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SUBCOMMITTEE FOR ISOTOPIC ABUNDANCE MEASUREMENTS**

ISOTOPIC COMPOSITIONS OF THE ELEMENTS 1997

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ISOTOPIC COMPOSITIONS OF THE ELEMENTS 1997

Abstract- The Commission's Subcommittee for the Isotopic Composition of the Elements (SIAM) 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.

INTRODUCTION

Previous compilations of "The isotopic compositions of the elements" were published in 1983 (ref. 1), 1984 (ref. 2) and 1991 (ref. 3) for the purpose of yielding atomic weights consistent with the Commission's "Table of Standard Atomic Weights" [4, 5, 6].

During the past six 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.

REFERENCES

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THE TABLE OF ISOTOPIC COMPOSITIONS OF THE ELEMENTS AS DETERMINED BY MASS SPECTROMETRY

The Subcommittee for Isotopic Abundance Measurements (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: 1s, 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 fulfil 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 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) 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 Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Annot- ations	Best		Reference (App. A)	Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)
					Terrestrial Source (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* CEA IAEA NIST	99.9850 (70) 0.0115 (70) ^b (in water)
		2	0.0184 - 0.0025		0.015574 (5)				
2	He	3	4.6x10 ⁻⁸ -0.0041	g,r	0.0001343(13)	1s C	88SAN1	Air*	0.000137 (3) 99.999863 (3) (in air)
		4	100 - 99.9959		99.9998657 (13)				
3	Li	6	7.21 - 7.71	m,r	7.589 (24)	2s C	97QI1	IRMM-016* IAEA IRMM NIST	[7.59(4)] ^c [92.41(4)]
		7	92.79 - 92.29		92.411 (24)				
4	Be	9			100		63LEI1		100
5	B	10	18.927 - 20.337	m,r	19.82 (2)	2s C	69BIE1	IRMM-011* NIST	19.9 (7) 80.1 (7)
		11	81.073- 79.663		80.18 (2)				
6	C	12	98.85 - 99.02	r	98.8922 (28)	P C	90CHA1	NBS19* IAEA NIST	98.93 (8) 1.07 (8)
		13	1.15 - 0.98		1.1078 (28)				
7	N	14	99.890 -99.652	r	99.6337 (4)	P C	58JUN1	Air* IAEA NIST	99.632 (7) ^d 0.368 (7)
		15	0.411 - 0.348		0.3663 (4)				
8	O	16	99.7384 -99.7756	r	99.7628 (5)	1s N	76BAEI	VSMOW*	99.757 (16)
		17	0.0399 - 0.0367		0.0372 (4) ^e		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*	90.48 (3) 0.27 (1) 9.25 (3) (in air)
		21	1.71 - 0.266		0.2696 (5)				
		22	9.96 - 9.20	9.2465 (90)					
11	Na	23			100		56WHI1		100
12	Mg	24			78.992 (25)	2s C	66CAT1	NIST-SRM980*	78.99 (4) 10.00 (1) 11.01 (3)
		25		10.003 (9)					
		26		11.005 (19)					
13	Al	27			100		56WHI1		100

Atomic Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Annot- ations	Best	Reference (App. A)	Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)	
					Measurement from a Single Terrestrial Source (Atom %)				
1	2	3	4	5	6	7	8	9	
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 (48)		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*	75.78 (4)	
		37	24.36 - 24.14		24.229 (45)				24.22 (4)
18	Ar	36		g	0.3365 (6) P C	50NIE1	Air*	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) 2s C	75GAR1	NIST-SRM985*	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*	96.941 (156) ^h	
		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*	4.345 (13)	
		52			83.7895 (117)				83.789 (18)
		53			9.5006 (110)				9.501 (17)
		54			2.3647 (48)				2.365 (7)

Atomic Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Annot- ations	Best		Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)	
					Measurement from a Single Terrestrial Source (Atom %)	Reference (App. A)			
1	2	3	4	5	6	7	8	9	
25	Mn	55			100	63LEI1		100	
26	Fe	54			5.845(23)	2s C	92TAY1	IRMM-014*	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*	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*	60.108 (9)
		71			39.8921 (62)				39.892 (9)
32	Ge	70			21.234 (31)	1s L	86GRE1		20.84 (87) ^k
		72			27.662 (29)				27.54 (34)
		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*	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)

