 27.76		27.8346 (132)			27.835 (13)
38	Sr	84	0.58 - 0.55	G	0.5574 (16) 3σ C	82MOO1	NBS-SRM's 987*, 988, 607	0.56 (1)
		86	9.99 - 9.75		9.8566 (34)			9.86 (1)
		87	7.14 - 6.94		7.0015 (26)			7.00 (1)
		88	82.75 - 82.29		82.5845 (66)			82.58 (1)
39	Y	89	---		100	57COL1		100
40	Zr	90	51.7 - 51.12	G	51.449 (59) σ C	78SHI2		51.45 (12)
		91	11.32 - 10.8		11.320 (15)			11.27 (16)
		92	17.4 - 17.1		17.189 (21)			17.17 (6)
		94	17.57 - 17.283		17.283 (21)			17.33 (17)
		96	2.9 - 2.759		2.759 (4)			2.78 (6)

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values 4	Annotations 5	Best Measurement from a Single Natural Source 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition 9
41	Nb	93	---		100	56WHI1		100
42	Mo	92	15.05 - 14.74	G	14.8362 (148) 2σ	74MOO1		14.84 (4)
		94	9.35 - 9.11		9.2466 (92)			9.25 (2)
		95	15.93 - 15.78		15.9201 (159)			15.92 (4)
		96	16.71 - 16.56		16.6756 (167)			16.68 (4)
		97	9.6 - 9.48		9.5551 (96)			9.55 (2)
		98	24.42 - 24.00		24.1329 (241)			24.13 (6)
		100	9.63 - 9.60		9.6335 (96)			9.63 (2)
43	Tc	--	---		---			---
44	Ru	96	5.57 - 5.47	G	5.52 (1) σ	76DEV1		5.52 (5)
		98	1.91 - 1.84		1.86 (1)			1.88 (5)
		99	12.77 - 12.7		12.74 (2)			12.7 (1)
		100	12.69 - 12.56		12.60 (2)			12.6 (1)
		101	17.1 - 17.01		17.05 (1)			17.0 (1)
		102	31.7 - 31.52		31.57 (3)			31.6 (2)
		104	18.67 - 18.5		18.66 (3)			18.7 (2)
45	Rh	103	---		100	63LEI1		100
46	Pd	102	1.021 - 0.99	G,R	1.020 (8) 2σ C	78SHI1		1.020 (12)
		104	11.14 - 10.97		11.14 (5)			11.14 (8)
		105	22.33 - 22.18		22.33 (5)			22.33 (8)
		106	27.33 - 27.25		27.33 (2)			27.33 (5)
		108	26.69 - 26.46		26.46 (6)			26.46 (9)
		110	11.91 - 11.72		11.72 (6)			11.72 (9)
47	Ag	107	---	G	51.8392 (51) 3σ C	82POW1	NBS-SRM 978*	51.839 (5)
		109			48.1608 (51)			48.161 (5)
48	Cd	106	---	G	1.25 (2) 2σ C	80ROS1		1.25 (3)
		108			0.89 (1)			0.89 (1)
		110			12.49 (6)			12.49 (9)
		111			12.80 (4)			12.80 (6)
		112			24.13 (7)			24.13 (11)
		113			12.22 (4)			12.22 (6)
		114			28.73 (14)			28.73 (21)
		116			7.49 (6)			7.49 (9)

