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COMMISSION ON ATOMIC WEIGHTS AND ISOTOPIC ABUNDANCES*

ISOTOPIC COMPOSITIONS OF THE ELEMENTS 1983

Prepared for publication by

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ISOTOPIC COMPOSITIONS OF THE ELEMENTS 1983

Abstract - The Commission's biennial review of isotopic compositions as determined by mass spectrometry and other relevant methods has been undertaken by the Subcommittee for the Assessment of Isotopic Composition (SAIC). The Subcommittee's critical evaluation of the published literature element by element forms the basis of the Table of Isotopic Compositions as Determined by Mass Spectrometry, 1983, which is presented in this Report. Atomic Weights calculated from the tabulated isotopic abundances are consistent with $\underline{A}_r(E)$ values listed in the Table of Standard Atomic Weights 1983.

INTRODUCTION

Ten years have elapsed since the Commission on Atomic Weights at its meeting in Munich undertook to assemble, evaluate, and disseminate data on the isotopic compositions of the elements determined by mass spectrometry. The Commission at that time established the IUPAC Mass Spectrometric Evaluation Group (IMSEG) which produced the first interim version of the "Table of Isotopic Compositions of the Elements as Determined by Mass Spectrometry" which was published with minor amendments by the Commission in its Report "Atomic Weights of the Elements 1975" (Ref. 1). Although the information for elements with three or more stable isotopes was more detailed than that formerly provided by a single atomic weight value, it was recognized that the atomic weight calculated from the best mass spectrometrically determined isotopic composition for a given element, might not necessarily agree precisely with the best atomic weight value derived from all significant published measurements by all methods. Accordingly, at the 1975 meeting of the Commission in Madrid, IMSEG was reconstituted as the Subcommittee for the Assessment of Isotopic Composition (SAIC) with the widened task of deriving isotopic compositions not only from mass spectrometry but also from all relevant methods. The objective in the longer term was to develop a table of critically evaluated isotopic compositions which when converted to atomic weights would be completely self-consistent with the best values published in the IUPAC Table of Standard Atomic Weights. At the 1977 and 1979 meetings of the Commission in Warsaw and Davos, respectively, the SAIC continued to report refined interim tabulations of the range of published mass-spectrometrically determined isotopic abundances for each of the naturally occurring elements, together with the result of what was 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. The "Table of Isotopic Compositions of the Elements as Determined by Mass Spectrometry" (Refs. 2 and 3) listed isotopic compositions which when converted into atomic weights yielded improved but not always fully consistent $\underline{A}_r(E)$ values with those given in the Table of Standard Atomic Weights. Discrepancies were particularly marked in the cases of zinc, germanium and selenium where the interim values fell outside the limit of uncertainty on the standard atomic weight, $\underline{A}_r(E)$.

The SAIC continued to review the literature exhaustively and evaluate the published data on atomic weights and isotopic compositions on an element by element basis and, at its meeting at Leuven in 1981, the Commission departed from its past practice by publishing its report on isotopic compositions of the elements (Ref. 4) separately from that on atomic weights of the elements (Ref. 5). The Commission at Leuven directed the SAIC to complete its exhaustive element by element review of all changes to atomic weight values which have been made since 1961, including all measurements for deriving isotopic compositions. This challenging objective has now been achieved and the Commission, at its meeting at Lyngby in 1983, received and endorsed for publication the draft of a report by the SAIC entitled, "Element by Element Review of Their Atomic Weights". The appearance of this Review will be timely, for more than twenty years have elapsed since the previous review was prepared by Cameron and Wichers (Ref. 6). In the intervening decades, there have been many new measurements made especially by mass spectrometry, new nuclidic mass data have become available, more attention has been given to abnormal geological occurrences leading to anomalies in atomic weights, and there has been a growing awareness of problems arising from inadvertent or undisclosed modifications of isotopic composition - all of which have an impact on the precision of the tabulated standard atomic weights. In the future, the Commission plans to disseminate standard atomic weights applicable to all normal materials with the greatest possible precision consistent with an uncertainty of between ±1 and ±9 in the last tabulated figure. The Element by Element Review will provide the essential background information on which the Commission will base their estimation of uncertainties in future Reports. The task set in 1973 for the Subcommittee for the Assessment of Isotopic Composition has now been completed and the Commission at Lyngby, dissolved the SAIC. The objective of publishing a Table of Isotopic Compositions which is entirely consistent with the Table of Standard Atomic Weights has been achieved in the present two Reports of the Commission. This in no way obviates the need for new and more precise determinations of atomic weight for a number of elements where the uncertainty intervals of atomic weights calculated from isotopic abundances compared with those of $\underline{A}_r(E)$ values just meet or barely overlap as in the cases of zinc, germanium and selenium.

TABLE OF ISOTOPIC COMPOSITIONS AS DETERMINED BY MASS SPECTROMETRY

The Subcommittee for the Assessment of Isotopic Composition has examined all of the available literature published through August 1983. A critical evaluation of these data has resulted in the table given below of recommended isotopic abundances of the elements. The values listed are for normal terrestial materials only, materials of meteoritic or other extra-terrestial origin being excluded. These values of isotopic abundances when converted to atomic weights are consistent with the 1983 Table of Standard Atomic Weights published in Part 1 of the Commission's Report. Following the SAIC's element by element reviews in 1982 and 1983 of atomic weights and isotopic compositions of the elements, a better but not perfect correspondence between atomic weights calculated from the Table and the IUPAC Standard values $\underline{A}_r(E)$ has now been achieved for zinc, germanium and selenium (see the 1979 and 1981 Reports).

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

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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 1983. 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.

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.