Atomic Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Best		Reference (App. A)	Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)
				Annot- ations	Measurement from a Single Terrestrial Source (Atom %)			
1	2	3	4	5	6	7	8	9
37	Rb	85 87		g	72.1654 (132) 2s C 27.8346 (132)	69CAT1	NIST-SRM984	72.17 (2) 27.83 (2)
38	Sr	84 86 87 88	0.58 - 0.55 9.99 - 9.75 7.14 - 6.94 82.75 - 82.29	g,r	0.5574 (16) 2s C 9.8566 (34) 7.0015 (26) 82.5845 (66)	82MOO1	NIST-SRM 987* NIST	0.56 (1) 9.86 (1) 7.00 (1) ^h 82.58 (1)
39	Y	89			100	57COL1		100
40	Zr	90 91 92 94 96		g	51.452 (9) 2s N 11.223 (12) 17.146 (7) 17.380 (12) 2.799 (5)	83NOM1		51.45 (40) 11.22 (5) 17.15 (8) 17.38 (28) 2.80 (9)
41	Nb	93			100	56WHI1		100
42	Mo	92 94 95 96 97 98 100		g	14.8362 (148) 2s N 9.2466 (92) 15.9201 (159) 16.6756 (167) 9.5551 (96) 24.1329 (241) 9.6335 (96)	74MOO1		14.84 (35) 9.25 (12) 15.92 (13) 16.68 (2) 9.55 (8) 24.13 (31) 9.63 (23)
43	Tc					--	---	-----
44	Ru	96 98 99 100 101 102 104		g	5.5420 (1) 1s N 1.8688 (2) 12.7579 (6) 12.5985 (4) 17.0600 (10) 31.5519 (11) 18.6210 (11)	97HUA1		5.54 (14) 1.87 (3) 12.76 (14) 12.60 (7) 17.06 (2) 31.55 (14) 18.62 (27)
45	Rh	103			100	63LEI1		100
46	Pd	102 104 105 106 108 110		g,r	1.020 (8) 2s C 11.14 (5) 22.33 (5) 27.33 (2) 26.46 (6) 11.72 (6)	78SHI1		1.02 (1) 11.14 (8) 22.33 (8) 27.33 (3) 26.46 (9) 11.72 (9)
47	Ag	107 109		g	51.8392 (51) 2s C 48.1608 (51)	82POW1	NIST-SRM978*	51.839 (8) 48.161 (8)

Atomic Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Best		Reference (App. A)	Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)
				Annot- ations	Measurement from a Single Terrestrial Source (Atom %)			
1	2	3	4	5	6	7	8	9
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) ^f	84ROS1	0.66 (1)	
		115			0.339 (3) ^f	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) ^k
		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

Atomic Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Annot- ations	Best		Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)
					Measurement from a Single Terrestrial Source (Atom %)	Reference (App. A)		
1	2	3	4	5	6	7	8	9
56	Ba	130		g	0.1058 (2)	3se F	69EUG1	0.106 (1)
		132			0.1012 (2)			0.101 (1)
		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) ^h
		140	88.449 - 88.446		88.449 (34)			88.450 (18)
		142	11.114 - 11.114		11.114 (34)			11.114 (17)
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) ^h
		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

Atomic Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Best		Reference (App. A)	Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)	
				Annot-	Measurement				
1	2	3	4	5	Terrestrial Source (Atom %)	6	7	8	9
66	Dy	156		g	0.056 (1) 2 _{se} 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) 2 _{se} 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)		
		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) 2 _{se} 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) 2 _{se} N	83PAT1		97.41 (2)	
		176			2.584 (5)		2.59 (2)		
72	Hf	174	0.1621 - 0.1619		0.1620 (9) 2 _{se} N	83PAT1		0.16 (1)	
		176	5.271 - 5.206		5.2604 (56)		5.26 (7) ^h		
		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) 1 _{se} N	56WHI1		0.012 (2)	
		181			99.9877 (3)		99.988 (2)		
74	W	180			0.1198 (2) 1 _s 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) 2 _s C	73GRA1	NIST-SRM989*	37.40 (2)	
		187			62.602 (16)			62.60 (2)	