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values 4	Annotations 5	Best Measurement from a Single Natural Source 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition 9
49	In	113	4.33 - 4.16	G	4.33 (4)	56WHI1		4.3 (2)
		115	95.84 - 95.67		95.67 (4)			95.7 (2)
50	Sn	112	1.017 - 0.90	G	1.01 (3)	65LAE1		1.0 (2)
		114	0.681 - 0.61		0.67 (3)			0.7 (2)
		115	0.38 - 0.33		0.38 (3)			0.4 (2)
		116	14.78 - 14.07		14.76 (5)			14.7 (3)
		117	7.767 - 7.51		7.75 (3)			7.7 (2)
		118	24.31 - 23.84		24.30 (8)			24.3 (4)
		119	8.68 - 8.45		8.55 (3)			8.6 (2)
		120	33.11 - 32.34		32.38 (8)			32.4 (4)
		122	4.78 - 4.559		4.56 (3)			4.6 (2)
		124	6.11 - 5.626		5.64 (3)			5.6 (2)
51	Sb	121	---	O	57.25 (3)	48WHI1		57.3 (9)
		123			42.75 (3)			42.7 (9)
52	Te	120	---	G	0.0960 (7) 2σ	78SMI1		0.096 (2)
		122			2.603 (3)			2.60 (1)
		123			0.908 (1)			0.908 (3)
		124			4.816 (3)			4.816 (8)
		125			7.139 (3)			7.14 (1)
		126			18.952 (5)			18.95 (1)
		128			31.687 (7)			31.69 (2)
		130			33.799 (7)			33.80 (2)
53	I	127	---		100	49LEL1		100
54	Xe	124	0.102 - 0.095	G,M	0.096 (1) P	50NIE2	Air*	0.10 (1)
		126	0.098 - 0.088		0.090 (1)			0.09 (1)
		128	1.93 - 1.91		1.919 (4)			1.91 (3)
		129	26.51 - 26.24		26.44 (8)			26.4 (6)
		130	4.08 - 3.68		4.08 (1)			4.1 (1)
		131	21.24 - 21.04		21.18 (5)			21.2 (4)
		132	27.12 - 26.88		26.89 (7)			26.9 (5)
		134	10.54 - 10.43		10.44 (2)			10.4 (2)
		136	8.98 - 8.87		8.87 (1)			8.9 (1)
55	Cs	133	---		100	56WHI1		100

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values 4	Annotations 5	Best Measurement from a Single Natural Source 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition 9
56	Ba	130	---	G	0.1058 (2) S.E. C	69EUG1		0.106 (2)
		132			0.1012 (2)			0.101 (2)
		134			2.417 (3)			2.417 (27)
		135			6.592 (2)			6.592 (18)
		136			7.853 (4)			7.854 (39)
		137			11.232 (4)			11.23 (4)
		138			71.699 (7)			71.70 (7)
57	La	138	-[d]	G	0.089 (2)	56WHI1		0.09 (2)
		139			99.911 (2)	47ING2		99.91 (2)
58	Ce	136	0.195 - 0.190	G	0.1904 (3) 2σ	62UME1		0.19 (1)
		138	0.265 - 0.250		0.2536 (4)			0.25 (1)
		140	88.48 - 88.449		88.475 (8)			88.48 (10)
		142	11.098 - 11.07		11.081 (7)			11.08 (10)
59	Pr	141	---			57COL1		100
60	Nd	142	27.3 - 26.80	G	27.16 (4) 2σ	81HOL1		27.13 (10)
		143	12.32 - 12.12		12.18 (2)			12.18 (5)
		144	23.97 - 23.795		23.83 (4)			23.80 (10)
		145	8.35 - 8.23		8.30 (2)			8.30 (5)
		146	17.35 - 17.06		17.17 (3)			17.19 (8)
		148	5.78 - 5.66		5.74 (1)			5.76 (3)
		150	5.69 - 5.53		5.62 (1)			5.64 (3)
61	Pm	---	---		---			---
62	Sm	144	3.16 - 2.87	G	3.076 (1)	75LUG2		3.1 (1)
		147	15.10 - 14.87		14.995 (1)			15.0 (2)
		148	11.35 - 11.22		11.242 (1)			11.3 (1)
		149	13.96 - 13.82		13.819 (1)			13.8 (1)
		150	7.47 - 7.36		7.380 (1)			7.4 (1)
		152	26.90 - 26.55		26.738 (2)			26.7 (2)
		154	22.88 - 22.43		22.750 (1)			22.7 (2)
63	Eu	151	47.86 - 47.75	G	47.77 (20)	48HES1		47.8 (5)
		153	52.25 - 52.14		52.23 (20)			52.2 (5)

[d] The only two available measurements give identical values.