Warning

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 (Atom %) 4	Annotations 5	Best Measurement from a Single Natural Source (Atom %) 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition (Atom %) 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 - 4.6×10^{-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	7.525 (29) 2σ C	83MIC1	NBS-RS LSVEC	7.5 (2)[b]
		7	92.70 - 92.32	M	92.475 (29)		CBNM-GEEL*	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	G	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,G	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)
		17	0.0407 - 0.035		0.0372 (4)		IAEA-V-SMOW*,	0.038 (3)[c]
		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)

[a] Available hydrogen gases vary from 0.0044% 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 was derived from a measurement on air.

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values (Atom %) 4	Annotations 5	Best Measurement from a Single Natural Source (Atom %) 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition (Atom %) 9
11	Na	23	---		100	56WHI1		100
12	Mg	24	---		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	IAEA	95.02 (9)
		33	0.780 - 0.731		0.750 (7)		C.E.A.	0.75 (1)
		34	4.562 - 4.001		4.215 (4)			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)

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values (Atom %) 4	Annotations 5	Best Measurement from a Single Natural Source (Atom %) 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition (Atom %) 9
21	Sc	45	---		100	50LEL1		100
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*	4.345 (9)
		52			83.7895 (117)			83.789 (12)
		53			9.5006 (110)			9.501 (11)
		54			2.3647 (48)			2.365 (5)
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 C	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)

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values (Atom %) 4	Annotations 5	Best Measurement from a Single Natural Source (Atom %) 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition (Atom %) 9
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)
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	0.908 - 0.897	R	0.88 (1)	48WHI1		0.9 (1)
		76	9.052 - 8.982		8.95 (3)			9.0 (2)
		77	7.630 - 7.590		7.65 (3)			7.6 (2)
		78	23.550 - 23.487		23.51 (11)			23.6 (6)
		80	49.718 - 49.655		49.62 (14)			49.7 (7)
		82	9.209 - 9.141		9.39 (9)			9.2 (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	R,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)[e]
		88	82.75 - 82.29		82.5845 (66)			82.58 (1)

[e]Representative isotopic composition is for most but not all commercial samples.

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values (Atom %) 4	Annotations 5	Best Measurement from a Single Natural Source (Atom %) 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition (Atom %) 9
39	V	69	---		100	57COL1		100
40	Zr	90	51.7 - 51.12	G	51.452 (9) 2σ C	83NOM1		51.45 (2)
		91	11.32 - 10.8		11.223 (12)			11.22 (2)
		92	17.4 - 17.1		17.146 (7)			17.15 (1)
		94	17.57 - 17.283		17.380 (12)			17.38 (2)
		96	2.9 - 2.759		2.799 (5)			2.80 (1)
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)

Atomic Number 1	Element 2	Mass Number 3	Evaluated Limits of Published Values (Atom %) 4	Annotations 5	Best Measurement from a Single Natural Source (Atom %) 6	Reference (Appendix A) 7	Available Reference Materials (Appendix B) 8	Representative Isotopic Composition (Atom %) 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)
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	0.973 (3) σ C	83DEV1		0.97 (1)
		114	0.681 - 0.61		0.652 (3)			0.65 (1)
		115	0.38 - 0.33		0.359 (3)			0.36 (1)
		116	14.78 - 14.07		14.532 (36)			14.53 (11)
		117	7.767 - 7.51		7.675 (23)			7.68 (7)
		118	24.31 - 23.84		24.218 (36)			24.22 (11)
		119	8.68 - 8.45		8.583 (13)			8.58 (4)
		120	33.11 - 32.34		32.590 (33)			32.59 (10)
		122	4.78 - 4.559		4.629 (9)			4.63 (3)
		124	6.11 - 5.626		5.789 (18)			5.79 (5)
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)

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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
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)	47ING2		0.09 (1)
		139			99.911 (2)			99.91 (1)
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

[d] All available measurements give identical values.

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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)
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)

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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	97.416 (5) 2σ	83PAT1		97.41 (2)
		176			2.584 (5)			2.59 (2)
72	Hf	174	0.199 - 0.163		0.1621 (9)	83PAT1		0.162 (2)
		176	5.23 - 5.15		5.2056 (17)			5.206 (4)
		177	18.61 - 18.39		18.6060 (13)			18.606 (3)
		178	27.30 - 27.08		27.2969 (13)			27.297 (3)
		179	13.78 - 13.62		13.6289 (19)			13.629 (5)
		180	35.44 - 35.07		35.1005 (22)			35.100 (6)
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)

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75	Re	185	---		37.398 (16) 3σ 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
80	Hg	196	0.16 - 0.147		0.146 (20) P	50NIE2		0.14 (10)
		198	10.12 - 10.02		10.018 (9)			10.02 (7)
		199	17.01 - 16.83		16.837 (15)			16.84 (11)
		200	23.21 - 23.07		23.127 (15)			23.13 (11)
		201	13.27 - 13.12		13.222 (14)			13.22 (11)
		202	29.81 - 29.64		29.799 (18)			29.80 (14)
		204	6.85 - 6.69		6.851 (6)			6.85 (5)
81	Tl	203	---		29.524 (9) 3σ C	80DUN1	NBS-SRM 997*	29.524 (9)
		205			70.476 (9)			70.476 (9)

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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)[f]	69SMI1	NBS-SRM's	0.0055 (5)
		235	0.7202 - 0.7198		0.7200 (1) σ	76COW1	U0002-U970*	0.7200 (12)
		238	99.2752 - 99.2739		99.2745 (10)		C.E.A.	99.2745 (15)

[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

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 Bievre
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. J. Cesario
Centre d'Etudes Nucleaires de Saclay
B.P. n°2 - 91190 Gif-sur-Yvette (France)