Atomic Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Annot- ations	Best Measurement from a Single Terrestrial Source		Reference (App. A)	Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)
					(Atom %)				
1	2	3	4	5	6	7	8	9	
76	Os	184 186 187 188 189 190 192		g,r	0.0197 (5) 1.5859 (44) 1.9644 (12) 13.2434 (19) 16.1466 (16) 26.2584 (14) 40.7815 (22)	1s N	91VÖL1	0.02 (1) 1.59 (3) 1.96 (2) ^h 13.24 (8) 16.15 (5) 26.26 (2) 40.78 (19)	
77	Ir	191 193			37.272 (15) 62.728 (15)	1s N	93WAL1	37.3 (2) 62.7 (2)	
78	Pt	190 192 194 195 196 198			0.013634 (68) 0.782659 (35) 32.96700 (77) 33.831557 (42) 25.24166 (36) 7.16349 (42)	1s N	96TAY1	0.014 (1) 0.782 (7) 32.967 (99) 33.832 (10) 25.242 (41) 7.163 (55)	
79	Au	197			100		63LEI1	100	
80	Hg	196 198 199 200 201 202 204			0.15344(19) 9.968 (13) 16.873 (17) 23.096 (26) 13.181 (13) 29.863 (33) 6.865 (7)	1s N	89ZAD1	0.15 (1) 9.97 (20) 16.87 (22) 23.10 (19) 13.18 (9) 29.86 (26) 6.87 (15)	
81	Tl	203 205			29.524 (9) 70.476 (9)	2s C	80DUN1	NIST-SRM997*	29.524 (14) 70.476 (14)
82	Pb	204 206 207 208	1.65 - 1.04 27.48 - 20.84 23.65 - 17.62 56.21 - 51.28	g,r	1.4245 (12) 24.1447 (57) 22.0827 (27) 52.3481 (86)	2s C	68CAT1	NIST-SRM981* NIST	1.4 (1) 24.1 (1) ^h 22.1 (1) ^h 52.4 (1) ^h
83	Bi	209			100		63LEI1	100	
84	Po								
85	At								
86	Rn								
87	Fr								
88	Ra								
89	Ac								

Atomic Number	Symbol	Mass Number	Range of Natural Variations (Atom %)	Annot- ations	Best Measurement from a Single Terrestrial Source		Reference (App. A)	Available Reference Materials ^a (App. B)	Representative Isotopic Composition (Atom %)
					(Atom %)	(Atom %)			
1	2	3	4	5	6	7	8	9	
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) ⁱ	1s N	69SMI1	IRMM-184	[0.0055(2)]
		235	0.7202 - 0.7198	r	0.7200 (1)		76COW1	CEA	[0.7200(51)] ^{c,h}
		238	99.2752 - 99.2739			99.2745 (10)			IRMM NBL

*Reference material used for the best measurement.

^a NIST materials were previously labelled NBS. IRMM materials were previously labelled CBNM.

^b The range of ²H in tank hydrogen is 0.0032 to 0.0184 atom percent.

^c Materials depleted in ⁶Li and ²³⁵U are commercial sources of laboratory shelf reagents. In the case of Li such samples are known to have ⁶Li abundances in the range 2.007-7.672 atom percent, with natural materials at the higher end of this range.

^d The Commission recommends that the value of 272 be employed for ¹⁴N/¹⁵N of N₂ in air for the calculation of atom percent ¹⁵N from measured δ¹⁵N values.

^e The reference reported a calibrated ¹⁶O/¹⁸O ratio on VSMOW; ¹⁷O abundance was derived from 88LI1.

^f Due to ¹¹⁵In contamination and an error in the ¹¹⁴Sn abundance the ¹¹⁵Sn and ¹¹⁴Sn abundances reported by 83DEV1 were adjusted using data from 84ROS1.

^g Not used since g is used in column 5.

^h Evaluated isotopic composition is for most but not all commercial samples.

ⁱ The ²³⁴U abundance is from 69SMI1, ²³⁵U and ²³⁸U are from 76COW1.

^k An electron multiplier was used for these measurements and the measured abundances were adjusted the using a square root of the masses.

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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