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values 4	Annotations 5	Best Measurement from a Single Natural Source 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition 9
64	Gd	152	0.205 - 0.20	G	0.2029 (5)	70EUG1		0.20 (1)
		154	2.23 - 2.1		2.1809 (6)			2.18 (3)
		155	15.1 - 14.68		14.800 (3)			14.80 (5)
		156	20.67 - 20.36		20.466 (2)			20.47 (4)
		157	15.73 - 15.64		15.652 (2)			15.65 (3)
		158	24.96 - 24.5		24.835 (4)			24.84 (12)
		160	22.01 - 21.6		21.863 (2)			21.86 (4)
65	Tb	159	---		100	57COL1		100
66	Dy	156	0.064 - 0.0524	G	0.056 (1) 2σ	81HOL1		0.06 (1)
		158	0.105 - 0.0902		0.096 (2)			0.10 (1)
		160	2.36 - 2.294		2.34 (2)			2.34 (5)
		161	19.0 - 18.73		18.91 (5)			18.9 (1)
		162	25.53 - 25.36		25.51 (7)			25.5 (2)
		163	24.97 - 24.9		24.90 (7)			24.9 (2)
		164	28.47 - 28.1		28.19 (8)			28.2 (2)
67	Ho	165	---		100	57COL1		100
68	Er	162	0.154 - 0.136	G	0.137 (1) 2σ	81HOL1		0.14 (1)
		164	1.61 - 1.56		1.609 (5)			1.61 (1)
		166	33.61 - 33.36		33.61 (7)			33.6 (2)
		167	22.94 - 22.82		22.93 (5)			22.95 (13)
		168	27.07 - 26.79		26.79 (7)			26.8 (2)
		170	15.04 - 14.88		14.93 (5)			14.9 (1)
69	Tm	169	---		100	57COL1		100
70	Yb	168	---	G	0.127 (2) 2σ	81HOL1		0.13 (1)
		170			3.04 (2)			3.05 (5)
		171			14.28 (8)			14.3 (2)
		172			21.83 (10)			21.9 (3)
		173			16.13 (7)			16.12 (18)
		174			31.83 (14)			31.8 (4)
		176			12.76 (5)			12.7 (1)
71	Lu	175	---	G	97.393 (5) 2σ	76MCC1		97.40 (2)
		176			2.607 (5)			2.60 (2)

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values 4	Annotations 5	Best Measurement from a Single Natural Source 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition 9
72	Hf	174	0.199 - 0.163		0.163 (2)	56WHI1		0.16 (1)
		176	5.23 - 5.15		5.21 (2)			5.2 (1)
		177	18.56 - 18.39		18.56 (6)			18.6 (3)
		178	27.23 - 27.08		27.10 (10)			27.1 (5)
		179	13.78 - 13.73		13.75 (5)			13.74 (25)
		180	35.44 - 35.07		35.22 (10)			35.2 (5)
73	Ta	180	0.0123 - 0.0117		0.0123 (3)	56WHI1		0.012 (2)
		181	99.9883 - 99.9877		99.9877 (3)			99.988 (2)
74	W	180	0.16 - 0.126		0.126 (6)	48WHI1		0.13 (3)
		182	26.41 - 26.09		26.31 (3)			26.3 (2)
		183	14.43 - 14.24		14.28 (1)			14.3 (1)
		184	30.68 - 30.63		30.64 (3)			30.67 (15)
		186	28.85 - 28.38		28.64 (3)			28.6 (2)
75	Re	185	---		37.398 (16) $\tilde{3}\sigma$ C	73GRA1	NBS-SRM 989*	37.40 (2)
		187			62.602 (16)			62.60 (2)
76	Os	184	0.02 - 0.018	G	0.018 (2) P	37NIE1		0.02 (1)
		186	1.67 - 1.59		1.59 (5)			1.58 (10)
		187	1.67 - 1.60		1.64 (5)			1.6 (1)
		188	13.27 - 13.15		13.27 (12)			13.3 (2)
		189	16.21 - 16.08		16.14 (14)			16.1 (3)
		190	26.42 - 26.15		26.38 (20)			26.4 (4)
		192	41.21 - 40.96		40.96 (14)			41.0 (3)
77	Ir	191	---	O	37.3	54BAL1		37.3 (5)
		193			62.7			62.7 (5)
78	Pt	190	0.0127 - 0.012		0.0127 (5)	56WHI1		0.01 (1)
		192	0.78 - 0.78		0.78 (1)			0.79 (5)
		194	32.9 - 32.8		32.9 (1)			32.9 (5)
		195	33.8 - 33.7		33.8 (1)			33.8 (5)
		196	25.4 - 25.2		25.2 (1)			25.3 (5)
		198	7.23 - 7.19		7.19 (4)			7.2 (2)
79	Au	197	---		100	63LEI1		100

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values 4	Annotations 5	Best Measurement from a Single Natural Source 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition 9
80	Hg	196	0.16 - 0.147		0.156 (10) σ	55DIB1		0.15 (5)
		198	10.12 - 10.02		10.12 (10)			10.1 (5)
		199	17.01 - 16.83		16.99 (9)			17.0 (5)
		200	23.21 - 23.07		23.07 (12)			23.1 (6)
		201	13.27 - 13.12		13.27 (7)			13.2 (4)
		202	29.81 - 29.64		29.64 (15)			29.65 (75)
		204	6.85 - 6.69		6.79 (5)			6.8 (3)
81	Tl	203	---		29.524 (9) 3σ C	80DUN1	NBS-SRM 997*	29.524 (9)
		205			70.476 (9)			70.476 (9)
82	Pb	204	1.65 - 1.04	R,G	1.4245 (12) 3σ C	68CAT1	NBS-SRM 981*	1.4 (1)[e]
		206	27.48 - 20.84		24.1447 (57)			24.1 (1)
		207	23.65 - 17.62		22.0827 (27)			22.1 (1)
		208	56.21 - 51.28		52.3481 (86)			52.4 (1)
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	---	---					---
92	U	234	0.0059 - 0.0050	R,G,M	0.00548 (2)	69SMI1	NBS-SRM's	0.0055 (5)
		235	0.7202 - 0.7198		0.7200 (1) σ[f]	76COW1	U0002-U970*	0.7200 (12)
		238	99.2752 - 99.2739		99.2745 (10)		C.E.A.	99.2745 (15)
93	Np	237	---					---

[e] Representative isotopic composition is for most but not all commercial samples.
[f] The ^{234}U abundance is from 69SMI1, ^{235}U and ^{238}U are from 76COW1.

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Appendix B

Sources of Reference Materials

I.A.E.A.

Samples such as V-SMOW, SLAP, and GISP may be obtained from:

International Atomic Energy Agency
Section of Isotope Hydrology
P. O. Box 100
1400 Vienna, Austria

TROILITE

Canon Diablo Troilite may be obtained from:

Mr. Glenn I. Huss
Director, American Meteorite Laboratory
P.O. Box 2098
Denver, Colorado 80201 (U.S.A.)

NBS-SRM's

NBS Standard Reference Materials may be purchased through:

Office of Standard Reference Materials
National Bureau of Standards
B311 Chemistry Building
Washington, D. C. 20234 (U.S.A.)

CBNM-GEEL

Reference Materials may be obtained through:

Dr. Paul De Bièvre
Central Bureau for Nuclear Measurements
Commission of the European Communities
B-2440 Geel, (Belgium)

NBS-RS (Reference Samples)

Samples may be obtained through:

Dr. I. Lynus Barnes
National Bureau of Standards
A23 Physics Building
Washington, D. C. 20234 (U.S.A.)

NOTE: Samples of N and Li previously available from Professor H. J. Svec have been sent to NBS for distribution.

C.E.A.

Standards may be obtained through:

Dr. R. Hagemann
Centre d'Etudes Nucléaires de Saclay
B.P. n°2 - 91190 Gif-sur-Yvette (France)